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Australia's State of the Forests Report 2018

A five-yearly report prepared by the Montreal Process Implementation Group for Australia and the National Forest Inventory Steering Committee on behalf of the Australian, state and territory governments

AUSTRALIAN BUREAU OF AGRICULTURAL AND RESOURCE ECONOMICS AND SCIENCES

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The Australian Government Department of Agriculture and Water Resources acknowledges the traditional custodians of country throughout Australia and their continuing connections to land, sea and community. We pay our respect to their cultures and elders past, present and future.

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Photo: iStockphoto/pinkomelet

Bees on eucalypt flowers. iStockphoto/Gromushka

Foreword

Australia's forests are diverse, extensive, and highly regarded for their ecological, economic and social values. They provide a range of benefits including wood and non-wood forest products and ecosystem services. The range of services covers water protection and supply, soil protection, carbon storage and sequestration, habitat for flora and fauna species, tourism and recreation, and cultural values for both non-Indigenous and Aboriginal and Torres Strait Islander peoples.

Australia's State of the Forests Report 2018 presents a comprehensive national synthesis of information describing Australia's forests. The information is presented systematically against sustainable forest management criteria and indicators that are based on the framework of the international Montreal Process Working Group. This framework provides a common basis to describe, monitor, assess and report on forests, and to assess performance against the principles of sustainable forest management.

The fifth report in the series, *Australia's State of the Forests Report 2018* enables an efficient connection between state, national and international reporting processes. The report is driven through national processes such as reporting requirements for regional forest agreements and Australia's national forest policy. In turn, it provides data directly to international processes including the Global Forest Resources Assessment led by the Food and Agriculture Organization of the United Nations, the United Nations Sustainable Development Goals, and the Global Forest Goals of the United Nations Forum on Forests.

The completion of this report represents a substantial effort from two national committees comprising representatives from state and territory forest management and policy agencies, and Commonwealth government agencies. Essential input has also come from academia, research organisations and industry bodies. Production of the report was undertaken by the Australian Bureau of Agricultural and Resource Economics and Sciences in the Australian Government Department of Agriculture and Water Resources.

Australia's State of the Forests Report 2018 is an essential resource for all who work in, manage or value Australia's forests. The report provides data, information and sufficient narrative context to let the reader explore the implications for sustainable forest management of changes in the social, environmental and economic aspects of Australia's forests.

Steve Hatfield-Dodds
Executive Director
ABARES

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1 Until January 2013, Forests NSW.

2 Until July 2017, Forestry Tasmania.

3 Until January 2015, the Department of Environment and Primary Industries.

4 Until July 2017, the Department of Parks and Wildlife.

5 Until February 2015, the Department of Agriculture, Fisheries and Forestry.

6 Until January 2018, the Department of Environment and Heritage Protection.

7 Until March 2018, the Department of Environment, Water and Natural Resources.

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8 Until July 2016, the Department of the Environment.

Acronyms and abbreviations[9]

ABARES	Australian Bureau of Agricultural and Resource Economics and Sciences (Australian Government)
ABS	Australian Bureau of Statistics (Australian Government)
ACIAR	Australian Centre for International Agriculture Research (Australian Government)
ACT	Australian Capital Territory
AFAC	Australasian Fire and Emergency Service Authorities Council
AFSC	Australian Forest Certification Scheme
ANU	Australian National University
ANZECC	Australian and New Zealand Environment and Conservation Council
ANZIC	Australia and New Zealand Industry Classification
ARC	Australian Research Council
ATSC	Australian Tree Seed Centre
AVHRR	Advanced Very High Resolution Radiometer
BRS	Bureau of Rural Sciences (Australian Government)
BMAD	Bell-Miner-Associated Dieback
CAPAD	Collaborative Australian Protected Areas Database
CAR	Comprehensive, Adequate and Representative
CCWA	Conservation Commission of Western Australia
CFI	Carbon Farming Initiative
C&I	criteria and indicators
COAG	Council of Australian Governments
CO_2	carbon dioxide
CO_2-e	carbon dioxide-equivalent
CPCWA	Conservation and Parks Commission, Western Australia
CPH	Census of Population and Housing
CPI	Consumer Price Index
CRA	Comprehensive Regional Assessment
CRC	Cooperative Research Centre
CSIRO	Commonwealth Scientific and Industrial Research Organisation (Australian Government)
DBCA	Department of Biodiversity, Conservation and Attractions (Western Australian Government)
DCCEE	Department of Climate Change and Energy Efficiency (Australian Government)
DEC	Department of Environment and Conservation (Western Australian Government)
DEDJTR	Department of Economic Development, Jobs, Transport and Resources (Victorian Government)
DEHP	Department of Environment and Heritage Protection (Queensland Government)
DELWP	Department of Environment, Land, Water and Planning (Victorian Government)
DEPI	Department of Environment and Primary Industries (Victorian Government)
DENR	Department of Environment and Natural Resources (Northern Territory Government)
DERM	Department of Environment and Resource Management (Queensland Government)
DEW	Department for Environment and Water (South Australian Government)
DEWNR	Department of Environment, Water and Natural Resources (South Australian Government)
DFA	Defined Forest Area
DIA	Department of Indigenous Affairs (Australian Government)
DIIS	Department of Industry, Innovation and Science (Australian Government)
DLCM	Dynamic Land Cover Mapping
DLRM	Department of Land Resource Management (Northern Territory Government)
DNRE	Department of Natural Resources and Environment (Victorian Government)
DoEE	Department of the Environment and Energy (Australian Government)
DPaW	Department of Parks and Wildlife (Western Australian Government)
DPI (NSW)	Department of Primary Industries (New South Wales Government)
DPI (Victoria)	Department of Primary Industries (Victorian Government)
DPIPWE	Department of Primary Industries, Parks, Water and Environment (Tasmanian Government)
DPIR	Department of Primary Industry and Resources (Northern Territory Government)
DSE	Department of Sustainability and Environment (Victorian Government)
DSG	Department of State Growth (Tasmanian Government)
DSEWPaC	Department of Sustainability, Environment, Water, Population and Communities (Australian Government)
EMS	Environmental Management System
EPA	Environment Protection Authority (New South Wales Government)
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
EPL	Environment Protection Licence
EPSDD	Environment, Planning and Sustainable Development Directorate (Australian Capital Territory Government)
ERF	Emissions Reduction Fund
ERIN	Environmental Resources Information Network
ESDD	Environment and Sustainable Development Directorate (Australian Capital Territory Government)
FAO	Food and Agriculture Organization of the United Nations
FCNSW	Forestry Corporation of New South Wales

9 A subsequent table relates agency names that applied during the SOFR 2018 reporting period, to agency names in use at 31 July 2018.

FFMG	Forest Fire Management Group
FFPC	Forestry and Forest Products Committee
FMP	Forest Management Plan
FPA	Forest Practices Authority, Tasmania
FPC	Forest Products Commission of Western Australia
FPC	Foliage Projective Cover
FPPF	Future Potential Production Forest
FSC	Forest Stewardship Council
FT	Forestry Tasmania (Tasmanian Government Business Enterprise)
FTAs	free trade agreements
FTE	full-time-equivalent
FullCAM	Full Carbon Accounting Model
FWPA	Forest and Wood Products Australia
GA	Geoscience Australia (Australian Government)
GDP	gross domestic product
GFCF	gross fixed capital formation
GFRA	Global Forest Resources Assessment (FAO)
GIS	geographic information system
GVP	gross value of production
HCV	high conservation value
HWP	harvested wood products
IFOA	Integrated Forestry Operations Approval
ILC	Indigenous Land Corporation
ILUA	Indigenous Land Use Agreement
IPA	Indigenous Protected Area
IUCN	International Union for Conservation of Nature
LGA	Local Government Area
LTER	Long-Term Ecological Research
LTERN	Long-Term Ecological Research Network
LULUCF	Land Use, Land-Use Change and Forestry
MCFFA	Ministerial Council on Forestry, Fisheries and Aquaculture
MIG	Montreal Process Implementation Group for Australia
MIS	managed investment scheme
MLE	Multiple Lines of Evidence
MODIS	Moderate-resolution Imaging Spectroradiometer
Mt C	million tonnes of carbon
NCAS	National Carbon Accounting System
NAFI	North Australia and Rangelands Fire Information
NCLD	National Conservation Lands Database
NCP	National Competition Policy
NFI	National Forest Inventory
NFISC	National Forest Inventory Steering Committee
NGGI	National Greenhouse Gas Inventory
NHL	National Heritage List
NIHSA	Non-Indigenous Heritage Sites of Australia
NIR	National Inventory Report
NNTT	National Native Title Tribunal
NPI	National Plantation Inventory
NPWS	National Parks and Wildlife Service (New South Wales Government)
NRM	Natural Resource Management
NRMMC	Natural Resource Management Ministerial Council
NRS	National Reserve System
NSW	New South Wales
NT	Northern Territory
NVIS	National Vegetation Information System
NWFP	non-wood forest product
NWI	National Water Initiative
OEH	Office of Environment and Heritage (New South Wales Government)
PBCRC	Plant Biosecurity Cooperative Research Centre
PFT	Private Forests Tasmania
PIRSA	Department of Primary Industries and Regions SA (South Australian Government)
PJ	Petajoule (10^{15} joules)
Qld	Queensland
R&D	research and development
RD&E	research, development and extension
RFA	Regional Forest Agreement
RIRDC	Rural Industries Research and Development Corporation (Australian Government)
RNE	Register of the National Estate
SA	South Australia
SAC	Self-Assessable Vegetation Clearing Code (Queensland)
SCoPI	Standing Council on Primary Industries
s.l.	sensu lato (“in the broad sense”)
SLA	Statistical Local Area
SLATS	State-wide Landcover and Trees Study
SEEA	System of Integrated Environmental and Economic Accounts
SNC	Spring Needle Cast
SoE	State of the Environment
SOFR	State of the Forests Report
SPOT5	Satellite Pour l’Observation de la Terre 5
SPRAT	Species Profile and Threats Database
s.s.	sensu stricto (“in the narrow sense”)
STBA	Southern Tree Breeding Association
STT	Sustainable Timber Tasmania (Tasmanian Government Business Enterprise)
TAFE	Technical and Further Education
Tas.	Tasmania
TERN	Terrestrial Ecosystem Research Network
UNESCO	United Nations Educational, Scientific and Cultural Organization
VET	Vocational Education and Training
VFMP	Victorian Forest Monitoring Program
Vic.	Victoria
WA	Western Australia
WHA	World Heritage Area

Eucalyptus saligna, Willowdale Arboretum. Mark Parsons

Agency name changes

Agency names used in this report are the names correct during the SOFR 2018 reporting period (01 July 2011 to 30 June 2016). This table shows the agency name as at 31 July 2018 for those agencies for which different agency names were used during the reporting period.

Jurisdiction	Agency name and acronym during part or all of SOFR 2018 reporting period (01 July 2011 to 30 June 2016)		Agency name and acronym as at 31 July 2018	
Commonwealth	Department of Agriculture, Fisheries and Forestry	DAFF	Department of Agriculture and Water Resources	DAWR
	Department of Agriculture	DA	Department of Agriculture and Water Resources	DAWR
	Department of Sustainability, Environment, Water, Population and Communities	DSEWPaC	Department of the Environment and Energy	DoEE
	Department of the Environment	DoE	Department of the Environment and Energy	DoEE
Australian Capital Territory	Environment and Sustainable Development Directorate	ESDD	Environment, Planning and Sustainable Development Directorate	EPSDD
New South Wales	Department of Environment and Heritage Protection	DEHP	Department of Environment and Science	DES
	Forests NSW	FNSW	Forestry Corporation of NSW	FCNSW
Northern Territory	Department of Natural Resources, Environment, the Arts and Sport	DNREAS	Department of Environment and Natural Resources	DENR
	Department of Land Resource Management	DLRM	Department of Environment and Natural Resources	DENR
Queensland	Department of Agriculture, Fisheries and Forestry	DAFF	Department of Agriculture and Fisheries	DAF
	Department of Environment and Heritage Protection	DEHP	Department of Environment and Science	DES
South Australia	Department of Environment, Water and Natural Resources	DEWNR	Department for Environment and Water	DEW
Tasmania	Forestry Tasmania	FT	Sustainable Timber Tasmania	STT
Victoria	Department of Sustainability and Environment	DSE	Department of Environment and Primary Industries	DEPI
	Department of Environment and Primary Industries	DEPI	Department of Environment, Land, Water and Planning	DELWP
Western Australia	Department of Parks and Wildlife	DPaW	Department of Biodiversity, Conservation and Attractions	DBCA
	Conservation Commission of Western Australia	CCWA	Conservation and Parks Commission, Western Australia	CPCWA
Non-government	Australian Forestry Standard Limited	AFS Ltd	Responsible Wood	RW


Eucalypt forest, Cowaramup, Western Australia. iStockphoto/metriognome

Executive summary

Australia's State of the Forests Report 2018 (SOFR 2018) is the fifth in a series of national five-yearly reports on Australia's forests, and covers a range of social, economic and environmental values. Previous national SOFR reports were published in 1998, 2003, 2008 and 2013.

As far as possible, SOFR 2018 presents data for the five-year period between July 2011 and June 2016. However, the varied nature of available data means that not all reported figures cover this range. SOFR 2018 also reports trends over longer periods of time where this is possible.

Australia's forests are recognised and valued for their diverse ecosystems and unique biodiversity; for their cultural heritage; for their provision of goods and services such as wood, carbon sequestration and storage, and soil and water protection; and for their aesthetic values and recreational opportunities. At the same time, Australia's forests are subject to a range of pressures, including extreme weather events, drought and climate change; invasive weeds, pests and diseases; changed fire regimes; clearing for urban development, mining, infrastructure or agriculture; and the legacy of previous land-management practices.

The sustainable management and conservation of Australia's forests, whether on public or on private land, requires a sound understanding of their extent, type, use and management. SOFR 2018 provides comprehensive information from a wide range of sources that can contribute to a better understanding of the broad range of values relating to Australia's forests and their current management.

The information presented in SOFR 2018 covers primarily the five-year period from 2011 to 2016, or otherwise using the best available data. The report is organised under a framework of seven criteria for sustainable forest management developed by the international-level Montreal Process Working Group on Criteria and Indicators for the Conservation and Sustainable Management of Temperate and Boreal Forests, and then under 44 separate indicators. This Executive Summary draws together data from the material presented under these 44 indicators into a number of key themes.

This icon indicates data, maps or graphics from *Australia's State of the Forests Report 2018* that are available for electronic download. Data used in figures and tables in the Executive Summary, together with higher resolution versions of maps, are available via www.doi.org/10.25814/5be12aa83aa34 and www.doi.org/10.25814/5be3bc4321162.

Australia's forest area

The area, type, tenure and management category of forests provides the base data for describing the state of Australia's forests, and changes over time.

Australia's forest area as at 2016

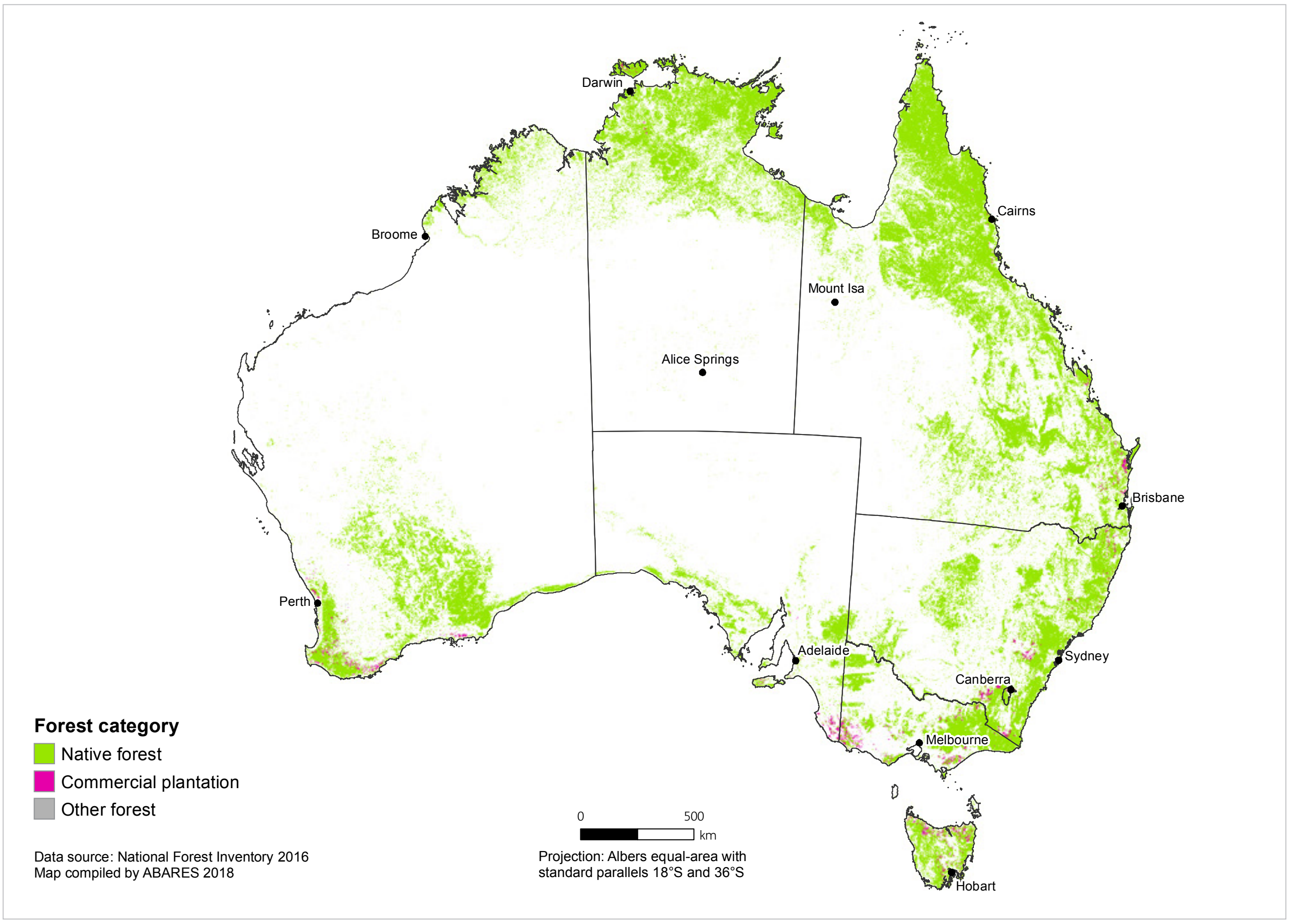
Australia has 134 million hectares of forest, covering 17% of Australia's land area. Australia has approximately 3% of the world's forests, and globally is the country with the seventh largest forest area.

Queensland has the largest area of forest (39% of Australia's forest), with the Northern Territory (18%), Western Australia (16%), and New South Wales (15%), making up much of the balance.

Australia's forests can be divided into three categories:

- 'Native forest' – 132 million hectares, 98% of Australia's forest area
- 'Commercial plantations' – 1.95 million hectares, 1.5% of Australia's forest area
- 'Other forest' – 0.47 million hectares, 0.4% of Australia's forest area, and comprising mostly non-commercial plantations, and planted forests of various types.

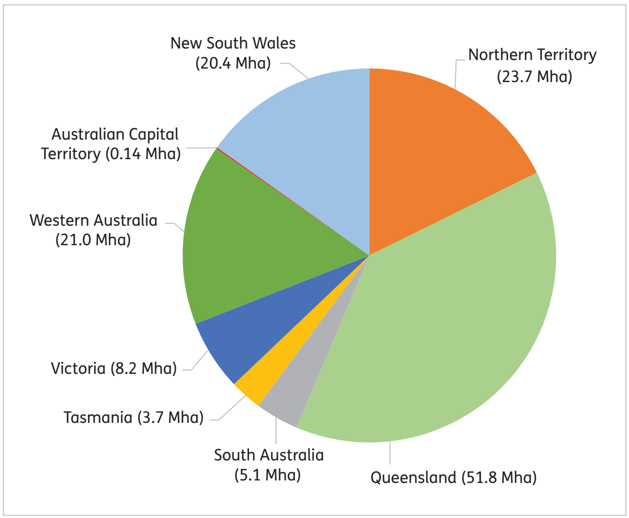
Australia's forests, by forest category



'Other forest' is not visible at this scale.

A higher resolution version of this map is available via www.doi.org/10.25814/5be3bc4321162

Australia's forest area, by jurisdiction



Mha, forest area in million hectares

The data used to create this figure are available in Microsoft Excel via www.doi.org/10.25814/5be12aa83aa34

Native forest

Native forest is the most extensive category of Australia's forests, covering 132 million hectares.

Native forests are dominated by eucalypt forests (101 million hectares) and acacia forests (11 million hectares).

The majority of native forests (91 million hectares) are woodland forests, which have a canopy cover between 20% and 50%.

By ownership, most of Australia's native forests (88 million hectares) are in private and leasehold tenures. The area of native forest in formal nature conservation reserves is 22 million hectares, and the area of multiple-use public native forests is 10 million hectares.

The Indigenous forest estate

The area of forest over which Indigenous peoples and communities have ownership, management or special rights of access or use is known as the Indigenous forest estate. This is a total of 70 million hectares of forest (52% of Australia's forests), almost all of which is native forest.

The term 'Indigenous' is used throughout the SOFR series to encompass all Aboriginal and Torres Strait Islander peoples.

The Indigenous forest estate is classified into four broad ownership and management categories:

Indigenous owned and managed	Indigenous co-managed
Indigenous managed	Forest subject to 'Other special rights'

The geographic distribution of these areas is presented later in this Executive Summary.

The area reported in SOFR 2018 for the Indigenous forest estate represents an increase of 28 million hectares over that previously reported.

- The increase has been driven primarily by an increase in the area of land over which Indigenous people have 'Other special rights', including through native title determinations and Indigenous Land Use Agreements.

Eucalyptus mannifera, Cuumbeun Nature Reserve, New South Wales.

Forest area change

Australia's forest area has increased progressively since 2008. The net increase in forest area over the period 2011 to 2016 was 3.9 million hectares.

This increase in forest area is due to the net effect of forest clearing or reclearing for agricultural use; regrowth of forest on areas previously cleared for agricultural use; expansion of forest onto areas not recently containing forest; establishment of environmental plantings; and changes in the commercial plantation estate.

- In each year of the period 2011–2016, the area of forest cleared or recleared was less than the area of forest regrowing from previous clearing.
- In the year 2015–16, first-time clearing was recorded for 60 thousand hectares of forest, 564 thousand hectares of forest regrew on land cleared after 1972, and reclearing of 395 thousand hectares of regrowth forest was recorded. The total area of forest recorded as cleared was 455 thousand hectares.

The change in forest area is determined from annual Landsat satellite data interpreted for Australia's National Greenhouse Gas Inventory.

- Temporary changes in forest area or canopy cover that result from a range of short-term factors, such as wildfire, wood harvesting, and regrowth or regeneration from these events, are not included in these area change figures.

Forest area data

The forest area dataset prepared for SOFR 2018 combines data from a wide range of different datasets, assembled using a Multiple Lines of Evidence methodology.

Data on Australia's forest area are assembled in the National Forest Inventory from a wide range of spatial datasets provided by states and territories, and from remotely sensed data sourced from various agencies. When these datasets disagree on whether an area is or is not forest, ABARES uses a formal process to determine the final allocation.

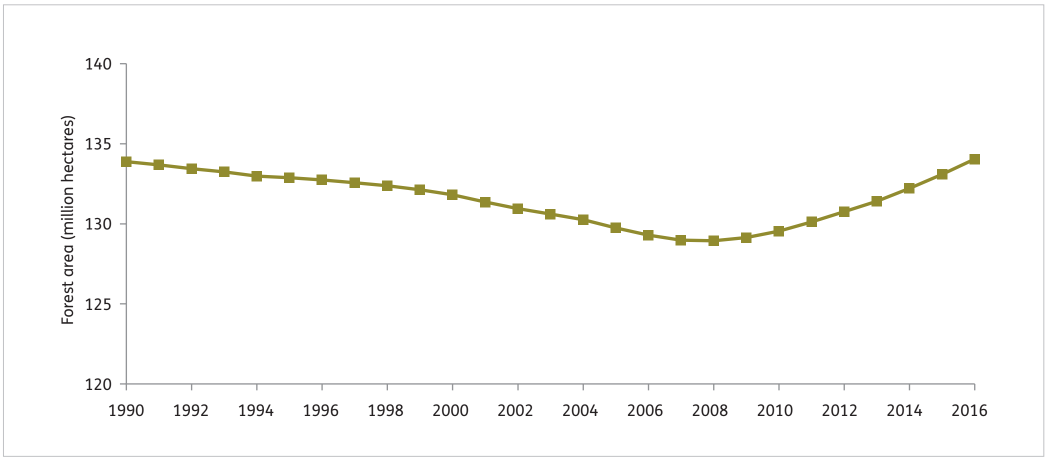
- The forest cover area statements in SOFR 2018 may therefore not align exactly with figures in individual datasets published in other Commonwealth reports or by individual states or territories.
- Spatial data for Commercial plantations are incorporated from the National Plantation Inventory.

SOFR 2013 reported a total forest area of 125 million hectares as at 2011, compared to the 134 million hectares of forest reported in SOFR 2018 as at 2016.

- Most of this difference in the understanding of Australia's forest extent derives from use of more accurate state, territory and national datasets and recent high-resolution imagery, not from actual on-ground changes in forest area.
- The change in reported forest area was greatest in the Northern Territory, where areas of woodland forest not reported as forest in SOFR 2013 have been identified, mapped, and reported as forest in SOFR 2018.

For further information on this theme, see Indicator 1.1a, Indicator 6.4a and Indicator 7.1d of *Australia's State of the Forests Report 2018*.

Australia's forest area since 1990



Calculated by ABARES from data in the National Inventory Report 2016, Australian Government Department of the Environment and Energy.

The data used to create this figure are available in Microsoft Excel via www.doi.org/10.25814/5be12aa83aa34

Forest biodiversity

In Australia, substantial emphasis is placed on the management of forest ecosystems for the conservation of biodiversity, including through the creation of reserves, development of management prescriptions, and identification and listing of threatened species.

Forest managed for protection of biodiversity

A total of 46 million hectares (35%) of Australia's native forest is on land protected for biodiversity conservation, or where biodiversity conservation is a specified management intent.

This area is the result of a range of formal and informal processes on both public and private land that are used to protect areas of forest for the conservation of biodiversity. Many areas of forest are protected by, and reported under, more than one process.

- Part of this area is contributed by Australia's National Reserve System, which includes 34 million hectares of forest (26% of Australia's native forests) that have a primary management intent of nature conservation.

Aichi Biodiversity Targets are articulated in the United Nations Strategic Plan for Biodiversity 2011–2020 under the international Convention on Biological Diversity, and include the target that at least 17% of terrestrial areas are protected. With 35% of Australia's native forest area managed for the protection of biodiversity, Australia has therefore met this Aichi Biodiversity Target with respect to native forests.

Forest biodiversity and threatened species

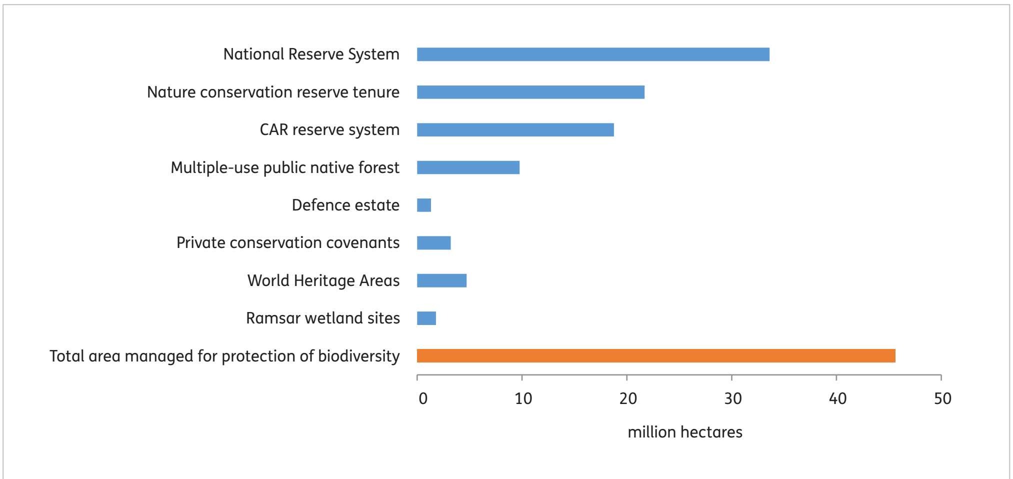
Australia's national lists of forest-dwelling species (species that use forests for part of their lifecycle) include 2,486 forest-dwelling native vertebrate fauna species (animals), and 16,836 forest-dwelling native vascular flora species (plants).

Of the forest-dwelling native vertebrate fauna species, 1,119 have been identified as forest-dependent species (species that require forest habitat for part of their lifecycle and could not survive or reproduce without it).

A total of 1,420 forest-dwelling fauna and flora species are listed as threatened species under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*.

Of the listed threatened forest-dwelling fauna and flora species, 842 species are forest-dependent.

Area of native forest managed for protection of biodiversity, 2016, by protection process



Many areas of forest are protected under more than one process.

The data used to create this figure are available in Microsoft Excel via www.doi.org/10.25814/5be12aa83aa34

The most common threats to nationally listed forest-dwelling fauna and flora include forest loss from clearing for agriculture and urban and industrial development; impacts of predators; small population sizes; and unsuitable fire regimes.

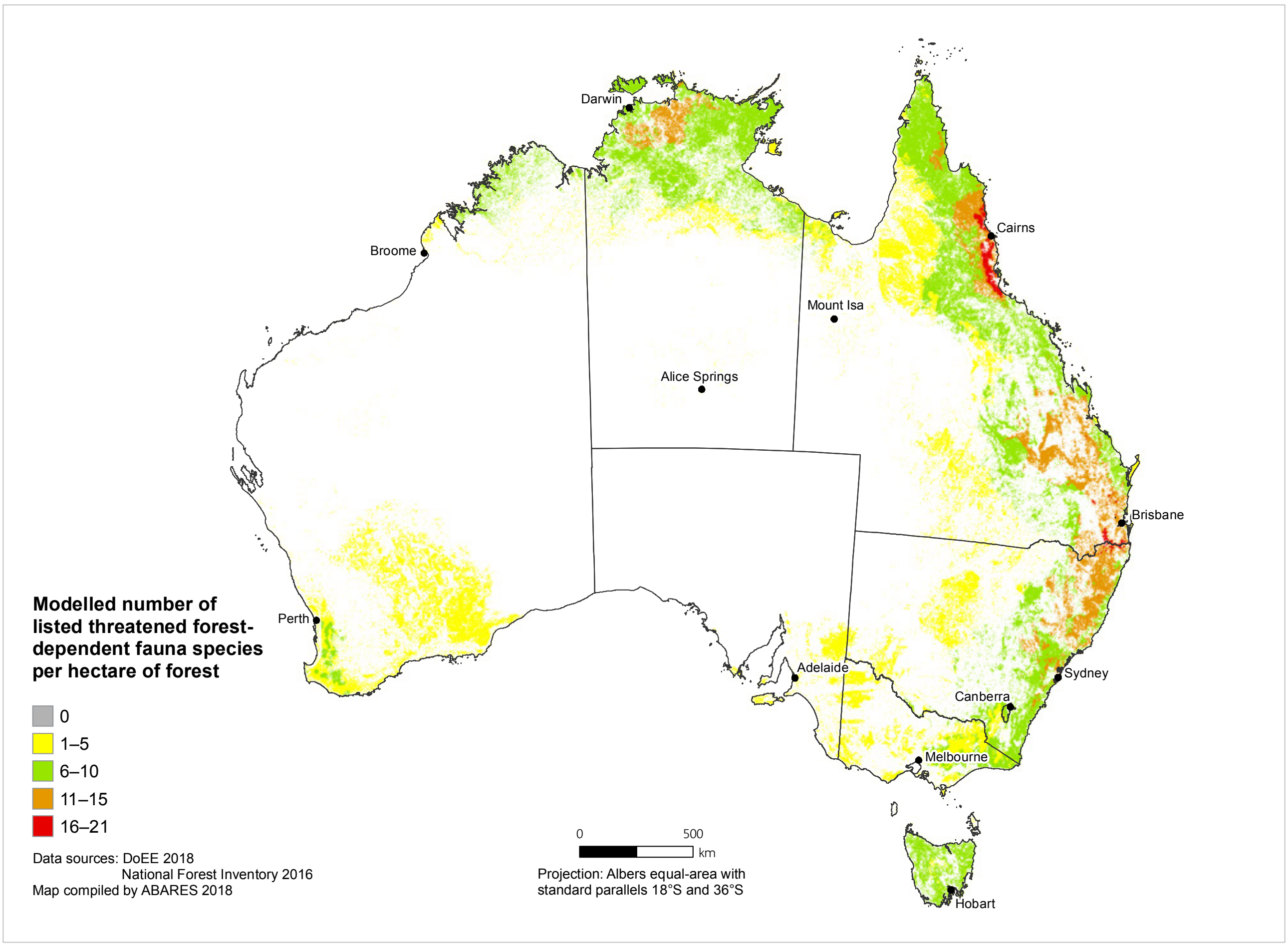
- For listed forest-dwelling fauna species, the most common threat categories are forest loss from clearing for agriculture and urban and industrial development, as well as predation by introduced predators.
- For listed forest-dwelling flora species, the most common threat categories are small population sizes, as well as mortality agents and unsuitable fire regimes.
- A total of 57% of Australia's listed threatened forest-dwelling fauna and flora species have genetic-related reasons contributing to their listing. This includes species with populations that are low in numbers or fragmented, or that have low genetic variability.
- Based on the emphasis given in listing advice documents in regard to their impacts, forestry operations pose a less significant threat to nationally listed forest-dwelling fauna and flora species compared with other threat categories.

The number of listed threatened forest-dwelling and forest-dependent flora and fauna species per hectare of forest have been separately modelled and mapped across Australia. As an example, the regions with the highest density of listed threatened forest-dependent fauna species are the coastal ranges between Townsville and Cooktown in north Queensland, and the border ranges between Queensland and New South Wales.

During the period 2011–16, a total of 68 forest-dwelling species were added to the national list of threatened species, and 77 forest-dwelling species were removed.

- Most additions were based on inherently small population sizes and/or ongoing impacts on habitat extent and quality, including impacts of introduced species and unsuitable fire regimes.
- Most removals of listed species were a result of improved information that indicated that species were no longer considered valid species or were not threatened.

Distribution of listed threatened forest-dependent fauna species



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Rainbow Pitta (*Pitta iris*), a forest-dwelling bird, in Kakadu National Park, Northern Territory.

Australia's forest genetic resources are conserved by a variety of means, including in situ in Australia's native forest and in restoration plantings, as well as in commercial and environmental plantations, seed orchards, arboreta and seed banks.

- There are also tree-breeding and genetic improvement programs for at least 48 native wood-producing and oil-producing species and varieties
- Some Australian native forest species also form a dominant part of the hardwood plantation industry overseas.

For further information on this theme, see Indicator 1.1c, Indicators 1.2a–c and Indicators 1.3a–b of *Australia's State of the Forests Report 2018*.

Forest condition and function

Australia's forests provide a range of ecosystem services in regards to biodiversity, carbon, soil and water. The extent to which these ecosystem services are delivered varies with forest growth stage, with the degree of fragmentation of the forest area, and as a result of the impacts of fire, climatic conditions, and pests and diseases.

Forest growth stage and old-growth forest

Australia's native forests comprise stands at regeneration, regrowth, mature and senescent growth stages, as well as stands of uneven-aged forest.

Data collected over the period 1995–2000 as part of Comprehensive Regional Assessments for Regional Forest Agreements showed that all forest growth stages were present on all tenures, although in different proportions.

- Considering the long time-spans over which forest development occurs, the distribution of growth stages across tenures is unlikely to have changed since data on growth stage were collected.

Old-growth forest is not a specific growth stage, but is defined in relation to stand structure, as 'ecologically mature forest where the effects of disturbance are now negligible'.

- The area of old-growth forest in Regional Forest Agreement regions is calculated to have decreased by 0.5 million hectares between the signing of Regional Forest Agreements and 2016.
- The majority of this decrease occurred in Victoria, almost entirely due to bushfires in the decade to 2009.

Forest fragmentation

The majority of Australia's native forest is continuous, not fragmented.

Forest fragmentation describes the extent to which forest areas are separated by or adjoin non forest areas. It can be assessed as the proportion of forest that is completely bounded by other forest, or alternatively as forest patch size.

- At the 1-hectare scale, 72% of Australia's native forest area is comprised of areas that are completely bounded by forest.
- A total of 68% of Australia's native forest is in patches of over 100 thousand hectares.

Native forest that is not fragmented is found in forested areas of higher rainfall, as well as in regions that have experienced the least clearing for agricultural land use, and in nature conservation reserves.

The most fragmented forests occur in drier regions where woodland forest naturally borders areas of vegetation with lower tree canopy cover, as well as in areas with higher impacts from historical land clearing for agriculture and from urban development.

Forest fire

The total area of forest in Australia burnt one or more times during the period 2011–12 to 2015–16 was 55 million hectares (41% of Australia's total forest area). Areas that burnt more than once during this period were more likely to be in northern Australia.

Of the cumulative area of fire in forests over this period, 69% was unplanned fire.

The annual area of fire in Australia's forests in the period 2011–12 to 2015–16 varied from a high value of 27.4 million hectares in 2012–13, to a low value of 14.9 million hectares in 2015–16.

- The cumulative area of fire in forest across this period (the sum of the forest fire areas for each of the five years) was 106 million hectares.
- The largest cumulative areas of fire in forests were in northern Queensland and the Northern Territory.
- However, this figure includes large areas of forest, especially in northern Australia, that were burnt in more than one of the five years comprising this period.

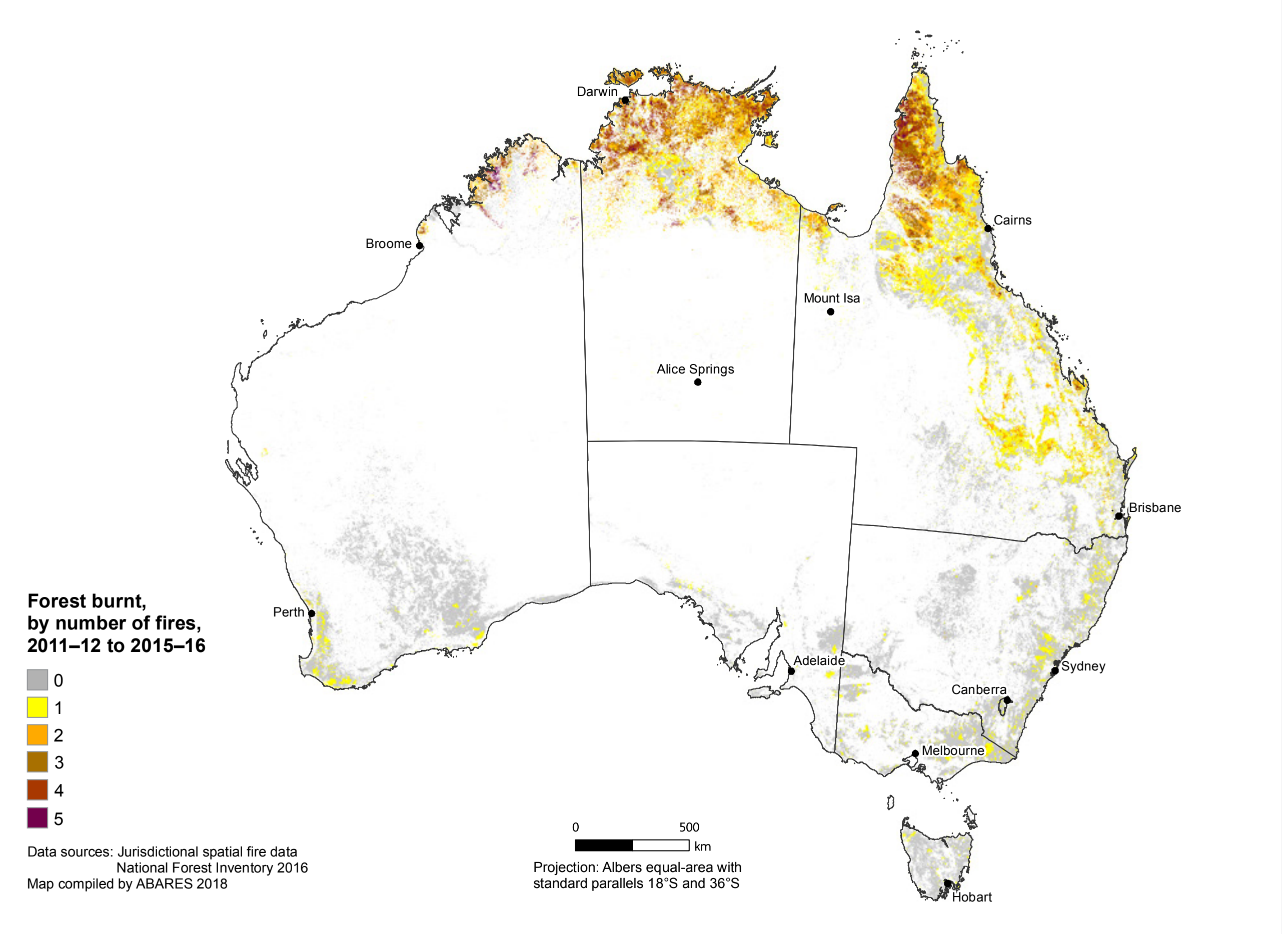
When areas of forest burnt in multiple years are allowed for, the total area of forest burnt one or more times during the period 2011–12 to 2015–16 was 55 million hectares (41% of Australia's total forest area). The balance (59% of Australia's forest area) did not experience fire in this period.

- Tasmania (6% of its forest area) and South Australia (6%) had the lowest proportions of forest area burnt one or more times during this period.
- The Northern Territory (84%) had the highest proportion of forest area burnt one or more times during this period.

Planned fire is used as a forest management tool in fire-adapted forest types for forest regeneration, to promote regeneration after harvest, to maintain forest health and ecological processes, and to reduce fuel loads and thereby increase the ability to manage bushfires and protect vulnerable communities.

- Of the cumulative area of fire in Australia's forests in the period 2011–12 to 2015–16, 69% was unplanned fire and 31% was planned fire, as identified by state and territory fire management agencies.

Distribution of forest burnt by fire in the period 2011–12 to 2015–16, by fire frequency



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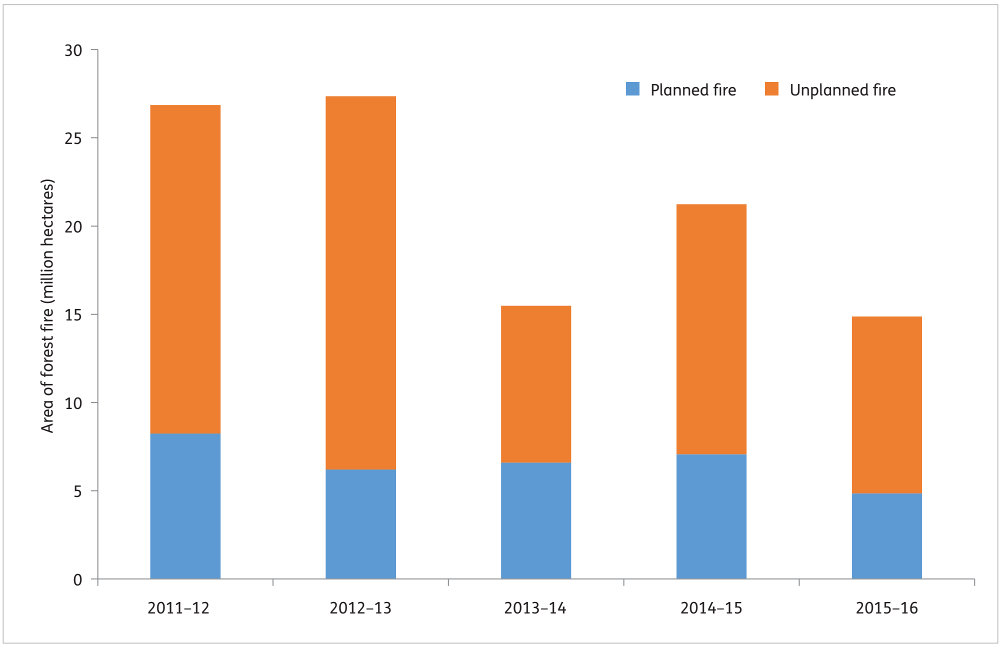
Area of planned and unplanned forest fire



The data used to create this figure are available in Microsoft Excel via www.doi.org/10.25814/5be12aa83aa34

Forest carbon

Carbon stocks in Australia's forests increased by 0.6%, to 21,949 million tonnes, during the period 2011–16.

In addition, 94 million tonnes of carbon was present in wood and wood products in use in 2016, and 50 million tonnes of carbon in wood and wood products in landfill.

Forests contributed to the net sequestration by the land sector of an amount of carbon dioxide that offset 3.5% of total human-induced greenhouse gas emissions in Australia over this period.

A total stock of 21,949 Mt C (million tonnes of carbon) was stored in Australia's forests at the end of June 2016. Of this forest carbon store:

- 85% was stored in non-production native forests, 14% in production native forests and 1.2% in plantations[10].
- 36% was in above-ground biomass and 64% was in below-ground biomass.

Over the period 2001–16, carbon stocks in forests have varied by no more than 0.7% of the total stock. Over the most recent five years (2011–16), forest carbon stocks increased by 129 Mt, due to a combination of recovery from past clearing, additional growth of plantations, reduced clearing of native forest, expansion of the area of native forests, and continued recovery from bushfire and drought.

In addition to carbon in forests, 94 Mt C was present in wood and wood products in use, and 50 Mt C in wood and wood products in landfill.

- Carbon stocks in both these pools increased steadily over the period 2001–16.
- Carbon stock in wood and wood products in use and in landfill increased by 25 Mt over the period 2001–16, which was greater than the 12 Mt decrease in carbon stocks in forests over this period.
- In total, 22,093 Mt C was held in Australia's forests plus harvested wood products at the end of June 2016.

These forest and wood products carbon stock figures are derived from the carbon stock data that are used to calculate emissions from the land-use, land-use change and forestry sector for Australia's National Greenhouse Gas Inventory. Those emissions values are determined according to the accounting rules specified under the United Nations Framework Convention on Climate Change or the Kyoto Protocol, and cannot simply be related to differences in forest carbon stocks over time.

During the period 2011–16, the land-use, land-use change and forestry sector contributed net sequestration of an amount of carbon dioxide that offset 3.5% of total human-induced greenhouse gas emissions for this period in Australia. This was primarily due to sequestration through forest growth and forest management practices exceeding emissions from activities such as land clearing.

Forest soil and water

A total of 27% of Australia's forests are managed primarily for protective functions, including protection of soil and water values.

The area of Australia's public forest managed primarily for protective functions, including protection of soil and water values, is 36.6 million hectares (27% of Australia's total forest area).

- This area includes formal nature conservation reserves, informal reserves in multiple-use public forests, forests protected by prescription (such as steep slopes, erodible soil types and riparian – streamside – zones where harvesting and road construction are not permitted), and forested catchments managed specifically for water supply.

The forest practices systems in Australia's states and territories contain regulations and guidelines designed to prevent or mitigate soil erosion, protect soil physical properties, manage activities that could affect water yields, and manage risks to water quality. Processes are also in place to monitor and ensure compliance with measures that protect forest soil and water resources.

Carbon stored in forests and harvested wood products, 2001 to 2016

	Carbon (million tonnes)			
Forest category	**2001**	**2006**	**2011**	**2016**
Native forests	21,765	21,583	21,557	21,676
Plantations	190	222	252	258
Other forests	6	8	11	15
Total forest	**21,961**	**21,813**	**21,820**	**21,949**
Wood products in use	77	83	89	94
Wood products in landfill	42	46	49	50
Total wood products	**119**	**129**	**138**	**144**
Total forests and wood products	**22,080**	**21,943**	**21,958**	**22,093**

Source of data: Australian Government Department of the Environment and Energy.
The data used to create this table are available in Microsoft Excel via www.doi.org/10.25814/5be12aa83aa34.

[10] Land uses as defined for the National Greenhouse Gas Inventory

Forest health

The range of native and established introduced pathogens and insect pests active during the period 2011–16 is comparable with previous reporting periods.

Myrtle rust is present in all states and territories except the Australian Capital Territory, South Australia and Western Australia. Forests continue to be impacted by climatic conditions.

A total of 25 introduced vertebrate pest species, and 110 weed species, were reported as having an adverse effect on forests in one or more jurisdictions.

- Introduced vertebrate pests with widespread adverse impacts on forests in one or more jurisdictions were deer, cats, rabbits, pigs, foxes and cane toads.
- Weed species with widespread adverse impacts on forests in one or more jurisdictions were Gamba grass, bridal creeper, Mission grass, lantana, St Johns wort, prickly pear, and blackberry.
- In most jurisdictions, a greater number of vertebrate and weed species were reported as damaging to native forest in conservation reserves and in multiple-use public forests, than to plantations.

The range of native and established introduced pathogens and insect pests active during the period 2011–16 is comparable with previous reporting periods.

- However, for several of the insect pests of plantations previously reported to be most damaging, there were sharp declines over this period in the number of populations that required management.

Myrtle rust is present in all eastern states of Australia and in the Northern Territory.

- Subtropical wet sclerophyll forest or rainforest communities that have mid-storey and understorey layers rich in species of the Myrtaceae family are being severely altered by myrtle rust, with populations of two widespread species, *Rhodamnia rubescens* and *Rhodomyrtus psidioides*, in rapid local decline.

Forests affected by extended drought in southern Australia commenced recovery in the period 2011–16, and the activity of secondary pests and pathogens that attacked drought-stressed trees declined. However, the trend of increasing mean annual temperatures for Australia continued during the period 2011–16, with each year between 2013 and 2016 setting a new record for annual average temperature.

Historic water wheel, Lowden Forest Park, New South Wales.

Most of the forests that suffered extensive damage from tropical cyclone Yasi in 2011 are also recovering. In February 2015, tropical cyclone Marcia caused significant damage to pine plantations in the Byfield area, Queensland, and 600 thousand cubic metres of logs were salvaged from damaged plantations.

Extensive areas of mangrove along the southern coast of the Gulf of Carpentaria suffered rapid dieback and mortality in late 2015.

- The event coincided with unusually low sea-levels and several climate anomalies, which in combination are thought to have produced hypersaline conditions that were beyond levels tolerated by the mangrove species.

Australia has developed a Plantation Forest Biosecurity Plan and a National Forest Biosecurity Surveillance Strategy Implementation Plan to strengthen surveillance systems and minimise the threats from forest pests and pathogens.

For further information on this theme, see Indicator 1.1b, Indicator 1.1d, Indicators 3.1a–b, Indicators 4.1a–e, Indicator 5.1a and Indicator 6.1c of *Australia's State of the Forests Report 2018*.

Production forests

Australia's plantations and native forests provide for commercial production of wood products, under a range of silvicultural systems. Following harvest, areas are regenerated or replanted.

Commercial plantations

The area of commercial plantation was 1.95 million hectares in 2014–15. This area increased from 1990 to 2010, but reduced by 44 thousand hectares (2%) between 2010–11 and 2014–15.

The area proportion of commercial plantations where the trees are privately owned increased to 79% in 2014–15.

As determined from the National Forest Inventory spatial dataset, the area of commercial plantations in 2014–15 was 1.95 million hectares, comprising 1.0 million hectares of softwood species (mostly pines), 0.9 million hectares of hardwood species (mostly eucalypts), and 0.01 million hectares of unknown or mixed species plantations.

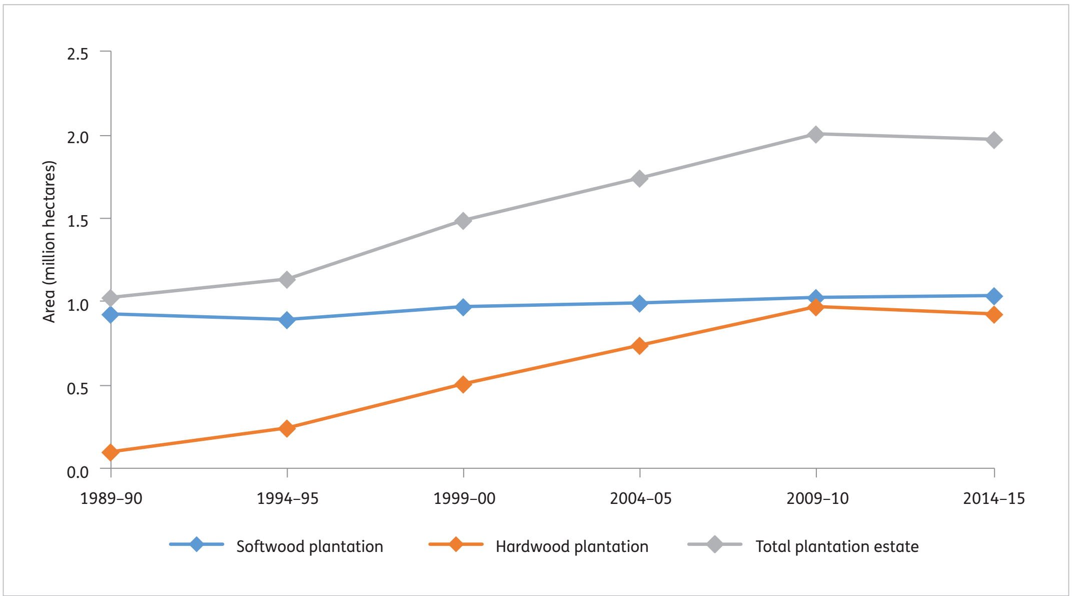
The area of commercial plantations reduced by 44 thousand hectares (2%) between 2010–11 and 2014–15.

- This change reflects a combination of plantation land that was not commercially productive being converted to agricultural or other land uses, and revisions of area figures on land use by plantation managers.
- The area of commercial softwood plantations increased by 1% between 2010–11 and 2014–15, while the area of commercial hardwood plantations decreased by 5%.

The area proportion of Australia's commercial plantation estate where the trees are owned by government organisations decreased from 24% to 21% between 2010–11 and 2014–15, while the proportion where the trees are privately owned increased from 76% to 79%.

The average rate of re-establishment of commercial plantations after harvest between 2011–12 and 2015–16 was 38,500 hectares per year. Across different jurisdictions over this period, the average area proportion of re-established commercial plantation that met stocking standards varied between 93% and 99%.

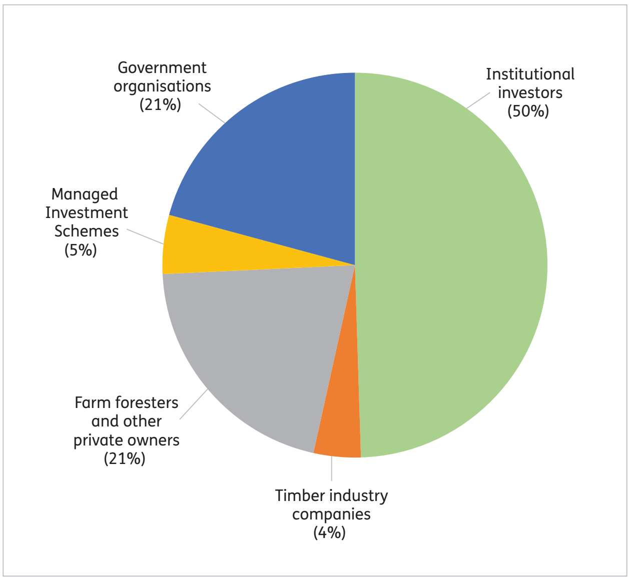
Australia's commercial plantation area, 1989–90 to 2014–15



Total plantation estate data for 1999–2000 to 2014–15 also includes plantations in the 'Unknown or mixed' category.

The data used to create this figure are available in Microsoft Excel via www.doi.org/10.25814/5be12aa83aa34

Ownership of Australia's commercial plantations, 2014–15



Ownership data refer to ownership of trees. Joint venture arrangements between government agencies and private owners are included under 'Government organisations' where government is the manager of the plantation resource.

Note: totals may not tally due to rounding.

The data used to create this figure are available in Microsoft Excel via www.doi.org/10.25814/5be12aa83aa34

Production native forest

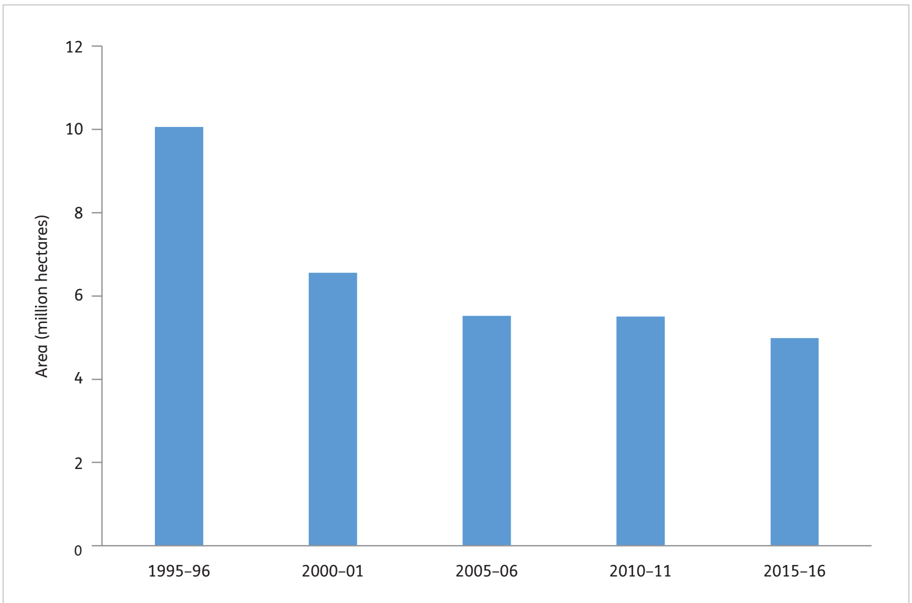
The extent of native forest that is available and suitable for commercial wood production on private and public land was 28.1 million hectares in 2015–16. This area decreased from 2011–12 to 2015–16.

The net harvestable area of multiple-use public native forests was 5.0 million hectares in 2015–16. This area also decreased from 2010–11 to 2015–16.

The extent of native forest that is available and suitable for commercial wood production was 28.1 million hectares in 2015–16. This is a decrease from 29.3 million hectares in 2010–11.

- This area of 28.1 million hectares includes 21.8 million hectares on leasehold and private tenure. However, much of this area is rated as low commerciality (on the basis of its suitability for commercial wood production), is isolated from markets, and harvesting is not financially viable, and is therefore used predominantly for grazing or for other purposes.
- This area of 28.1 million hectares also includes 6.3 million hectares of multiple-use public native forests, much of which is located in the higher rainfall areas of south-west, south-east and eastern Australia.
- When additional exclusions and restrictions to manage non-wood values are taken into account, this available and suitable area of multiple-use public native forests is further reduced to a 'net harvestable area' of 5.0 million hectares. This is a decrease from 5.5 million hectares in 2010–11.
- The decreases in these area measures from 2011–12 to 2015–16 mostly resulted from transfer of areas of multiple-use public native forest to nature conservation reserves, as well as increases in areas to which harvesting restrictions apply.

Net harvestable area of multiple-use public native forest



Area figures do not include harvestable areas on leasehold or private lands accessible to public forest agencies for wood harvesting.

The data used to create this figure are available in Microsoft Excel via www.doi.org/10.25814/5be12aa83aa34

The average annual area of multiple-use public native forest from which wood was harvested decreased to 78 thousand hectares over the period 2011–12 to 2015–16.

Within this area, the proportion harvested by clearfelling systems decreased to 9%.

The average annual area of multiple-use public native forests harvested in Australia in the period 2011–12 to 2015–16 was 78 thousand hectares.

- This is a 24% decrease from the annual average of 102 thousand hectares for the period 2006–07 to 2010–11, which in turn was a 21% decrease from the annual average of 129 thousand hectares for the period 2001–02 to 2005–06.
- The total area harvested on multiple-use public native forests in 2015–16, 73 thousand hectares, is 1.5% of the net harvestable area of public native forest, and 0.75% of the total area of multiple-use public native forest.

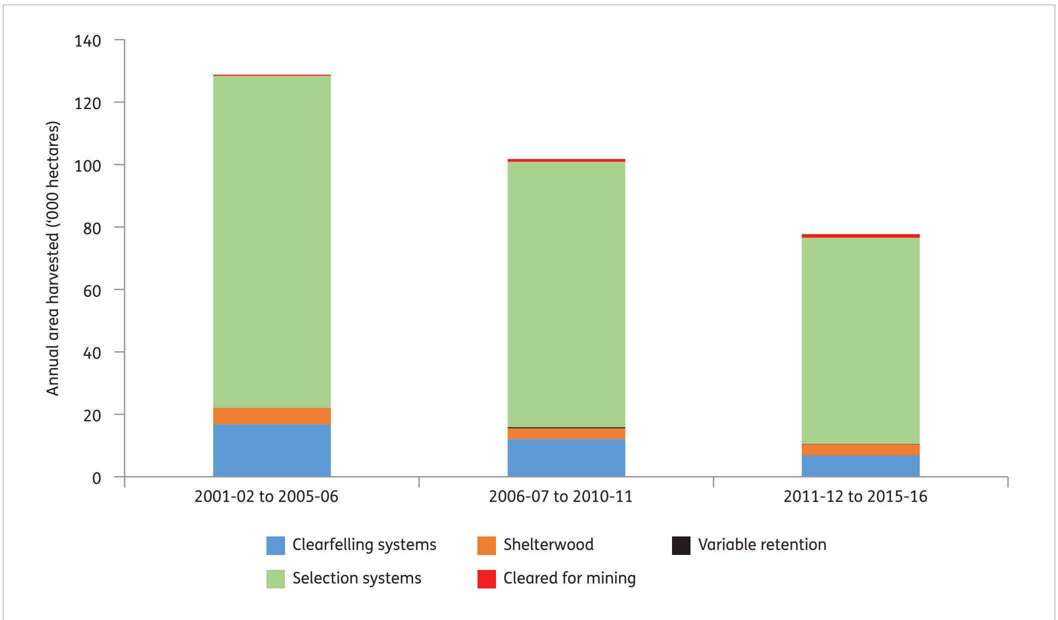
A range of silvicultural systems are used for forest harvesting.

- Of the area of multiple-use public native forest harvested over the period 2011–12 to 2015–16, 86% was harvested using selection systems (selection, native cypress pine silviculture and commercial thinning), 9% by clearfelling systems (clearfelling, fire-salvage clearfelling and intensive silviculture with retention), 5% by shelterwood systems, and 0.2% by variable retention systems.
- The annual average area harvested by clearfelling systems decreased from 17 thousand hectares in 2001–02 to 2005–06, to 12 thousand hectares in 2006–07 to 2011–12, to 7 thousand hectares in 2011–12 to 2015–16.

Across the period 2011–12 to 2015–16, the annual average proportion of harvested multiple-use public native forest that was effectively regenerated, as assessed against stocking standards, was 79% in New South Wales, 100% for Queensland, 95% for Tasmania and 92% for Victoria. For Western Australia, the level of regeneration was assessed as adequate, with more detailed reporting to be provided in the mid-term performance review of the *Forest Management Plan 2014–2023*.

For further information on this theme, see Introduction, Indicator 1.1a and Indicators 2.1a–c of *Australia's State of the Forests Report 2018*.

Average annual area harvested from multiple-use public native forest, by silvicultural system



The area of variable retention harvesting is not visible at this scale. Jarrah forests in Western Australia that are harvested as part of clearing for bauxite mining are shown as 'cleared for mining'. The three time-periods refer to the reporting periods for SOFR 2008, SOFR 2013 and SOFR 2018 respectively.

The data used to create this figure are available in Microsoft Excel via www.doi.org/10.25814/5be12aa83aa34

Harvested wood and non-wood products

Wood and non-wood products from Australia's forests make a substantial contribution to the economy and to society more generally. An increasing proportion of Australia's wood is produced in plantations.

Wood volumes harvested

Australia's log harvest in 2015–16 was 30.1 million cubic metres, a 13% increase from 2010–11.

The volume of logs harvested from commercial plantations increased over this period, and 86% of the total log harvest was derived from commercial plantations in 2015–16.

A progressive reduction in total native forest harvest volumes has occurred in all jurisdictions since the period 2001–06. The national harvest of sawlogs from private native forests has also declined progressively since that period.

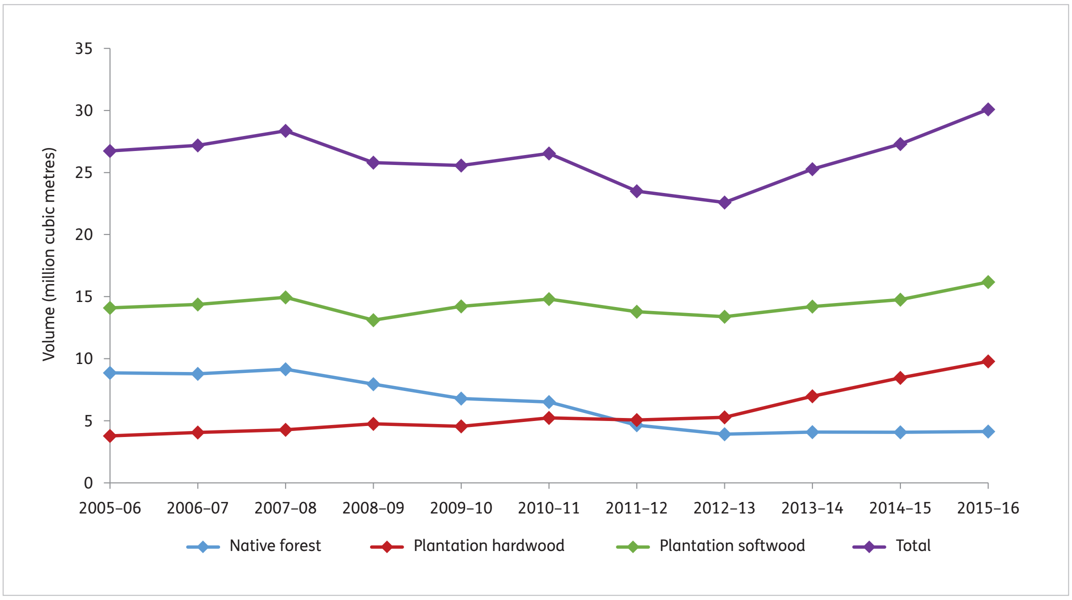
The total volume of Australia's log harvest in 2015–16 was 30.1 million cubic metres, a 13% increase from 26.5 million cubic metres in 2010–11.

Over the period 2010–11 to 2015–16, the volume of logs harvested from commercial hardwood and softwood plantations increased by 30%, from 20.0 million cubic metres to 26.0 million cubic metres.

- The volume of logs harvested in 2015–16 comprised 9.8 million cubic metres of plantation hardwood logs and 16.2 million cubic metres of plantation softwood logs.
- Over the period 2000–01 to 2015–16, the annual plantation hardwood pulplog harvest increased from 0.9 million cubic metres to 9.6 million cubic metres.
- Approximately 60% by volume of the total plantation log harvest in the period 2011–16 was sawlogs, and 39% by volume was pulplogs. However, of the total plantation hardwood log harvest in this period, only 2% by volume was sawlogs and 98% by volume was pulplogs.
- In 2015–16, 86% of the volume of logs harvested in Australia was from commercial plantations.

The availability of sawlogs and pulplogs for harvest from softwood plantations is expected to remain relatively constant over the period from 2015–19 to 2055–59. During the same period, the total availability of sawlog for harvest from hardwood plantations is expected to increase, while the total availability of pulplog for harvest from hardwood plantations is expected to decrease.

Volume of logs harvested from native forests and commercial plantations



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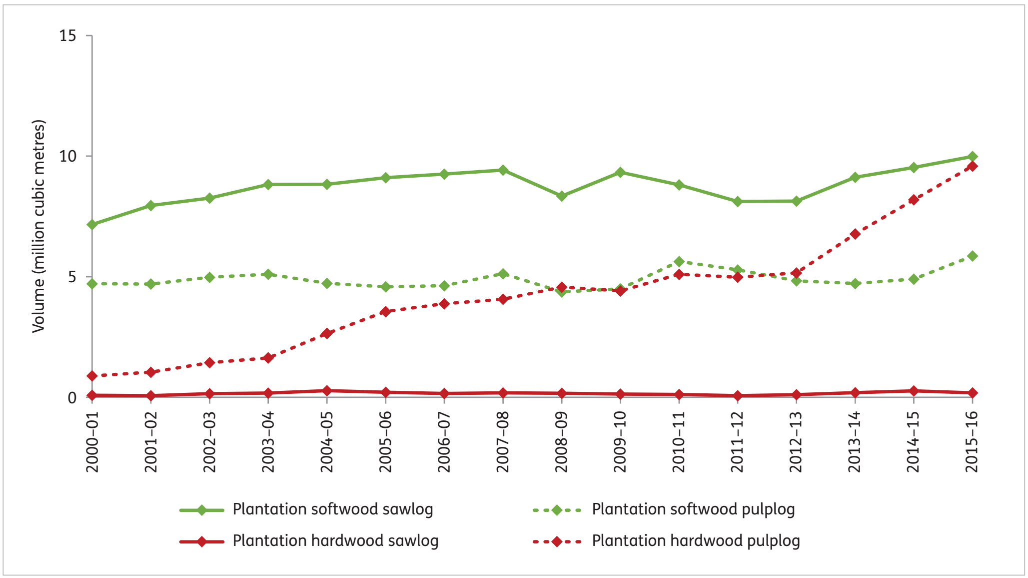
Volume of hardwood and softwood sawlogs and pulplogs harvested from plantations



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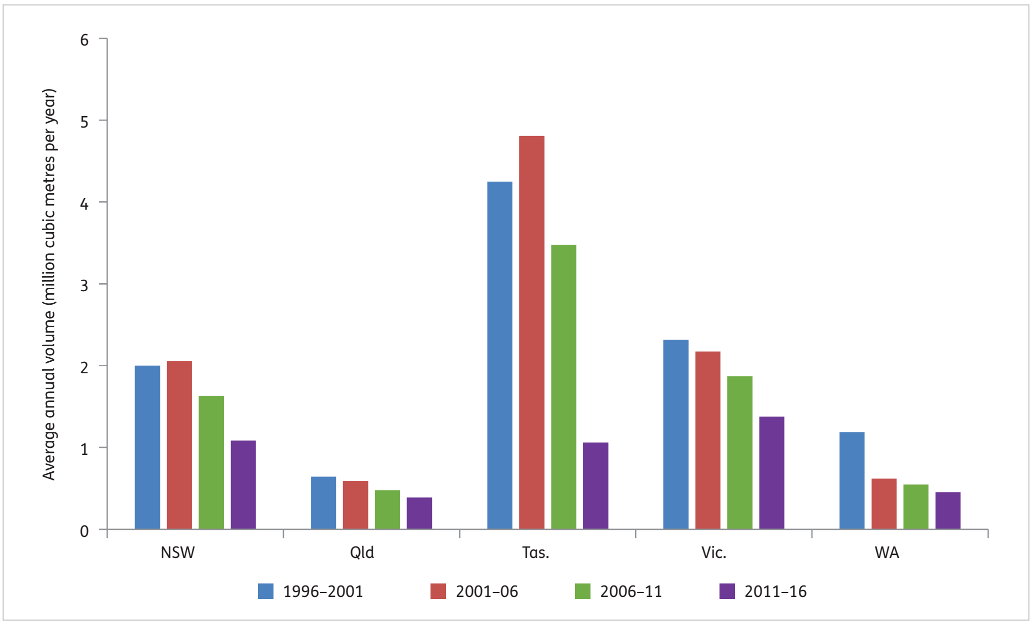
Volume of logs harvested from native forests across Australia



No harvesting of public native forest occurs in Australian Capital Territory, the Northern Territory or South Australia.

The data used to create this figure are available in Microsoft Excel via www.doi.org/10.25814/5be12aa83aa34

Over the period 2010–11 to 2015–16, the volume of logs harvested from native forests declined by 37%, from 6.5 million cubic metres to 4.1 million cubic metres. A progressive reduction in native forest harvest volumes has occurred over the last 20 years in all jurisdictions in which there is harvesting of native forest, due to reduction in areas available for wood production, and changes in national and international markets.

The national harvest of sawlogs from private native forests has declined progressively since the period 2001–06. The reasons for this decline differ between states, and are not always clear.

Native forests remain the main source of hardwood sawlogs, because most hardwood plantations cannot be managed to produce sawlogs of comparable quality, although there is on-going research on this topic. Native forest sawlogs are primarily used to make feature-grade sawn timber products.

Production from plantations and native forests can also be analysed as sawnwood, wood-based panels, and paper and paperboard. Over the period 2010–11 to 2015–16:

- The total volume of sawnwood production increased by 12%, from 4.6 to 5.1 million cubic metres.
- The total volume of wood-based panel production decreased by 2%, from 1.73 million cubic metres to 1.70 million cubic metres.
- The total weight of paper and paperboard production increased by 2%, from 3.16 million tonnes to 3.22 million tonnes.

In 2015–16, the value of logs harvested from native forests and commercial plantations was $2.3 billion.

In 2015–16, the value of production of wood products industries was $23.7 billion.

In 2015–16, the value added by the forest and wood products industries was $8.6 billion, representing a contribution to Australia's gross domestic product of 0.52%.

The value of logs harvested from native forests and commercial plantations (calculated at the mill door) increased by 22% over the period 2010–11 to 2015–16, from $1.9 billion to $2.3 billion.

- The value of logs harvested from native forests decreased from $0.50 billion to $0.39 billion over this period.
- The value of logs harvested from commercial plantations increased from $1.36 billion to $1.88 billion over this period.

The value of production (total industry turnover, or sales and service income) of the wood products industries decreased by 2% over the period 2010–11 to 2015–16, from $24.0 billion to $23.7 billion.

- The value of sawnwood production decreased by 7%, from $3.8 billion in 2010–11 to $3.5 billion in 2014–15.
- The value of wood-based panel production decreased by 3%, from $1.62 billion in 2010–11 to $1.57 billion in 2015–16.
- The value of paper and paperboard production decreased by 4%, from $10.9 billion in 2010–11 to $10.5 billion in 2015–16.

The value added by the forest and wood products industries was $8.6 billion in 2015–16, representing a contribution to Australia's gross domestic product of 0.52%. In 2010–11 the value added was $8.3 billion, a contribution of 0.59%.

Sustainable harvest of native forests

The volume of sawlogs harvested from public native forests in the period 2011–12 to 2015–16 was within sustainable yield levels in New South Wales, Tasmania, Victoria and Western Australia, and was within the allowable cut in Queensland.

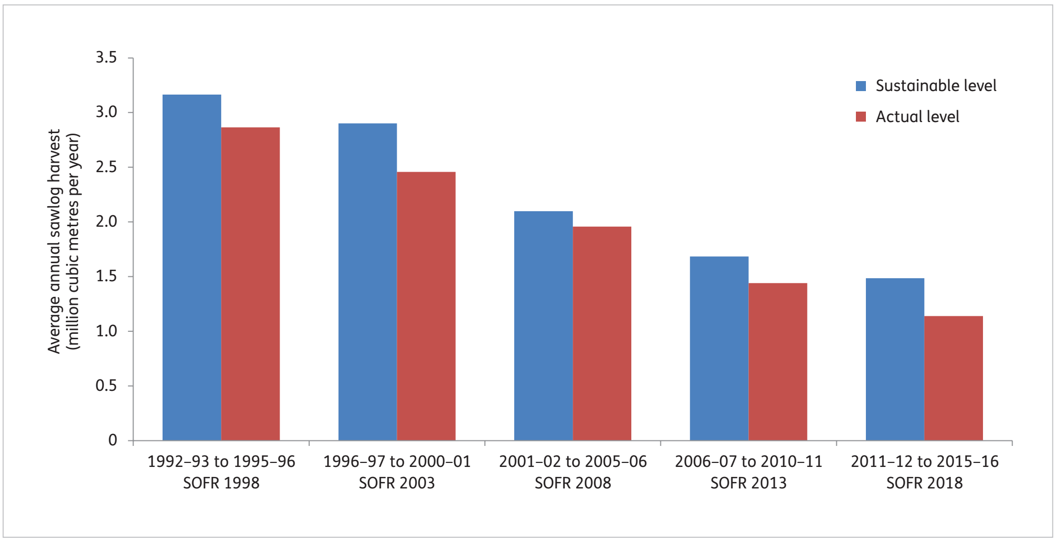
An average annual volume of 1.14 million cubic metres of high-quality sawlog was harvested from multiple-use public native forests (including other native forests where timber is owned by the Crown) nationally in the period 2011–12 to 2015–16.

- This is a 21% decrease from the annual average volume of 1.44 million cubic metres in the period 2006–07 to 2010–11, which in turn was a 26% decrease from the annual average of 1.96 million cubic metres for the period 2001–02 to 2005–06.

The sustainable annual yield of high-quality sawlogs from multiple-use public native forests is the yield that can be removed each year while ensuring maintenance of the functioning of the native forest system as a whole and the supply of wood products in perpetuity. This sustainable yield has declined by 53% from 1992–93 to 2015–16.

- Reasons for the decline in sustainable yield from multiple-use public native forests include the transfer of multiple-use public native forests into nature conservation reserves, increased restrictions on harvesting, revised estimates of growth and yield, and (especially in Victoria) impacts of occasional, intense broad-scale bushfires.

National average annual harvest and sustainable yield of sawlog from multiple-use public native forests



Includes harvest from private and leasehold native forests where timber rights are owned by the Crown.

The data used to create this figure are available in Microsoft Excel via www.doi.org/10.25814/5be12aa83aa34

However, the volume of sawlogs harvested from public native forests in each of the five reporting periods from 1992–93 to 2015–16 remained within sustainable yield levels in New South Wales, Tasmania, Victoria and Western Australia or within allowable tolerances, and was within the allowable cut in Queensland. No harvesting of public native forest occurs in the Australian Capital Territory, the Northern Territory, or South Australia.

Nationally, the sustainable yield of high-quality sawlogs from publicly managed native forests is forecast to continue to decline until the period 2030–34. After that time, it is forecast to increase slightly, given no further reductions in net harvestable area, and successful management of risk from wildfire, disease and climate change.

Non-wood forest products

Australia produces a wide range of non-wood forest products derived from forest fauna, flora and fungi, and many non-wood forest products supply commercial domestic and export markets. High-value non-wood forest products include wildflowers, seed, honey, and aromatic products derived from tea-tree and sandalwood.

Data on annual removals are limited for many non-wood forest products, but are available for some of the more commercially significant non-wood forest products such as tree ferns in Tasmania, eastern grey kangaroo and wallaroo in Queensland, Bennett's wallaby and brushtail possum in Tasmania, and honey nationally. Information on the production, consumption and trade of non-wood forest products is also often difficult to obtain because of the generally small size of industries based on these products and their dispersed nature.

Beekeeping is one of the largest non-wood forest product industries. Over the period 2011–16:

- an annual average of 20.8 thousand tonnes of honey was produced, much of which was derived from forested lands
- the annual volume of honey production declined by 17%
- the gross annual value of honey production increased by 39%, to $110 million.

Banksia inflorescence, Queensland.

Consumption, trade and recycling of wood products

Australia's trade in wood products experienced strong growth over the past decade, with the sum of imports and exports (total merchandise trade) exceeding $8 billion for the first time in 2015–16.

Australia continues to be a net importer of wood and wood products.

The patterns of annual consumption of forest products in Australia changed over the period 2010–11 to 2015–16.

- Annual consumption of sawnwood increased by 12%, to 5.6 million cubic metres.
- Annual consumption of wood-based panels increased by 5%, to 2.1 million cubic metres.
- Annual consumption of paper and paperboard fell by 8%, to 3.7 million cubic metres.

Australia's trade in wood products experienced strong growth over the past decade, with the sum of imports and exports (total merchandise trade) exceeding $8 billion for the first time in 2015–16.

- Between 2010–11 and 2015–16, the total annual value of wood product imports increased from $4.4 billion to $5.5 billion, driven mainly by higher imports of miscellaneous forest products and wood-based panels.
- The total value of annual wood product exports increased from $2.5 billion to $3.1 billion over this period, primarily due to higher exports of roundwood, woodchips, and paper and paperboard.
- Australia continues to be a net importer of wood and wood products.

Residential use of firewood declined by 12% between 2006–11 and 2011–16, whereas industrial use of fuelwood increased by 19%.

- In the period 2011–16, industrial fuelwood was used to generate an annual average of 40 petajoules of energy.

In 2015–16, 1.7 million tonnes of recycled paper were used for domestic paper and paperboard production in Australia, contributing 53% of paper and paperboard produced.

- A total of 1.4 million tonnes of recycled paper were also exported in 2015–16.
- Altogether, in 2014–15 Australia recycled 60% of the 5.3 million tonnes of paper and cardboard waste generated.

For further information on this theme, see Indicators 2.1c–e, Indicators 6.1a–b and Indicators 6.1d–e of *Australia's State of the Forests Report 2018*.

Employment and education

The forest sector is a significant employer in rural and regional Australia. Educated workers are integral to the development of the forest and wood products industries, and economic diversity, community wellbeing and capital resources contribute to resilient communities.

Employment, wages and safety

Total national direct employment in the forest sector was 51,983 persons in 2016, a 24% decrease from 2011.

A total of 30 Local Government Areas are rated as dependent on forest and wood products industries through having 2% or more of their working population employed in the sector and containing more than 20 workers employed in these industries.

Total national direct employment in the forest sector was estimated at 51,983 persons in 2016, down by 24% from 68,596 persons in 2011. Forest sector employment decreased in all jurisdictions except the Northern Territory during this period.

- Between 2011 and 2016, national direct employment decreased in the wood product manufacturing subsector and the pulp, paper and converted paper product manufacturing subsector, but increased in the smaller forestry and logging and forestry support services subsectors.
- The key drivers for the reduction in total employment in the forest sector were consolidation of processing into larger facilities with higher labour efficiencies, and restructuring of the sector.
- The forestry and wood products sector also creates employment indirectly, in activities that support or depend on this sector.

In 2016, there were 30 Local Government Areas (LGAs) rated as dependent on forest and wood products industries through having 2% or more of their working population employed in the sector and containing more than 20 workers employed in these industries.

- Five of these LGAs had 8% or more of their workforce employed in the forest and wood products industries.
- Employment in forest and wood products industries declined in 21 of these 30 LGAs over the period 2011–16. With the exception of LGAs in Victoria, these declines were greater than the declines observed in total employment within each LGA.
- Large proportional increases in forest and wood products industries employment were in LGAs in south-west Victoria and northern Tasmania.

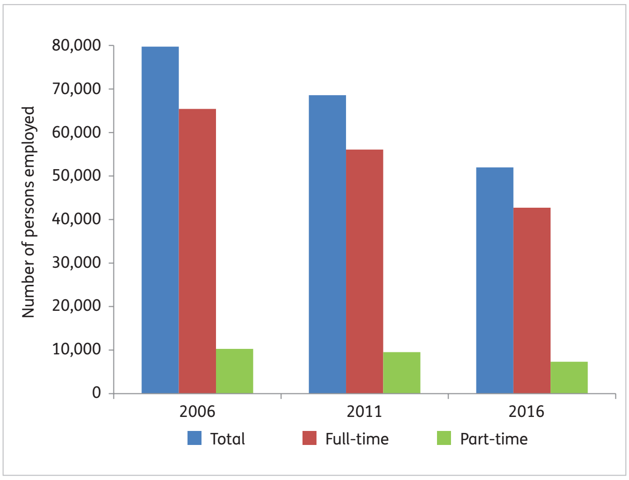
Total annual wages and salaries in the forest sector were between $4.0 and $4.3 billion over the period 2010–11 to 2015–16. In 2015–16:

- the average annual wage in the forestry and logging subsector was $41,538
- the average annual wage in the wood product manufacturing subsector was $53,233
- the average annual wage in the pulp, paper and converted paper product subsector was $94,125.

Nationally, 28% of forest sector workers households had weekly incomes below $800. This is slightly lower than the proportion for total workforce households.

- The proportion of households with weekly incomes below $800 fell by more in the forest sector over the five years to 2016, than in the broader workforce.

Total national employment in the forest sector



Total employment is slightly higher than the sum of full-time and part-time employment because total employment also includes a relatively small number of persons employed but away from work.

The data used to create this figure are available in Microsoft Excel via www.doi.org/10.25814/5be12aa83aa34

Between 2010–11 and 2014–15, the number of serious injury claims rose by 5% in the forestry and logging subsector (from 137 to 144), and fell by 25% in the wood and paper product manufacturing subsector (from 1,826 to 1,371).

- The incidence of serious injury claims per thousand employees in each sector varied similarly.

Education and community resilience

Levels of community adaptive capacity varied considerably across the 30 Local Government Areas rated as dependent on forest and wood products industries.

Nationally, 54% of forestry workers had non-school qualifications in 2016, compared with 65% in the total workforce.

Community adaptive capacity can be represented as a combination of economic diversity, community wellbeing, and capital resources. Higher levels of adaptive capacity in communities can indicate greater resilience to industry change.

- Levels of community adaptive capacity varied considerably across the 30 Local Government Areas rated as dependent on forest and wood products industries.

In 2016, the median age of forest and wood products workers was from 40 to 50 years in 22 of the 30 LGAs dependent on forest and wood products industries.

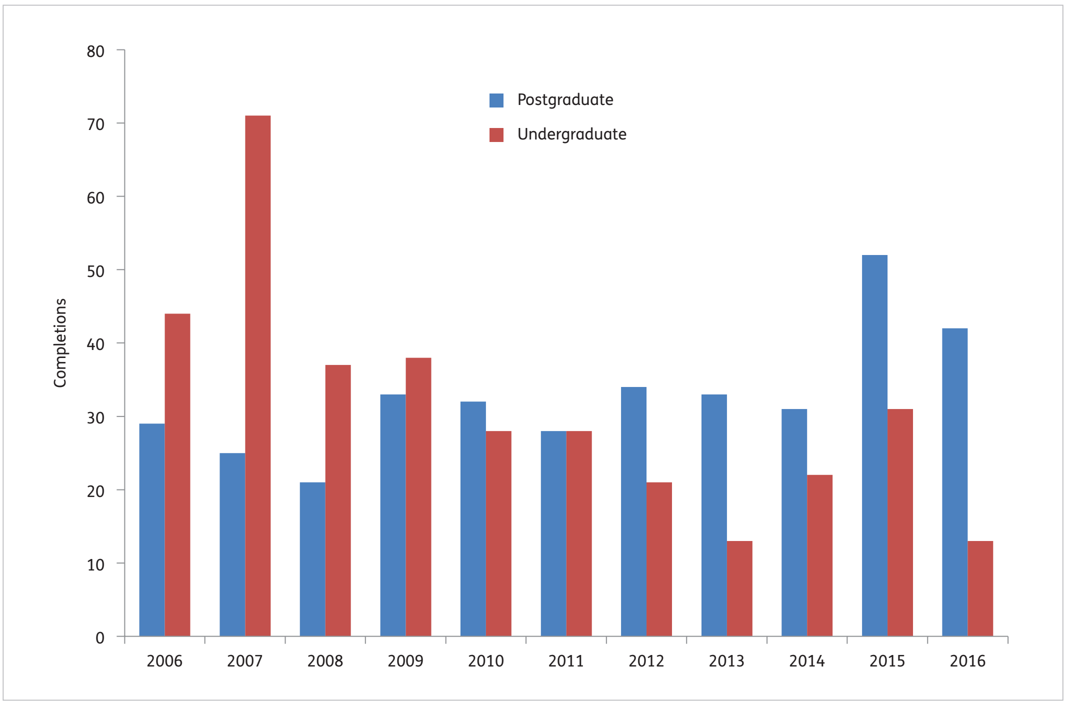
- There was a small increase in the median age of forest and wood products workers nationally between 2011 and 2016.
- In eight LGAs dependent on forest and wood products industries, four of which were in Tasmania, the median age of workers in this sector was lower in 2016 than in 2011.

Nationally, 54% of forestry workers had non-school qualifications in 2016 (such as certificates, diplomas or degrees), compared with 65% in the total workforce.

- In 25 of the 30 LGAs dependent on forest and wood products industries, the proportion of forestry workers with qualifications increased between 2011 and 2016.
- A range of training and education qualification options continues to be available in Australia across all areas relevant to sustainable forest management, from operational competency certificates, to coursework certificates and diplomas, and graduate and postgraduate degrees.
- Over time, there has been a decreasing trend in undergraduate degree completions, and an increasing trend in postgraduate degree completions.

For further information on this theme, see Indicators 6.5a–c and Indicators 7.1b–c of *Australia's State of the Forests Report 2018*.

Australian university degree completions in forest-related studies



Postgraduate degree completions include graduate diplomas.

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Social and community

Australia's forests provide multiple social values to the community. They provide opportunities for tourism and recreation, and include many sites that provide evidence of the interactions between people and forest landscapes.

Heritage

In 2016, 11.0 million hectares of forest was on non-Indigenous heritage-listed sites. In addition, in 2016 there were an estimated 126 thousand registered Indigenous heritage sites within forest.

Heritage represents the tangible and intangible connections that people have with the past, through landscapes, landmarks, places, historic buildings, objects, significant events, customs and ceremonies. Heritage sites are widespread across Australia's forests.

In 2016, 11.0 million hectares of forest was on non-Indigenous heritage-listed sites across all jurisdictions.

- This is an increase of 3.7 million hectares since 2011, mainly due to the registration of new heritage places.

In addition, in 2016 there were an estimated 126 thousand registered Indigenous heritage sites within forest.

- Excluding the Australian Capital Territory and Victoria, for which spatial data were not available, there were 1.8 million hectares of forest in registered Indigenous heritage sites in 2016.

Visitation

Most forests in nature conservation reserves and multiple-use public native forests in Australia are available to the general public for recreation or tourism purposes. An annual average of 4.2 million visitors visited major forested tourism regions for bushwalking in the period 2011–12 to 2015–16.

The total areas of native forest in nature conservation reserves and multiple-use public native forests tenures are 21.7 million hectares and 9.8 million hectares, respectively. These are the tenures generally available to the general public for recreation or tourism.

- Some land in other tenure categories may be similarly available.
- Kakadu National Park in the Northern Territory is an example of reserved forest on private land tenure that is available for recreation and tourism.

Tourism Australia data indicate that an annual average of 4.2 million visitors visited major forested tourism regions for bushwalking in the period 2011–12 to 2015–16, with 10% of these visitors identifying as international visitors.

- Data are also available at the state and territory level on the number of sites and facilities for a diverse range of recreational activities in both nature conservation reserves and state forests (multiple-use public forests), and the number of visitors.
- For example, Forestry Corporation of New South Wales estimated that there were 28 million recreational visitors to New South Wales state forests during 2015–16. Forestry Corporation of New South Wales manage and maintain more than 150 designated visitor sites.

Indigenous participation and employment

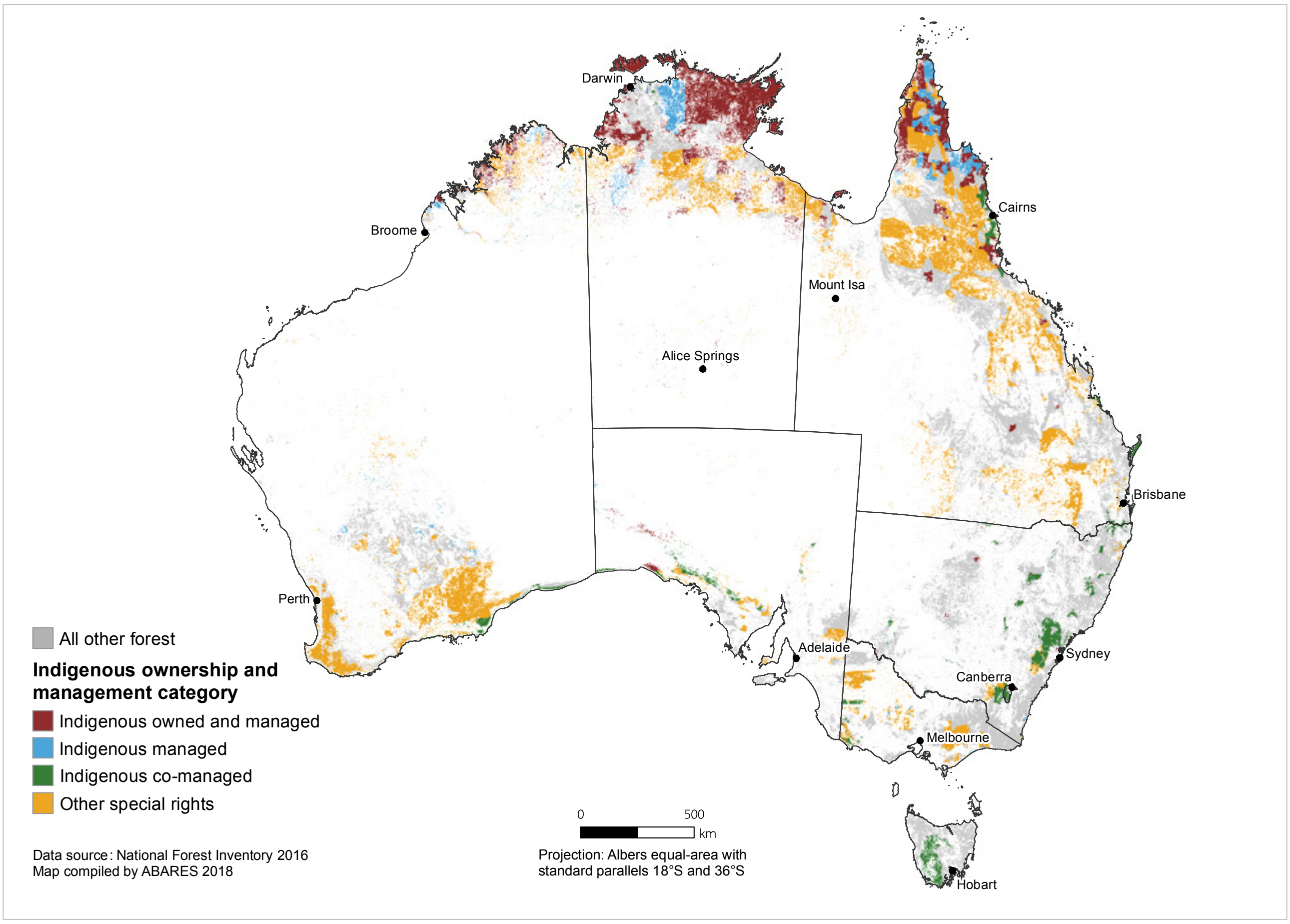
Four Indigenous ownership and management categories describe the degree of management control and influence that Indigenous people have over forest land.

In 2016, the forest and wood products industries directly employed 1,099 Indigenous people, while an estimated 337 Indigenous people were employed in conservation or park operation roles in areas with forested conservation reserves.

Access to native forests, and involvement in native forest management, enables Indigenous people to maintain or re-connect with cultural values, which in turn strengthens personal and community resilience.

- The degree of management control and influence that Indigenous people have over forest relates to the Indigenous ownership and management category into which the forest is classified: Indigenous owned and managed, Indigenous managed, Indigenous co managed, or covered by Other special rights. Together, land in these four categories comprises the Indigenous forest estate.
- This Indigenous forest estate covers a total of 70 million hectares of forest (52% of Australia's forests).
- The largest areas of forest in the Indigenous estate occur within Indigenous Land Use Agreement areas, and areas for which there has been a native title determination.
- Other large areas of forest occur within the Northern Territory Aboriginal Land Trusts, Queensland Aboriginal and Torres Strait Islander land trusts, Indigenous Protected Areas, and owned and leased-back conservation reserves.

Distribution of the Indigenous forest estate by land ownership and management categories



A higher resolution version of this map is available via www.doi.org/10.25814/5be3bc4321162

Indigenous participation in forest management occurs through a variety of mechanisms, including direct ownership, management, employment, co-management of reserve areas, consultation about cultural heritage, and programs for engagement of urban Indigenous people with forests.

- There are ongoing efforts to include Indigenous cultural, contemporary and aspirational values in forest management
- Over time, there has been increased Indigenous participation in the development and implementation of management plans for forest reserves, conservation reserves and regional conservation areas across Australia.

An estimated 337 Indigenous people were employed in conservation or park operation roles in areas with forested conservation reserves in 2016. Forest-related employment that draws on traditional activities and knowledge delivers both cultural and economic benefits.

Participation of Indigenous workers in the commercial forest and wood products industries can also support livelihoods through income, skills development, and a connection with forests through services and advice. In 2016, the forest and wood products industries directly employed 1,099 Indigenous people nationally.

- In seven Indigenous Locations across Australia, more than 10% of the Indigenous workforce was employed in the forest and wood products industries.

Public perceptions of forest management

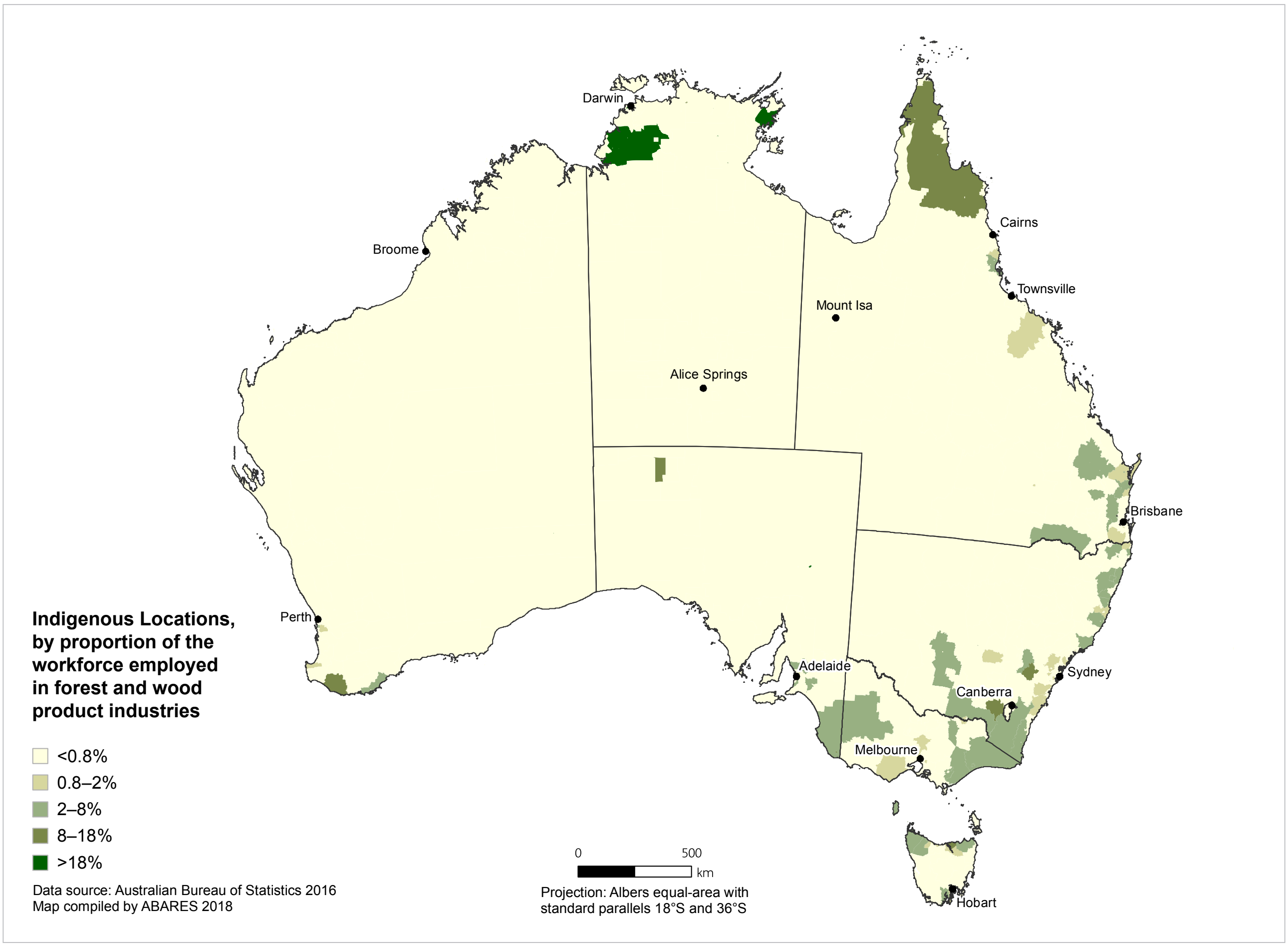
There is a range of public perceptions of forest management and of the acceptability of plantations.

Surveys conducted between 2008 and 2017 on behalf of Forest and Wood Products Australia indicate the attitudes of Australians to a range of forest-related issues. Averaged across these surveys:

- just under half of the respondents agreed that Australia's native forests are being managed sustainably
- a majority of respondents considered that wood is more environmentally friendly than alternative materials, and a large majority of respondents preferred the use of Australian trees rather than overseas trees to make wood products
- a majority of respondents also believed that harvesting trees is acceptable so long as the trees are replaced.

For further information on this theme, see Indicators 6.3a–b, Indicators 6.4a–d and Indicator 6.5d of Australia's *State of the Forests Report 2018*.

Indigenous Locations, by proportion of the Indigenous workforce employed in forest and wood products industries, 2016



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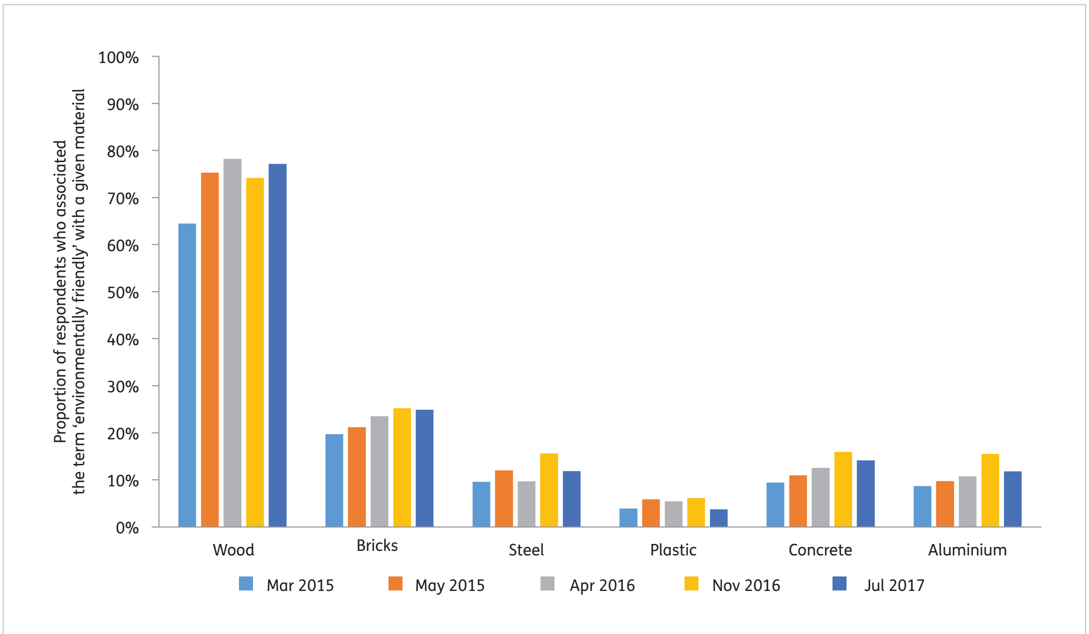
Perceptions of whether materials are 'environmentally friendly'



Average proportion of respondents who associated the term 'environmentally friendly' with a given material. Source: Forest and Wood Products Australia.

The data used to create this figure are available in Microsoft Excel via www.doi.org/10.25814/5be12aa83aa34

Investment, research and development

Investment in establishing and managing native forests and plantations is key to maintaining forest values and services. Research and development underpin improved management practices and new commercial technologies and facilities.

Investment

Between 2010–11 and 2014–15, funding for new commercial plantations was increasingly sourced from institutional investors. Capital investment in timber industry processing facilities was estimated at $938 million for the period 2012 to 2017.

Investment in the establishment of new commercial plantations, as well as re-establishment of harvested commercial plantations, is important for future wood availability.

- The annual rate of establishment of new commercial plantations in Australia declined from 4,200 hectares in 2011–12, to 900 hectares in 2014–15, then increased to 1,600 hectares in 2015–16.
- During the period 2011–12 to 2014–15, new plantings comprised mostly hardwood plantations in Victoria, Queensland and the Northern Territory.
- During the period 2014–15 to 2015–16, new plantings comprised solely softwood plantations in New South Wales and Western Australia.

Between 2010–11 and 2014–15, funding for new commercial plantations was increasingly sourced from institutional investors. Institutions have also been involved in purchases of established commercial plantations.

- In 2014–15, institutional investors owned 50% of Australia's commercial plantations, compared to 31% in 2010–11.
- During the same period, farm foresters and other private owners increased their area share of total commercial plantation area from 8% to 21%.
- This shift reflects the increasing contribution of private investment capital to the growth and development of the sector.

Further structural adjustment and consolidation of the sawmill industry also occurred over this period. The domestic softwood sawmill industry is becoming significantly more capital-intensive, and larger in scale.

Capital investment in timber industry processing facilities was estimated at $938 million for the period 2012 to 2017.

- The majority of these new investments targeted increased productivity, higher recovery and improved grade yield in the sawmilling sectors, and increased productivity and development of new products in the panel and plywood sectors.

Mangroves near Coffs Harbour, New South Wales.

Research and development

Two different surveys show that expenditure on research and development in forestry and forest products has declined over time, as has associated capacity. The number of people involved in research and development in forestry and forest products has also continue to decline.

Investment in research and development activities can lead to improvement in forest management practices, and to new technologies for commercial adoption. However, expenditure on research and development in forestry and forest products and associated capacity has declined.

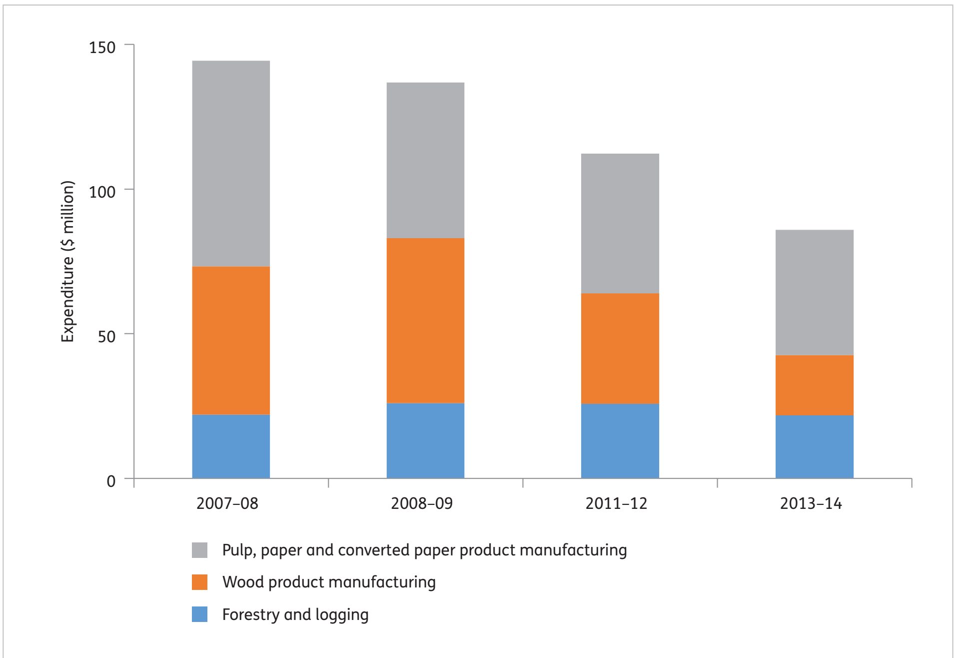
- Australian Bureau of Statistics data show that, from 2007–08 to 2013–14, total expenditure on research and development reported by businesses in the forest and wood products sector declined from $144 million to $86 million, although only partial data are available for some years.
- A separate series of surveys of the forest and forest products sector, using a different definition of the sector, reported that research and development expenditure on forestry and forest products decreased from $88 million in 2007–08, to $48 million in 2012–13.
- Ongoing changes in funding and delivery models reduced forest research and development capacity across a number of national organisations, but a number of new, university-based forestry and/or forest products research centres were also established during the period 2011–2016.

In parallel, the estimated number of researchers and technicians involved in research and development in forestry and forest products declined from 733 in 2008, to 455 in 2011, and to 276 in 2013.

- The decline has occurred across the public and private sectors, including government agencies and universities.
- The total number of forestry and forest products researchers employed by state and territory agencies was reported as 89.5 full-time-equivalent staff in 2015–16, approximately half the 171.8 full-time-equivalent reported for 2011–12.

For further information on this theme, see Indicators 6.2a–b, Indicator 7.1c and Indicator 7.1e of Australia's *State of the Forests Report 2018*.

Business research and development expenditure in the forest and wood products sector



Source of data: Australian Bureau of Statistics

The data used to create this figure are available in Microsoft Excel via www.doi.org/10.25814/5be12aa83aa34

Frameworks for forest policy, management, monitoring and reporting

Australia's forest policy and management is underpinned by legal, institutional and economic frameworks at the national and the state and territory levels. These frameworks provide for reporting to the community on the state of Australia's forests.

Australia has a well-established framework for forest management, guided by a National Forest Policy Statement, and including policy and legislative instruments, and codes of forest practice.

Two schemes certify forest management and provide chain-of-custody certificates for tracking wood products. At June 2018, approximately 8.9 million hectares of native forests and plantations were certified for forest management under either scheme.

Reporting to the community on Australia's forests occurs at the state level, nationally and internationally.

Legal and policy frameworks

All states and territories and the Australian Government have legislation that supports the conservation and sustainable management of Australia's forests.

- Australia's public native forests, including those held in nature conservation reserves and those available for wood production, are governed and managed under state or territory regulatory frameworks and management plans.
- Management of forests on private land is also regulated under various Acts of Parliament.

As at 2016, 43 million hectares (32% of Australia's forests) were covered by management plans relating to their conservation and sustainable management. Management plans are in place for 19 million hectares of forest in the National Reserve System (57% of the area of forest in the National Reserve System).

The effectiveness of government policies in promoting conservation and sustainable management of production forests and conservation reserves was assessed as effective or very effective by the Australia State of the Environment 2016 report.

Certification

At June 2018, approximately 8.9 million hectares of native forests and plantations were certified for forest management under either the Responsible Wood Certification Scheme or the Forest Stewardship Council scheme. Some forests and plantations were certified under both schemes.

In addition, at that date, a total of 189 chain-of-custody certificates for tracking wood from the forest to the final product were issued under the Responsible Wood Certification Scheme, and 258 chain-of-custody certificates were issued under the Forest Stewardship Council scheme.

Monitoring and reporting

Australia's *National Forest Policy Statement* (Commonwealth of Australia 1992) commits the Australian Government and state and territory governments to report on the state of the forests every five years. In addition, the Commonwealth *Regional Forest Agreements Act 2002* states that 'the Minister must cause to be established a comprehensive and publicly available source of information for national and regional monitoring and reporting in relation to all of Australia's forests'.

The *Australia's State of the Forests Report* (SOFR) series implements these commitments, and is the mechanism by which the state of Australia's forests, and changes over time in a range of social, economic and environmental forest-related indicators, are reported to government and industry stakeholders and the broader community.

Some states also publish five-yearly 'state of the forests' reports, based on a framework of criteria and indicators similar to the national SOFR series.

Australia also uses the data compiled for the SOFR series to report internationally on the state of its forests through:

- the Global Forest Resources Assessment and the State of the World's Forest Genetic Resources processes undertaken by the Food and Agriculture Organization of the United Nations
- the United Nations Sustainable Development Goals
- the Global Forest Goals of the United Nations Forum on Forests.

Eucalyptus delegatensis in the Australian Capital Territory.

The availability, coverage and currency of the data available for the national SOFR series vary considerably between indicators and also between reports in this series, but has improved overall for SOFR 2018 compared to SOFR 2013.

- The data available for SOFR 2018 were assessed as comprehensive in each of coverage, currency and frequency for 23 of the 44 national reporting indicators, and as comprehensive in two of these three aspects for a further 11 indicators.
- The most comprehensive information is available for multiple-use public forests, with less information on nature conservation reserves, and significant gaps in data collection and monitoring for leasehold and private forests and for other Crown land.
- A number of new and improved social, economic and environmental datasets compiled for the National Forest Inventory have been analysed and presented in SOFR 2018.
- There are also a number of topics for which data are missing or incomplete.

The national SOFR series presents data on all of Australia's forests, both public and private forests, and both forests managed for conservation and forests managed for production. Trends over time are reported when the data are of sufficient quality, and drivers of change are identified if these are clear.

However, SOFR 2018 does not present detailed analyses or interpretation in regard to the meaning or implications of the data. Such analyses are to be found in other publications by Commonwealth, state and territory government agencies, including ABARES, and by independent researchers.

Overall, *Australia's State of the Forests Report 2018* addresses its purpose of being a 'comprehensive national report', and provides the reader with information to assess progress towards sustainable forest management in Australia.

For further information on this theme, see Introduction and Indicators 7.1a–d of *Australia's State of the Forests Report 2018*.


Otway National Park, Victoria. Photo: iStockphoto/THPStock

Introduction

The forests of Australia are diverse and highly valued, and are among the country's most important natural resources.

Australia's native forests occur in a broad range of geographic landscapes and climatic environments, and contain many endemic species that occur naturally only in Australia or in a particular region within Australia, combining to form unique and complex ecosystems.

Australia's forests are recognised for their wide range of environmental, social and economic values. They support a variety of biodiversity, including many species found nowhere else. They provide ecosystem services such as clean water and soil protection, and opportunities for recreation, tourism, and scientific and educational pursuits, and have important cultural, heritage and aesthetic values. They also provide wood and non-wood products that are used by Australians in their everyday lives.

In 1992, the Australian Government and state and territory governments agreed a *National Forest Policy Statement* (Commonwealth of Australia 1992), which set out a vision for Australia's forests and associated goals, objectives and policies (Box I.i). The *National Forest Policy Statement* commits governments to report on the state of the forests every five years. In addition, the Commonwealth *Regional Forest Agreements Act 2002* states that 'the Minister must cause to be established a comprehensive and publicly available source of information for national and regional monitoring and reporting in relation to all of Australia's forests'.

The *Australia's State of the Forests Report* series implements these commitments. *Australia's State of the Forests Report 2018* (referred to as SOFR 2018) is the fifth report in this series, following those published in 1998, 2003, 2008 and 2013[11].

The SOFR series is the mechanism by which the state of Australia's forests, and changes over time in a range of social, economic and environmental forest-related indicators, are reported to government and industry stakeholders and the broader community. The SOFR series meets Australia's formal national reporting requirements for forest information, and the data assembled for SOFR are also used to meet Australia's international forest-related reporting requirements.

11 The *Australia's State of the Forests Report* series can be accessed at www.agriculture.gov.au/abares/forestsaustralia/sofr

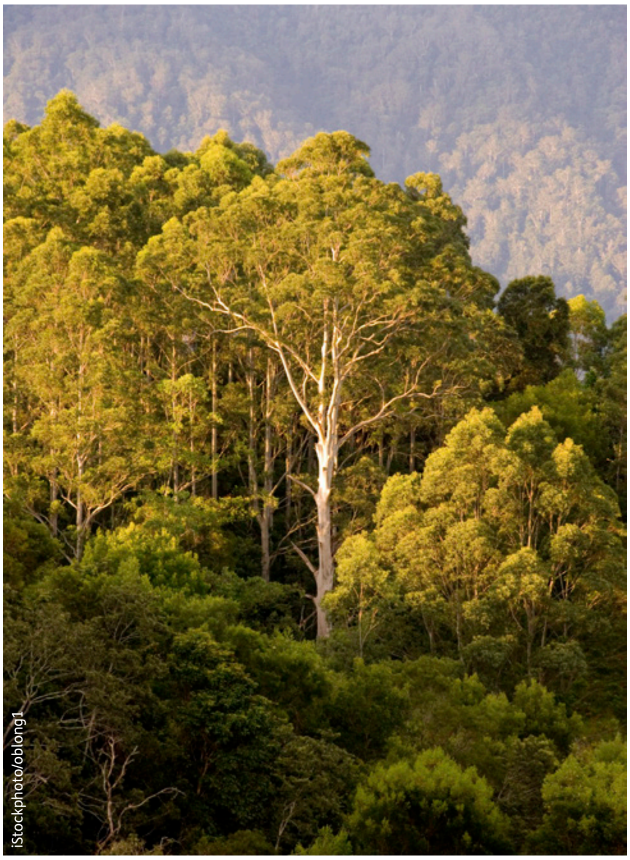
What is a forest in Australia?

The definition of forest used in this report is the same as that used in Australia's National Forest Inventory, and in all previous SOFRs:

> *An area, incorporating all living and non-living components, that is dominated by trees having usually a single stem and a mature or potentially mature stand height exceeding 2 metres and with existing or potential crown cover of overstorey strata about equal to or greater than 20 per cent. This includes Australia's diverse native forests and plantations, regardless of age. It is also sufficiently broad to encompass areas of trees that are sometimes described as woodlands.*

Under this definition, large expanses of tropical Australia where trees are spread out in the landscape are forest, as are many of Australia's multi-stemmed eucalypt mallee associations. What many people would typically regard as forests – stands of tall, closely spaced trees – comprise a relatively small part of the country's total forest estate.

Much of Australia's open and woodland forests are available for grazing. However, areas identified by the Australian Collaborative Land Use and Management Program[12] as urban and industrial land, land under horticultural land use (such as orchards), and land under intensive agricultural uses, are not included as forest.



Forest near Bellingen, New South Wales.

[12] data.gov.au/dataset/catchment-scale-land-use-of-australia-update-2017

Australia's forests

Forests extend across the continent's northern tropical regions, and down the east coast through sub-tropical regions to temperate cool-season wet and cold wet zones in the south-east; they are also found in Mediterranean climate zones in the south-east and south-west (see Figure I.i). In some regions, forests extend from these wetter, coastal and sub-coastal areas into central, drier parts of the continent (Figure I.ii). Through these regions, forests grow on soils that vary from ancient, fragile and infertile soils, to more recently formed, fertile soils of alluvial and volcanic origin.

Australia's forests are assigned to three broad categories in Australia's National Forest Inventory, with each category divided into various forest types (see Indicator 1.1a):

- 'Native forests', which are divided into eight national native forest types named after their key genus or structural form: Acacia, Callitris, Casuarina, Eucalypt, Mangrove, Melaleuca, Rainforest, and Other native forest. Across the wide range of rainfall and soil conditions that support forest, more than 80% of Australia's native forests are dominated by eucalypts and acacias.
- 'Commercial plantations', which are plantations grown on a commercial scale for wood production. 'Commercial plantations' were previously known as 'Industrial plantations'. The definition of plantations used in this report is that used in all previous SOFRs and for the National Plantation Inventory:

  Intensively managed stands of trees of either native or exotic species, created by the regular placement of seedlings or seeds.
- 'Other forest', which includes non-commercial plantations and planted forest of various types.

Native forests

Australia's native forests are classified into structural classes based on combinations of crown cover, stand height and form, to provide a better understanding of their characteristics.

In terms of crown cover:

- 'Closed forest' is forest where the tree canopies cover more than 80% of the land area.
- 'Open forest' is forest where the tree canopies cover between 50% and 80% of the land area.
- 'Woodland forest' is forest where the tree canopies cover between 20% and 50% of the land area.
- Land with trees where the tree canopies cover less than 20% of the land area is not classified in Australia as forest, but is categorised as various forms of non-forest vegetation.

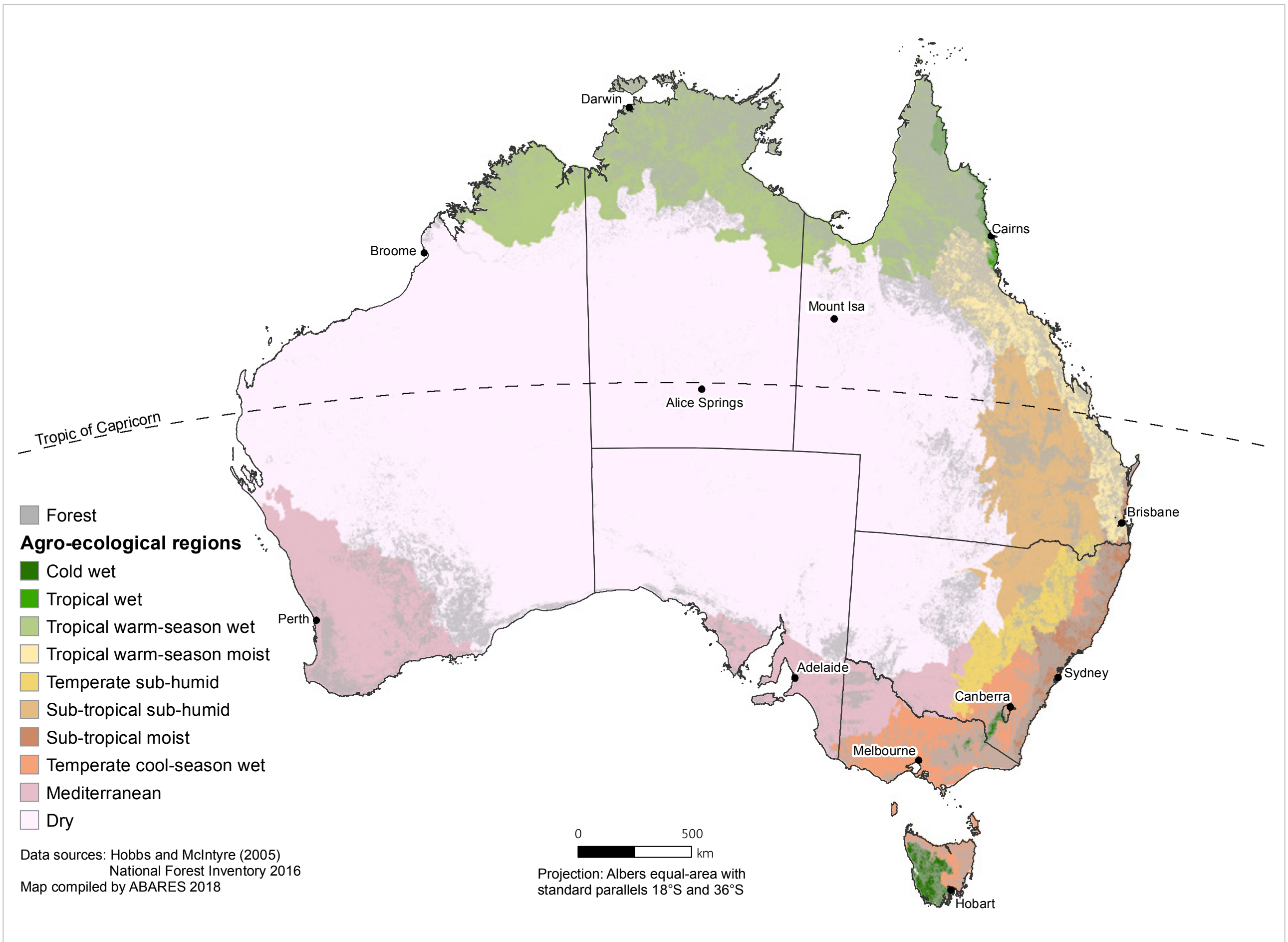
Box I.i: National goals set out in Australia's *National Forest Policy Statement*[13]

The Commonwealth, state and territory governments agree that, to achieve their vision for the forest estate and to ensure that the community obtains a balanced return from all forest uses, eleven broad national goals must be pursued. These goals should be pursued within a regionally based planning framework that integrates environmental and commercial objectives so that, as far as possible, provision is made for all forest values. The eleven broad national goals are as follows:

- **Conservation.** The goals are to maintain an extensive and permanent native forest estate in Australia and to manage that estate in an ecologically sustainable manner so as to conserve the full suite of values that forests can provide for current and future generations. These values include biological diversity, and heritage, Aboriginal and other cultural values.
- **Wood production and industry development.** The goal is for Australia to develop internationally competitive and ecologically sustainable wood production and wood products industries. Efficient industries based on maximising value-adding opportunities and efficient use of wood resources will provide the basis for expansion in wood products manufacturing, which in turn will provide national and regional economic benefits.
- **Integrated and coordinated decision making and management.** The goals are to reduce fragmentation and duplication in the land use decision-making process between the States and the Commonwealth and to improve interaction between forest management agencies in order to achieve agreed and durable land use decisions.
- **Private native forests.** The goal is to ensure that private native forests are maintained and managed in an ecologically sustainable manner, as part of the permanent native forest estate, as a resource in their own right, and to complement the commercial and nature conservation values of public native forests.
- **Plantations.** One goal is to expand Australia's commercial plantations of softwoods and hardwoods so as to provide an additional, economically viable, reliable and high-quality wood resource for industry. Other goals are to increase plantings to rehabilitate cleared agricultural land, to improve water quality, and to meet other environmental, economic or aesthetic objectives.
- **Water supply and catchment management.** The goals are to ensure the availability of reliable, high-quality water supplies from forested land and to protect catchment values.
- **Tourism and other economic and social opportunities.** The goal is to manage Australia's forests in an ecologically sustainable manner for a range of uses, including tourism, recreation and production of non-wood products.
- **Employment, workforce education and training.** The goal is to expand employment opportunities and the skills base of people working in forest management and forest-based industries.
- **Public awareness, education and involvement.** The goals are to foster community understanding of and support for ecologically sustainable forest management in Australia and to provide opportunities for effective public participation in decision making.
- **Research and development.** The goals are to increase Australia's national forest research and development effort and to ensure that it is well coordinated, efficiently undertaken and effectively applied. This research will expand and integrate knowledge about the many aspects of native forests, plantations, forest management, conservation, and forest product development.
- **International responsibilities.** The goals are to promote nature conservation and sustainable use of forests outside Australia and to ensure that Australia fulfils its obligations under relevant international agreements.

[13] Commonwealth of Australia (1992)

Figure I.i: Agro-ecological regions of Australia



Note: Grey shading under coloured agro-ecological regions shows SOFR 2018 forest coverage.

A higher resolution version of this map is available via www.doi.org/10.25814/5be3bc4321162

In terms of stand height:

- 'Tall forest' is forest with a stand height greater than 30 metres.
- 'Medium forest' is forest with a stand height between 10 and 30 metres.
- 'Low forest' is forest with a stand height greater than 2 metres and up to 10 metres.

In terms of tree form:

- 'Eucalypt mallee' forests contain multi-stemmed trees.

Australia's definition of forest uses the phrases 'mature or potentially mature' with regard to stand height, and 'existing or potential' with regard to crown cover. Use of these phrases allows forest areas that have temporarily lost some or all of their trees (for example, as a result of bushfires, cyclones or wood harvesting) to be identified as part of the forest estate.

The majority of Australia's native forest area is dominated by evergreen, broadleaf, hardwood tree species. For national reporting, the NFI classifies Australia's native forests into eight broad forest types defined by dominant species and structure. These eight types are described below[14].

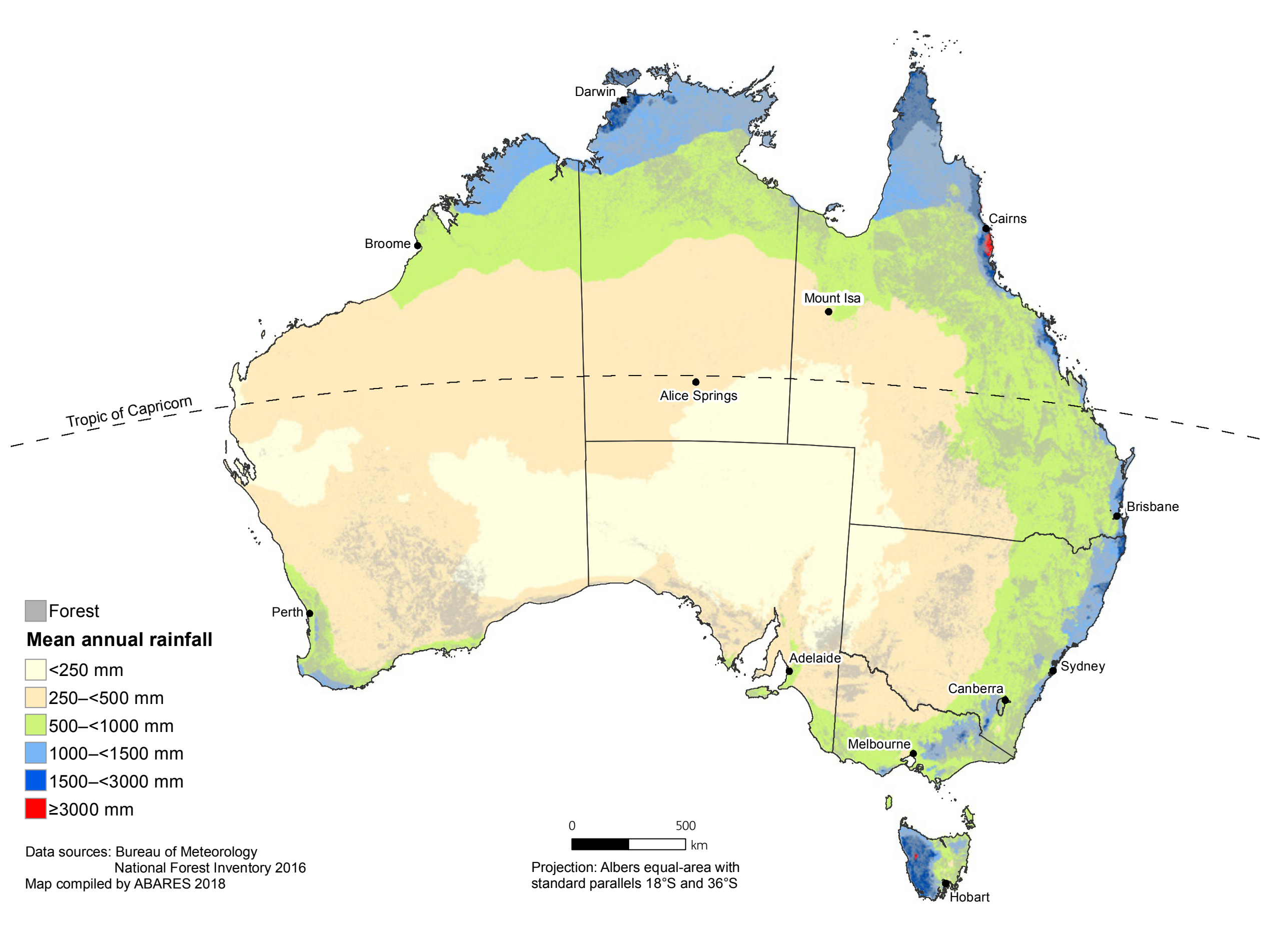
Acacia

Australia has almost 1000 species of *Acacia*, making it the nation's largest genus of flowering plants. Acacia species are remarkably varied in appearance, habit and location, from spreading shrubs to trees that are more than 30 metres tall.

Acacia forests are Australia's second most extensive forest type. They occur in all Australian states and the Northern Territory, with the largest areas in Queensland and Western Australia. Acacia forests are predominantly woodland forests in regions where the average annual rainfall is less than 750 millimetres. Mulga (*Acacia aneura* and related species) is widespread in many parts of the arid and semi-arid zones of Australia. Brigalow (*A. harpophylla*) is widespread in Queensland and northern New South Wales, forming dense forests on flat or undulating country with clay soils. Acacia forests are also present in wetter areas: in Tasmania, for example, blackwood (*A. melanoxylon*) dominates stands of swamp forest on poorly drained sites.

14 The names of the national native forest types have capitalised initial letters (e.g. Acacia forest). The related common names do not have capitalised initial letters (e.g. acacias) unless they commence a sentence. The related formal genus names are italicised and have capitalised initial letters (e.g. *Acacia*).

Figure I.ii: Mean annual rainfall across Australia



Note: Grey shading under coloured rainfall zones shows SOFR 2018 forest coverage.

A higher resolution version of this map is available via www.doi.org/10.25814/5be3bc4321162

Callitris

The genus *Callitris* comprises 15 species, of which 13 occur in Australia. Callitris trees are commonly called cypress pines because they are related to, and resemble, Northern Hemisphere cypresses; they are not true pines.

Callitris forests typically occur in small patches in drier inland regions, but occasionally cover wide areas. Pure stands of *Callitris* are generally restricted to undulating or flat land with sandy soils, or to upland rocky areas that are protected from fire. More commonly, *Callitris* trees are present in Acacia, Casuarina and Eucalypt forest types that have a shrubby, grassy or herbaceous understorey. White cypress pine (*Callitris glaucophylla*) is a species widely distributed across inland Australia that is used for timber production.

Casuarina

The family Casuarinaceae occurs naturally in Australia, south-east Asia and the Pacific region. The forest type Casuarina includes forests dominated by species of either *Casuarina* (6 species in Australia) or *Allocasuarina* (59 species in Australia). Commonly called sheoaks because of the similarity of their timber to that of European oaks, casuarinas are a distinctive part of many Australian coastal and riverine landscapes.

Most casuarina forests are low in height; the tallest casuarina forests grow along rivers, where trees can grow to more than 20 metres. Common inland species include belah (*Casuarina cristata*), desert oak (*Allocasuarina decaisneana*) and river sheoak (*C. cunninghamiana*).

Eucalypt

Eucalypts are iconic Australian forest trees. Eucalypt forests are by far the continent's most common forest type, covering about three-quarters of Australia's native forest estate and occurring in all but the continent's driest regions (Figure I.iii).

The term 'eucalypt' encompasses approximately 800 species in the three genera *Eucalyptus*, *Corymbia* and *Angophora*, with almost all of these species native to Australia. For national reporting, the Eucalypt forest type is divided into 11 forest subtypes based on the form of dominant individuals (multi-stemmed mallee or single-stemmed tree), height of mature trees (low, medium or tall) and crown cover (closed, open or woodland).

Closed forest: an aerial view of rainforest showing typical closed canopy. Barron River, Queensland.

Open forest, Wombeyan Karst Conservation Reserve, New South Wales.

Woodland forest, Undara Volcanic National Park, Queensland.

Non-forest carrying other woody vegetation, Northern Territory.

Eucalypt species have oil-rich foliage that burns readily, and they display a range of strategies to survive and recover from fire. The majority of eucalypt species are evergreen, retaining their leaves year-round.

River red gum (*Eucalyptus camaldulensis*) is the most widely distributed eucalypt, and is found in all Australian mainland states. The forests of south-eastern Australia contain a wide range of dominant eucalypt species, including major commercial timber species such as mountain ash (*E. regnans*), messmate stringybark (*E. obliqua*), alpine ash (*E. delegatensis*), silvertop ash (*E. sieberi*), blackbutt (*E. pilularis*) and spotted gum (*Corymbia maculata*). Some individual trees exceed 90 metres in height. Eucalypt forests in south-western Australia are dominated by jarrah (*E. marginata*) and karri (*E. diversicolor*). Typical eucalypts of northern Australia include Darwin woollybutt (*E. miniata*) and Darwin stringybark (*E. tetrodonta*). Many species of mallee eucalypts are found across the inland regions of southern Australia (Figure I.iv).

Mangrove

Although comprising less than 1% of Australia's forest cover, mangrove forests are an important and widespread ecosystem. They are found in the intertidal zones of tropical, subtropical and protected temperate coastal rivers, estuaries and bays, where they grow in fine sediments deposited by rivers and tides. Mangrove trees have a characteristic growth form, including aerial structural roots and exposed breathing roots, to help them cope with regular tidal inundation and a lack of oxygen in the soil.

Avicennia marina, known as white mangrove or grey mangrove, is a widely distributed species of mangrove.

Melaleuca

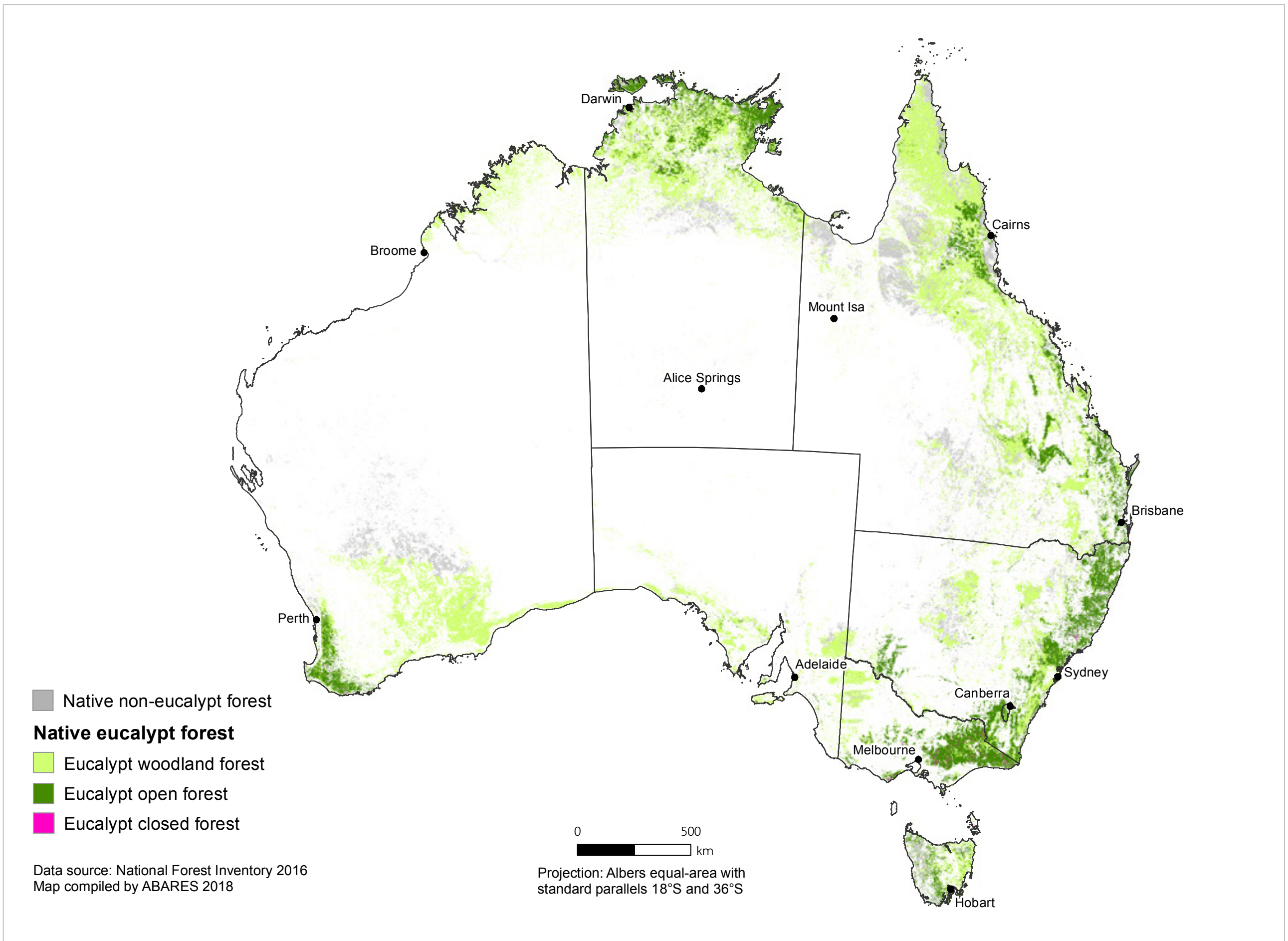
The genus *Melaleuca* contains more than 200 species, most of which are endemic to Australia. Only a few species develop the required community structure and height for stands to be classified as forests; these taller species are known as tea-trees or paperbarks. Common species include broad-leaved paperbark (*Melaleuca viridiflora*) and weeping paperbark (*M. leucadendra*).

Melaleuca forests occur mainly as tracts of low woodland forest across estuarine plains and seasonal swamps in the coastal and near-coastal areas of monsoonal northern Australia, as well as narrow strips beside streams. Most of Australia's Melaleuca forest is in Queensland, particularly Cape York Peninsula, and the northern part of the Northern Territory. Melaleuca forest also occurs on poorly drained sites on the east coast of mainland Australia and in north-western Tasmania.

Rainforest

Australia's rainforests are characterised by high rainfall, lush growth and closed canopies; they rarely support fire, and generally contain no eucalypts or only occasional individual eucalypts as emergent trees above the rainforest canopy. Tree species of the rainforest canopy are shade-tolerant when

Figure I.iii: Distribution of native eucalypt forest, by crown cover class



Note: Grey and coloured shading shows the forest coverage presented in Indicator 1.1a of SOFR 2018.

A higher resolution version of this map is available via www.doi.org/10.25814/5be3bc4321162

young, able to establish in the understorey of mature forest, and grow into large trees when events such as tree falls, lightning strikes or wind damage (including from cyclones) create gaps in the canopy.

There are many types of rainforest in Australia, varying with rainfall and latitude. Tropical and subtropical rainforests are found in northern and eastern Australia in wet coastal areas. Temperate rainforests occur in eastern and south-eastern Australia: warm temperate rainforests grow in New South Wales and Victoria, while cool temperate rainforests grow in Victoria and Tasmania, with outliers at high altitude in New South Wales and Queensland. Dry rainforests occur in pockets protected from frequent fire in sub-coastal and inland areas of northern and eastern Australia. Monsoon rainforests occur in northern Australia in seasonally dry coastal and sub-coastal regions.

Other native forest

The 'Other native forest' type includes a range of minor native forest types each named after its dominant genus, including Agonis, Atalaya, Banksia, Hakea, Grevillea, Heterodendron, Leptospermum, Lophostemon and Syncarpia, as well as native forests where the type is unknown.

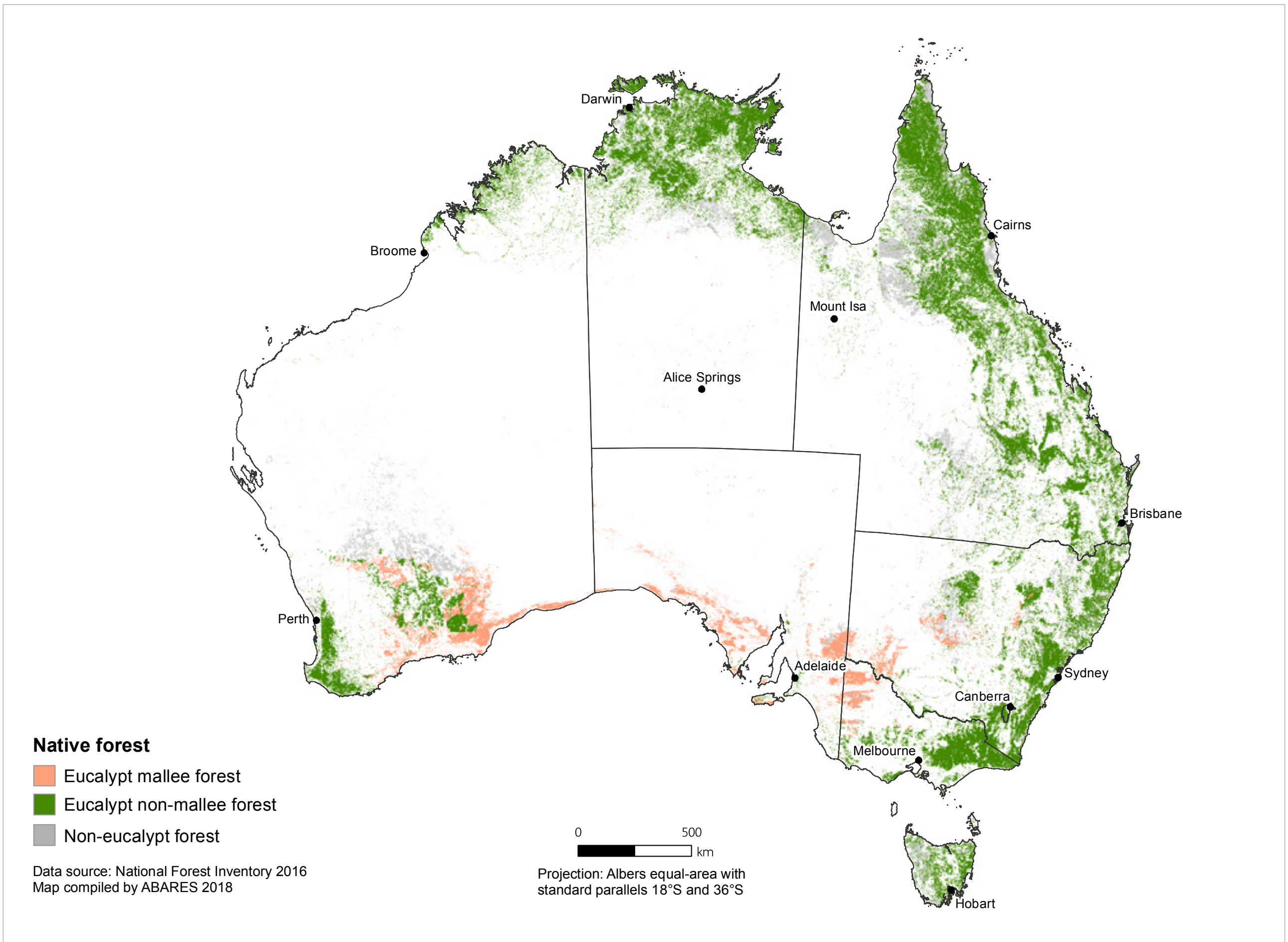
Commercial plantations

Australia's commercial plantations comprise both softwood species (predominantly radiata pine, *Pinus radiata*) and hardwood species (with the most common species being Tasmanian blue gum, *Eucalyptus globulus*). Their primary purpose is commercial wood production, and they produce the majority of the volume of logs harvested annually in Australia. Commercial plantations also provide a range of environmental services, such as salinity and erosion control, and support regional employment. Plantations provide habitat for some native flora and fauna species that generally do not inhabit cleared agricultural land, although the population densities of forest-dwelling species are usually lower in plantations than in native forests. Commercial plantations are identified in the National Plantation Inventory.

Fifteen plantation regions are used by the National Plantation Inventory to represent economic wood supply zones (Figure I.v). Five of the National Plantation Inventory regions span a state or territory border.

The main Australian commercial plantation species by climate region and rainfall, and the main uses for the wood they produce, are shown in Table I.i.

Figure I.iv: Eucalypt mallee, eucalypt non-mallee and non-eucalypt native forest



Note: Grey and coloured shading shows the forest coverage presented in Indicator 1.1a of SOFR 2018.

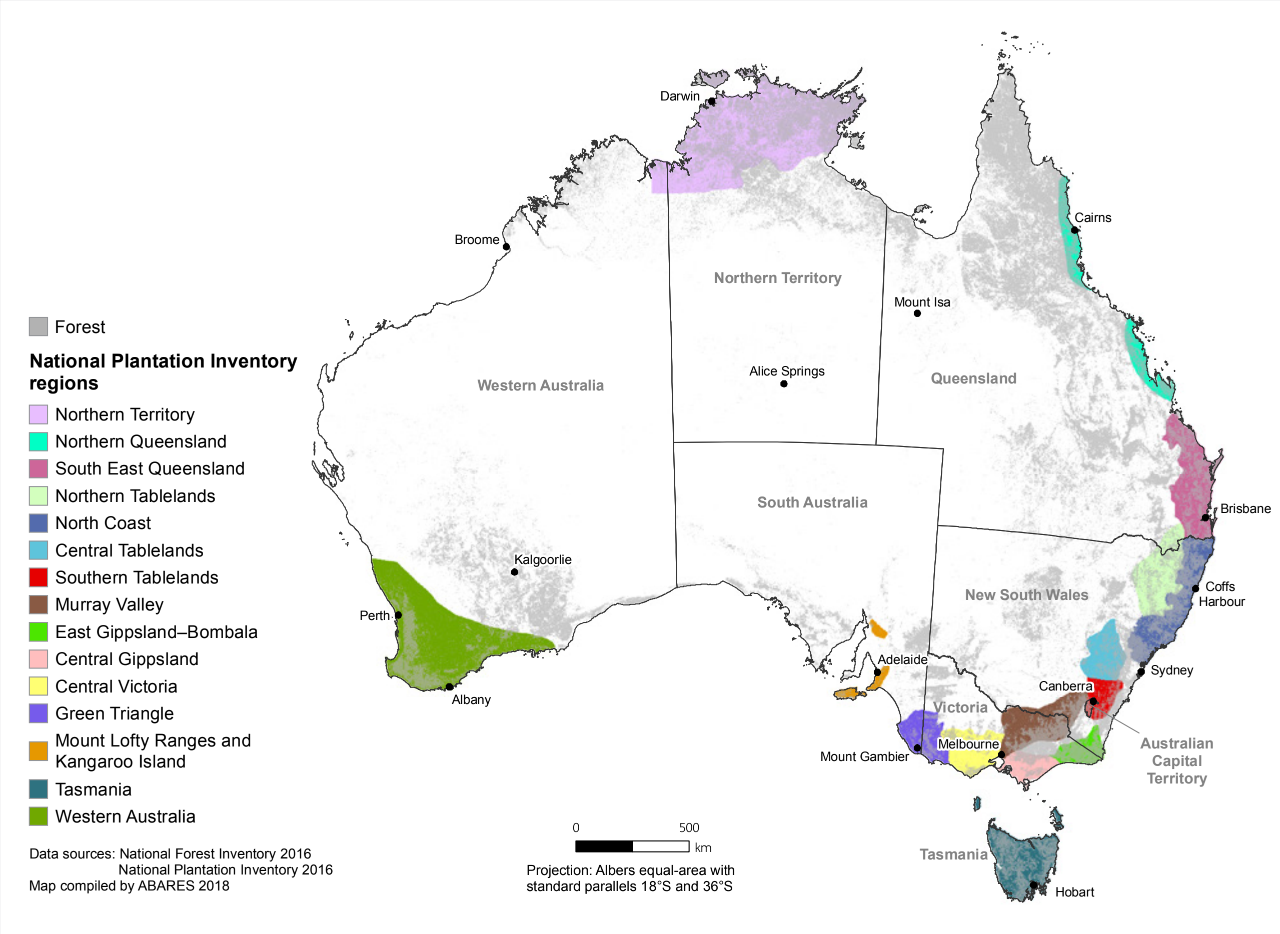
A higher resolution version of this map is available via www.doi.org/10.25814/5be3bc4321162

Table I.i. Main commercial plantation species by climatic region and rainfall, and main uses

Region	Rainfall	Main species	Main uses
Softwoods			
Tropical, subtropical	High	Hoop pine (*Araucaria cunninghamii*)	Sawn timber for building, joinery, furniture, plywood, other high-value uses, posts and poles; residues used for paper, particleboard and other panels
	Medium	Caribbean pine (*Pinus caribaea*), slash pine (*P. elliottii*), hybrid pines	Sawn timber for building, joinery, furniture, plywood, other high-value uses, posts and poles; residues used for paper, particleboard and other panels
Temperate	Medium	Radiata pine (*P. radiata*)	Sawn timber for building, joinery, furniture, plywood, other high-value uses, posts and poles; residues used for paper, particleboard and other panels
	Low to medium	Maritime pine (*P. pinaster*)	Sawn timber for building, joinery, furniture, plywood, other high-value uses, posts and poles; residues used for paper, particleboard and other panels
Hardwoods			
Tropical	High	Mangium (*Acacia mangium*)	Paper products, veneer and sawn timber
		African mahogany (*Khaya senegalensis*), teak (*Tectona grandis*), some native eucalypt species	Sawn timber for building and furniture and other high-value uses
Subtropical	Medium	Blackbutt (*Eucalyptus pilularis*), Flooded gum (*E. grandis*), Dunn's white gum (*E. dunnii*)	Paper products, veneer and sawn timber
Temperate	Medium	Southern (Tasmanian) blue gum (*E. globulus*), shining gum (*E. nitens*)	Paper products, veneer and sawn timber
Several regions	Low to medium	Various eucalypts	Sawn timber for building and furniture and other high-value uses

Source: Adapted from SOFR 2008

Figure I.v: National Plantation Inventory regions of Australia



Note: Grey shading shows the forest coverage presented in Indicator 1.1a of SOFR 2018.

A higher resolution version of this map is available via www.doi.org/10.25814/5be3bc4321162

Other forest

The 'Other forest' category comprises small areas of mostly non-commercial plantations and planted forests of various types, including plantations of sandalwood (*Santalum* spp.), some smaller farm forestry and agroforestry plantations, environmental plantings, plantations within the reserve system, and plantations regarded as non-commercial. Non-planted forest dominated by introduced species is also included in the Other forest category.

Tenure

The ownership or tenure of forest land, especially native forest, has a major bearing on its management. Different types of ownership are linked to who has the right to use and occupy land, the right to use forest resources, and the conditions that may be attached to these rights.

The six national land tenure classes used to classify land in the National Forest Inventory are as follows:

- **Leasehold forest**: Crown land held under leasehold title, and generally privately managed, although state and territory governments may retain various rights over the land, including over forests or timber on the land. This class includes land held under leasehold title with special conditions attached for designated Aboriginal and Torres Strait Islander communities (referred to collectively as Indigenous communities in SOFR 2018).
- **Multiple-use public forest**: publicly owned state forest, timber reserves and other land, managed by state and territory government agencies for a range of forest values, including wood harvesting, water supply, biodiversity conservation, recreation and environmental protection.
- **Nature conservation reserve**: publicly owned lands managed by state and territory government agencies that are formally reserved for environmental, conservation and recreational purposes, including national parks, nature reserves, state and territory recreation and conservation areas, and some categories of formal reserves within state forests. This class does not include informal reserves (areas protected by administrative instruments), areas protected by management prescription, or forest areas pending gazettal to this tenure. The harvesting of wood and non-wood forest products generally is not permitted in nature conservation reserves.

- **Other Crown land**: Crown land reserved for a variety of purposes, including utilities, scientific research, education, stock routes, mining, use by the defence forces, and to protect water-supply catchments, with some areas used by Indigenous communities.
- **Private forest**: land held under freehold title and private ownership, and usually privately managed. This class includes land with special conditions attached for designated Indigenous communities.
- **Unresolved tenure**: land where data are insufficient to determine land ownership status.

All land in each state and territory is allocated by ABARES to one of these six tenure classes using state, territory and national datasets of land titles and land tenure, then intersected with the national forest coverage to determine the areas of forest land in each tenure class.

These six national tenure classes are amalgamations of the wide range of classes used by various state and territory jurisdictions. The classes can be grouped on the basis of land ownership as public or private, with a small area of unresolved tenure. Publicly owned tenures include 'multiple-use public forest', 'nature conservation reserve' and 'other Crown land'. 'Leasehold forest' is Crown land (land that belongs to a national, state or territory government) that is privately managed, although state and territory governments may retain various rights over the land, including over forests or timber on the land. Some forests on private land are publicly managed as conservation reserves, for example Kakadu National Park in the Northern Territory. For commercial plantations, the ownership of the land can be different from ownership of the trees, and management arrangements can be complex.

Forest administration in Australia

Australia has three levels of government: Commonwealth or federal (also referred to as the Australian Government or the national government); state and territory; and local (city-based or regionally based). The term 'jurisdiction' is used in SOFR 2018 to denote any of the states or territories.

Australia's state and territory governments have responsibility for land allocation and land management, including forest management. The Commonwealth Government has limited forest management responsibilities, but may influence management through legislative powers associated with foreign affairs (particularly treaties and international agreements), commodity export licensing, taxation, and biodiversity conservation, and through targeted spending programs to meet environmental, social or economic objectives. Such programs are generally developed cooperatively with state and territory governments. Australia's forest policy, together with the management of Australia's forests, is guided by the *National Forest Policy Statement* (Commonwealth of Australia 1992), signed jointly by the Australian Government and state and territory governments (see Box I.i).

Australia's First Peoples

Preferences in terminology when referring to Australia's First Peoples can vary across Australia, and can change over time. Throughout SOFR 2018, the term Indigenous is used when describing Aboriginal and Torres Strait Islander peoples and communities. The term Indigenous is also used for consistency in titles of indicators, datasets, programs or reports, including Australia's framework of criteria and indicators[15]; this usage originated at the time this framework was published (2008).

Regional Forest Agreements

A key outcome of the *National Forest Policy Statement* was the negotiation of Regional Forest Agreements (RFAs) between the Australian Government and four state governments. Davey (2018a) describes the origins and development of Australia's RFAs. RFAs are 20-year agreements for the conservation and sustainable management of specific regions of Australia's native forests, and resulted from substantial scientific study, consultation and negotiation with a diverse range of stakeholders. Science-based methodologies and Comprehensive Regional Assessments (CRAs) were used to determine forest allocation for different uses and to underpin forest management strategies. The RFAs were designed to provide certainty for forest-based industries, forest-dependent communities and nature conservation. Certain obligations of the Commonwealth under RFAs were given effect through the Commonwealth *Regional Forest Agreements Act 2002*.

Ten RFAs were negotiated between the Australian Government and the New South Wales, Tasmania, Victoria and Western Australia State Governments (Figure I.vi). The Upper North East and Lower North East RFA regions of New South Wales were covered by a single RFA. The Australian and Queensland governments also completed a CRA for south-east Queensland.

River red gum (*Eucalyptus camaldulensis*) forest, Murray River, New South Wales.

15 *Australia's Sustainable Forest Management Framework of Criteria and Indicators 2008 – Policy Guidelines*, available at www.agriculture.gov.au/abares/forestsaustralia/Documents/ciframework.pdf

Forest inventory

Australia's National Forest Inventory was established in 1988 to collect and report data and information about Australia's forests. The National Forest Inventory is guided by the National Forest Inventory Steering Committee (NFISC) composed of members representing state, territory and Australian government bodies involved in forest information management[16].

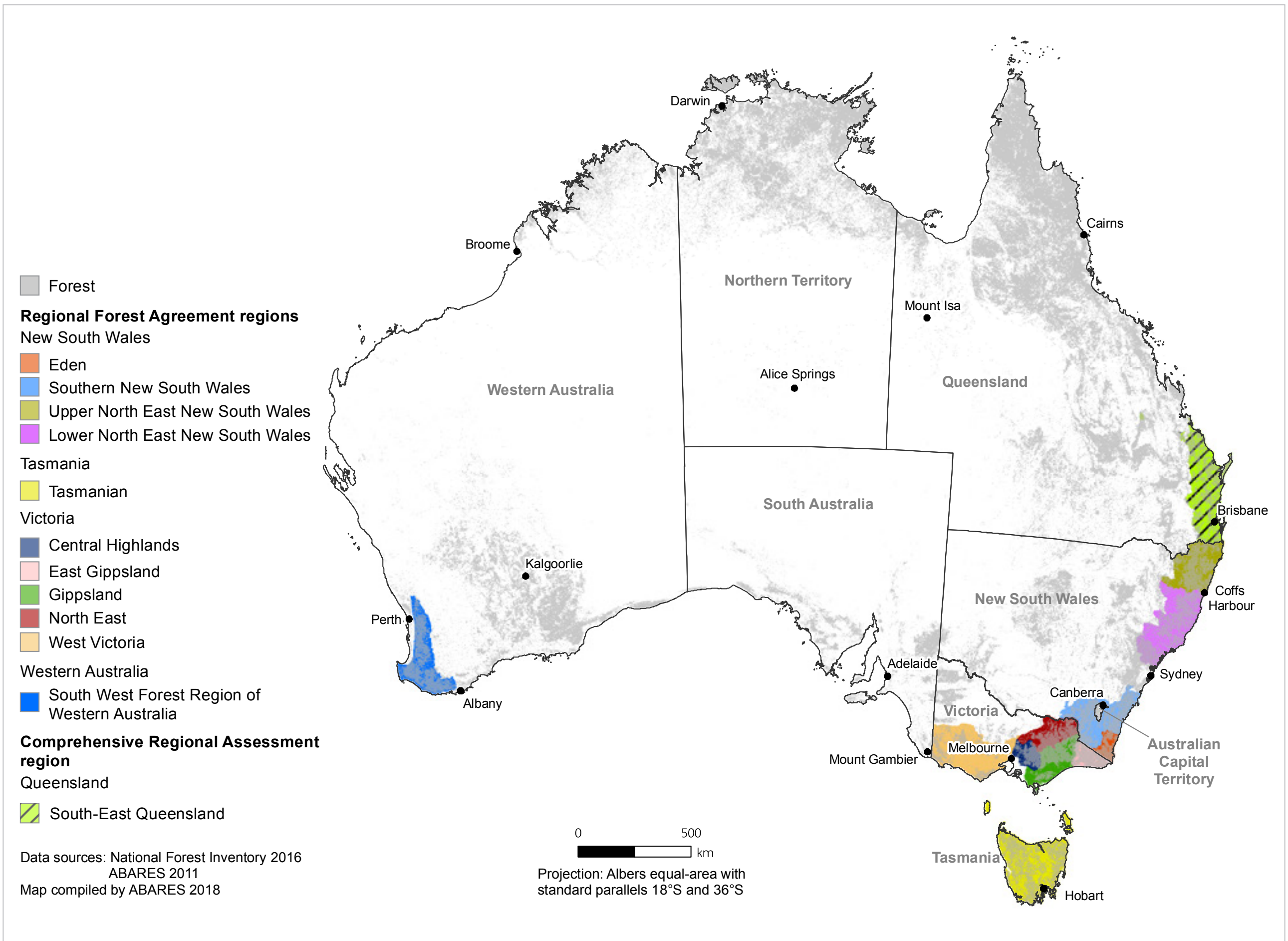
Forest description and measurement (inventory) activities have been undertaken in Australian forests for more than a century, mainly in publicly owned native forests managed for wood production and in plantations, and to a lesser extent in nature conservation reserves. Less is known about Australia's native forests on private or leasehold land.

Sustainable forest management and forest reporting

Sustainable forest management seeks to achieve environmental outcomes, promote economic development, and maintain the social values of forests, to meet the needs of society without compromising the ability of future generations to meet their needs.

This approach reflects the principal objectives of the United Nations Convention on Biological Diversity (CBD), to which Australia is a signatory – namely, the conservation and sustainable use of biological diversity, and the fair and equitable sharing of benefits arising from its use. The CBD recognises that the key to maintaining biological diversity is using it in a sustainable manner (Secretariat of the Convention on Biological Diversity 2005). Sustainably managed forests thus maintain a broad range of values into the future, and the Australian, state and territory governments have a range of processes to help meet this goal.

Figure I.vi: Regional Forest Agreement and related regions in Australia



Note: Grey shading under NPI regions shows the forest coverage presented in Indicator 1.1a of SOFR 2018.

A higher resolution version of this map is available via www.doi.org/10.25814/5be3bc4321162

16 See www.agriculture.gov.au/abares/forestsaustralia/australias-national-forest-inventory/national-forest-inventory-steering-committee. Queensland withdrew from the NFISC in 2010.

Criteria and indicators provide a common understanding of the components of sustainable forest management, and a common framework for describing, assessing and evaluating progress towards sustainable forest management. The criteria represent broad forest values that society seeks to maintain, while the indicators describe measurable aspects of those criteria (MIG 1998). The framework of criteria and indicators for sustainable forest management developed by the international-level Montreal Process Working Group on Criteria and Indicators for the Conservation and Sustainable Management of Temperate and Boreal Forests[17] was adopted in Australia in 1998. Development and application of these criteria and indicators in Australia occurs through the Montreal Process Implementation Group for Australia (MIG).

As with the international Montreal Process, Australia's framework includes the following seven criteria (Commonwealth of Australia 2008):

- conservation of biological diversity
- maintenance of productive capacity of forest ecosystems
- maintenance of ecosystem health and vitality
- conservation and maintenance of soil and water resources
- maintenance of forest contribution to global carbon cycles
- maintenance and enhancement of long-term multiple socio-economic benefits to meet the needs of societies
- legal, institutional and economic framework for forest conservation and sustainable management.

A set of 44 indicators for use in Australia was adapted from the Montreal Process Working Group's broader list of indicators, to better suit the particular characteristics of Australian forests, the goods and services they provide and the people who depend on or use them. These indicators now provide the standard reporting format for the Australia's State of the Forests Reports series. Appendix A lists the 44 indicators used in Australia, and shows the alignment with the 54 indicators of the international Montreal Process framework.

The National Forest Inventory and the SOFR series also provide the data for Australia's international forest reporting requirements. These include reporting through the Global Forest Resources Assessment run by the United Nations Food and Agriculture Organization (UN FAO)[18], the State of the World's Forest Genetic Resources[19] (also under the UN FAO), the Global Forest Goals of the UN Strategic Plan for Forests[20], and the UN Sustainable Development Goals[21].

The SOFR 2018 process

SOFR 2018 is the result of collaboration among the Australian, state and territory governments, led by the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) within the Australian Government Department of Agriculture and Water Resources, and coordinated by the National Forest Inventory Steering Committee (NFISC) and the Montreal Process Implementation Group for Australia (MIG).

In 2016, ABARES requested data from each of the states and territories to populate SOFR indicators. On the basis of responses to these requests and information obtained from national agencies and other sources, ABARES prepared summary tables, figures and text for each indicator, paying particular attention to changes and trends over time. The state and territory governments, through the MIG and the NFISC, and officers from Australian government agencies were invited to participate in a drafting group, which met in 2017 to review manuscripts and provide supplementary information. In 2018, the draft SOFR 2018 was reviewed by the MIG, the NFISC and relevant government agencies, and was endorsed by the national Forestry and Forest Products Committee under the Council of Australian Governments.

The SOFR series

The SOFR series is a system for reporting the state of Australia's forests, as well as changes in a range of social, economic and environmental values of forests. The SOFR series is therefore a resource for exploring the implications of such changes for sustainable forest management.

To the greatest extent possible, SOFR 2018 presents data for the five-year period between July 2011 and June 2016, continuing the five-yearly pattern of previous reports in the SOFR series. SOFR 2018 contains more information on trends over time than previous reports. However, the varied nature of the data available for the 44 indicators means that not all data conform to the standard five-year SOFR periods.

The forest area data presented in SOFR 2018 cover Australia's states and mainland territories and their close off-shore islands, but not the external territories of Norfolk Island, Lord Howe Island, Cocos (Keeling) Islands and Christmas Island. However, data for forest-dwelling species in these areas are reported in SOFR 2018. For the purposes of this report, forest data for the Jervis Bay Territory (administered by the Australian Capital Territory) are included in New South Wales data.

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17 www.montrealprocess.org/

18 www.fao.org/forest-resources-assessment/en/

19 www.fao.org/forestry/fgr/en/

20 www.un.org/esa/forests/documents/un-strategic-plan-for-forests-2030/index.html

21 www.un.org/sustainabledevelopment/sustainable-development-goals/

Eucalyptus rossii, Black Mountain, Australian Capital Territory.

How to use this report

SOFR 2018 is organised by the seven criteria for sustainable forest management listed above. Each criterion is presented as a separate chapter of SOFR 2018.

Within each criterion, various indicators address specific forest aspects and values. Individual indicators can be read as stand-alone papers by readers interested in particular aspects of Australia's forests and their management. A summary of key points is given at the start of each indicator, and case studies are presented within indicators as illustrations and to provide regional information.

The Executive Summary at the front of the report gives an overview of the state of Australia's forests across the seven criteria, and is followed by this Introduction. References, a Glossary and an Index are included at the end of the report.

SOFR 2018 and the four previous SOFRs are available at the Forests Australia website (www.agriculture.gov.au/abares/forestsaustralia) and the ABARES publications website (www.agriculture.gov.au/abares/publications).

This icon indicates data, maps or graphics from *Australia's State of the Forests Report 2018* that are available for electronic download. Higher resolution versions of maps in the Introduction are available via www.doi.org/10.25814/5be3bc4321162.

Criterion 1

Conservation of biological diversity

The Eastern Spinebill (*Acanthorhynchus tenuirostris*) is a species of honeyeater found in south-eastern Australian forests.

Criterion 1 Conservation of biological diversity

This criterion addresses various aspects of the conservation of the biological diversity of forests, also known as forest biodiversity. Biodiversity refers to the full range of plants, animals and microorganisms occurring in a given area, along with the genes they contain and the ecosystems they form. Conservation of biological diversity is a key part of sustainable forest management, and its goal is the continued existence of ecosystems, species and the genetic variability within these species.

Biological diversity is usually considered at three levels: ecosystem diversity, species diversity and genetic diversity. The nine indicators in this criterion are divided into three sub-criteria that match these levels.

Ecosystem diversity

The first group of indicators in Criterion 1, Indicators 1.1a to 1.1d, provides fundamental information on Australia's forests, as reported through Australia's National Forest Inventory. This includes the geographic distribution of forests, and their type, tenure, growth stages, and degree of fragmentation. These indicators also report on the forest area in reserves of various types or protected by management prescription or through other arrangements such as covenants. Together they provide the basic area data that underpin the description in various SOFR 2018 indicators of the development of legislation and policies, the management of forest ecosystems for multiple values, the monitoring of forest condition, and the assessment of forest management outcomes. Indicator 1.1a 'Area of forest by forest type and tenure' is therefore a keystone indicator.

The reported area of Australia's forest has changed over time as available technology, and the methods used for forest assessment, have improved. SOFR 2018 continues the use of a 'Multiple Lines of Evidence' approach to determining Australia's forest area, in which data from states and territories are combined with a range of remotely sensed forest cover data to map forest communities with greater accuracy than associated with any single input dataset.

Species diversity

The second group of indicators in Criterion 1, Indicators 1.2a to 1.2c, focuses on the species found in forests. Species are treated as forest-dwelling species if they are able to use a forest habitat for all or part of their lifecycles. A subset of these are forest-dependent species, which need to use a forest habitat to complete part or all of their lifecycles.

Knowledge of the plant, animal and other species present in a forest is a pre-condition for the effective management of that forest. Information on whether populations of species are increasing or decreasing, obtained through species monitoring programs, can indicate the extent and condition of, and changes in, forest habitat, and is needed to support conservation strategies. For forest covered by Regional Forest Agreements, state governments have developed a set of criteria

Native forest, Guy Fawkes River National Park, east of Armidale, New South Wales.

that include broad benchmarks for the in-situ conservation of forest biodiversity.

A number of forest-dwelling and forest-dependent species and forest ecosystems are listed as threatened on lists compiled nationally and by states and territories. Knowledge of the threats and threatening processes faced by listed species and ecosystems assists in developing management strategies for their protection.

Genetic diversity

The final group of indicators in Criterion 1, Indicators 1.3a and 1.3b, assesses conservation of forest genetic resources. This is linked both to the conservation of forest biodiversity and to the availability of forest species for commercial or environmental use.

Indicator 1.3a examines the risk of loss of the genetic diversity in forest plants and animals, and describes the conservation measures in place to minimise that risk. Native forest species and communities in Australia are conserved in protected areas such as nature conservation reserves and national parks and in other public and private forests. Conservation plantings and seed orchards (stands planted and managed for seed production) have also been established for a number of threatened species.

Indicator 1.3b assesses the genetic resources for native forest and commercial plantation species used for wood production, and provides an inventory of tree breeding and improvement programs for Australia's native forest trees and plantation species. Australia's forest genetic resources play an important role in maintaining and improving the productivity of commercial plantations grown for wood production in Australia and in other countries. They enable, for example, selection of trees that have high growth rates and superior wood quality, that are better adapted to changing climatic conditions such as lower rainfall or higher temperatures, or that are more resistant or tolerant to pests and diseases.

This icon indicates data, maps or graphics from *Australia's State of the Forests Report 2018* that are available for electronic download. Data used in figures and tables in this criterion, together with higher resolution versions of maps and other graphical elements, are available via www.doi.org/10.25814/5bda82c8d76d4 and www.doi.org/10.25814/5be3bc4321162.

Indicator 1.1a

Area of forest by forest type and tenure

Rationale

This indicator uses the area for each forest type over time as a broad measure of the extent to which forest ecosystems and their diversity are being maintained. Reporting on forest tenure aids our understanding of how different land management regimes may impact on forest biodiversity.

Key points

- Australia has 134.0 million hectares of forest, covering 17% of Australia's land area.
  - This area is determined from the spatial coverage held in Australia's National Forest Inventory as at 2016.
  - Of this total area, 131.6 million hectares (98%) are Native forests, 1.95 million hectares are Commercial plantations and 0.47 million hectares are Other forest.
  - Australia has approximately 3% of the world's forest area, and globally is the country with the seventh largest forest area.
- Native forest is the most extensive category of Australia's forest.
  - Australia's native forest is classified into forest types, and is dominated by Eucalypt forest (101 million hectares, 77% of the native forest area) and Acacia forest (11 million hectares, 8%). The area of Rainforest (3.5 million hectares, 2.7%) is relatively small.
  - By crown cover class, the majority of native forest is woodland forest (91 million hectares, 69%), which has a crown cover of 20–50%.
- Commercial plantations form the second most extensive category of Australia's forest.
  - As determined from the National Forest Inventory spatial coverage, commercial plantations total 1.95 million hectares, comprising 1.02 million hectares of softwood species (mainly pines), 0.92 million hectares of hardwood species (mainly eucalypts), and 0.01 million hectares of unknown or mixed species plantations.
- Other forest, the final category, contains 0.47 million hectares of forest not classified as Native forest or Commercial plantation.
  - Other forest comprises mostly non-commercial plantations, planted forests of various types, and non-planted forests dominated by trees of introduced species.
- The majority of Australia's native forest estate, 88 million hectares (67%), is on private and leasehold land. A further 22 million hectares of native forest (17%) is in formal nature conservation reserves, and 10 million hectares of native forest (7%) is in multiple-use public native forests.
- The National Forest Inventory forest cover dataset reported in *Australia's State of the Forests Report 2018* (SOFR 2018) has been developed by combining new or updated state, territory and national datasets with the SOFR 2013 forest cover dataset using a 'Multiple Lines of Evidence' approach, and using high-resolution imagery for validation.
  - The integration of these new or updated datasets has led to a larger forest area (134.0 million hectares) being reported in SOFR 2018 than the area (124.8 million hectares) that was reported in SOFR 2013.
  - Most of this difference in the understanding of Australia's forest extent derives from improvements in methods and datasets, not from actual on-ground changes in forest area. Most of the correction has occurred in the Northern Territory, where areas of woodland forest not reported as forest in SOFR 2013 have now been identified and mapped, and have been reported as forest in SOFR 2018.

Continued

Key points

- The best estimate of the actual change in Australia's total forest area over time is an increase of 3.9 million hectares from 2011 to 2016.
  - This increase is due to the net effect of forest clearing for agricultural use, regrowth of forest on areas cleared for agricultural use, expansion of forest onto areas not recently containing forest, establishment of environmental plantings, and changes in the plantation estate.
  - In each year of the period 2011–2016, the area of forest cleared or recleared was less than the area of forest regrowing from previous clearing.
  - This estimate of area change comes from annual Landsat satellite data interpreted for Australia's National Greenhouse Gas Inventory and published in annual National Inventory Reports by the Australian Government Department of the Environment and Energy[22].
  - Temporary changes in forest area or crown cover that result from a range of short-term factors, such as wildfire, wood harvesting, and regrowth or regeneration from these factors, are not included in these area change figures.

Australia's forest area

Data on Australia's forest estate are assembled in the spatial datasets of the National Forest Inventory (NFI), with spatial data for Commercial plantations incorporated from the National Plantation Inventory (NPI). These inventories are held by the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES), Australian Government Department of Agriculture and Water Resources[23], and are used to report on Australia's forests by national forest type and national land tenure.

Forest area[24] figures presented in this indicator are national figures compiled in the National Forest Inventory (NFI), and SOFR 2018 incorporate validated data from a range of different datasets assembled using a Multiple Lines of Evidence (MLE) methodology (Mutendeudzi et al. 2013a, b). The datasets and data sources used to create the national forest coverage reported in this indicator are listed below in Tables 1.12 and 1.13.

For various reasons, these figures may not align with figures published by individual states or territories or in other Commonwealth reports. These reasons include the timing of publication of SOFR 2018 compared with the timing of other publications, use of different input datasets at different scales and with different levels of validation, and varying interpretations of forest cover and forest communities between agencies, especially in areas of low crown cover. Similar reasons explain the difference between the forest area figure for Australia derived here from the NFI, and international estimates of Australia's forest cover using other data sources (Bastin et al. 2017 provides an example for forests of low crown cover[25]).

As at 2016, Australia had 134 million hectares of forest, covering 17% of the total land area (Table 1.1). This places Australia seventh in the world for countries ranked by forest area (FAO 2015), and Australia has approximately 3% of the world's forest area. The spatial distribution of Australia's forests is shown in Figure 1.1 (on page 53).

Queensland has the largest area of forest (51.8 million hectares, 39% of Australia's forest), with the Northern Territory (23.7 million hectares, 18%), Western Australia (21.0 million hectares, 16%), and New South Wales (20.4 million hectares, 15%), making up much of the balance (Table 1.1).

The forest area reported in SOFR 2018 is larger by 9.3 million hectares than the forest area reported in SOFR 2013. Much of this difference is due not to on-ground change in forest area, but instead to methodological improvements and the incorporation of new datasets. The best available estimate of the actual change in Australia's forest area during the reporting period for SOFR 2018 is determined from annual forest area estimates from Landsat satellite imagery data interpreted for Australia's National Greenhouse Gas Inventory (NGGI) and published in National Inventory Reports (the most recent being DoEE 2018a). These NGGI data show that Australia's forest area increased by 3.9 million hectares over the period 2011 to 2016 (see section 'Change in total forest cover over time'; Figure 1.5).

Australia's forests are assigned to three broad categories, with each category divided into various forest types (Table 1.2):

- 131.6 million hectares (98%) is Native forest dominated by the Eucalypt and Acacia forest types. Queensland has the largest area of native forest (51.6 million hectares, 39% of Australia's native forest), with the Northern Territory (23.7 million hectares, 18%), Western Australia (20.5 million hectares, 16%), and New South Wales (19.9 million hectares, 15%), making up much of the balance.
- 1.95 million hectares is Commercial plantations, comprising 1.02 million hectares of softwood plantations (mainly pines), 0.92 million hectares of hardwood plantations (mainly eucalypts), and 0.01 million hectares of unknown or mixed species plantations. Commercial plantations occur in both temperate and tropical regions of Australia (Figure 1.1). The category 'Commercial plantation' refers to plantations reported through the National Plantation Inventory (ABARES 2016b); these were reported as 'Industrial plantations' in SOFR 2013.
- 0.47 million hectares is Other forest, comprising mostly non-commercial plantations, planted forests of various types, and non-planted forests dominated by trees of introduced species. The largest areas of Other forest are in Victoria (0.16 million hectares) and Western Australia (0.15 million hectares).

22 Until July 2016, the Department of the Environment.

23 Until September 2015, the Department of Agriculture.

24 Forest area, cover and extent are used interchangeably in this report.

25 See also discussion in Schepaschenko et al. (2017) *Science* 358, eaao0166; de la Cruz et al. (2017) *Science* 358, eaao0369; and Griffith et al. (2017) *Science* 358, eaao1309.

Table 1.1: Australia's forest area, by jurisdiction

Jurisdiction	Native forest Area ('000 hectares)	Native forest Area as proportion of total Native forest (%)	Commercial plantation[a,b] Area ('000 hectares)	Commercial plantation Area as proportion of total Commercial plantation (%)	Other forest Area ('000 hectares)	Other forest Area as proportion of total Other forest (%)	Total forest Area ('000 hectares)	Total forest Area as proportion of total forest (%)	Total land[c] Area ('000 hectares)	Forest area as proportion of jurisdiction's land area (%)
ACT	130	0.1	7	0.4	5	1.0	142	0.1	236	60
NSW	19,925	15	380	20	62	13	20,368	15	80,131	25
NT	23,686	18	45	2	4	1.0	23,735	18	134,837	18
Qld	51,580	39	229	12	21	4	51,830	39	173,002	30
SA	4,856	4	178	9	25	5	5,060	4	98,430	5
Tas.	3,342	3	311	16	46	10	3,699	3	6,829	54
Vic.	7,645	6	415	21	162	34	8,222	6	22,742	36
WA	20,450	16	383	20	148	31	20,981	16	252,702	8
Australia	131,615	100	1,949	100	474	100	134,037	100	768,909	17

a The NFI spatial coverage used to report Commercial plantation areas in Indicator 1.1a of SOFR 2018 is a rasterised version of the NPI spatial dataset used to produce the data reported for 2014–15 in *Australian plantation statistics 2016* (ABARES 2016b). Conversion of the vector format dataset used in *Australian plantation statistics 2016* to the raster format dataset used in SOFR 2018 means that the area figure for Commercial plantations reported in SOFR 2018 (1.95 million hectares) is slightly lower than the area figure (1.97 million hectares) reported in *Australian plantation statistics 2016*.

b The Commercial plantation area data reported here is derived from the spatial data reported for 2014–15 in *Australian plantation statistics 2016* (ABARES 2016b). Updated tabular data for 2015–16 are available in *Australian plantation statistics 2017 update* (Downham and Gavran 2017) (area of 1.97 million hectares), and for 2016–17 in *Australian plantation statistics 2018 update* (Downham and Gavran 2018) (area of 1.96 million hectares).

c The land area data reported here is derived from the raster (grid) used for the NFI spatial coverage, and is slightly lower than the land area data reported in SOFR 2013 that was derived from Geosciences Australia vector data[26].

Note: Totals may not tally due to rounding.

Source: ABARES, National Forest Inventory, National Plantation Inventory.

This table, together with other data for Indicator 1.1a, is available in Microsoft Excel via www.doi.org/10.25814/5bda82c8d76d4

Native forest types

The vast majority of Australia's native forest area is dominated by evergreen, broadleaf, hardwood tree species. For national reporting, the NFI classifies Australia's native forests into eight broad forest types defined by dominant species and structure (as described in the Introduction). The first seven distinctive types are Acacia, Callitris, Casuarina, Eucalypt, Mangrove, Melaleuca and Rainforest. Of these, Callitris is the only native forest type dominated by coniferous softwood tree species. The eighth type, Other native forest, comprises less common native forest types with relatively small individual areas, as well as native forests where the type is unknown (generally because of an absence of floristic information in the National Vegetation Information System (NVIS)). Commercial plantations are divided into two main types: hardwood (broadleaf) and softwood (coniferous) plantations. 'Other forest' includes mostly non-commercial plantations, planted forests of various types, and non-planted forests dominated by trees of introduced species. The areas of these forest types are presented in Table 1.2.

Native eucalypt forest in the Blue Mountains, New South Wales.

The Eucalypt forest type, comprising forests dominated by members of the genera *Eucalyptus*, *Corymbia* and *Angophora*, is dominant across most of Australia's forest area, with a total of 101 million hectares (77% of Australia's native forest area). It is generally reported as subtypes by height class, crown cover class and structural form, including mallees (stands of multi-stemmed eucalypts). The second most common forest type is Acacia, comprising forests dominated by species of the genus *Acacia*, with a total of 11 million hectares (8%). Despite the overwhelming dominance of these two forest types, Australia's forests are nonetheless very diverse. There are more than 800 species of *Eucalyptus*, *Corymbia* and *Angophora*, and almost 1,000 species of *Acacia*, as well as many other genera of trees, in a rich array of ecosystems that vary in their floristic composition, their structure and the fauna they support. Rainforest covers 3.5 million hectares (2.7% of Australia's forest area); some rainforests are particularly rich in floral and faunal biodiversity.

26 The land area for Australia, states and territories reported in SOFR 2013, Table 1.1, was derived from the Geosciences Australia "GEODATA COAST 100K 2004" vector dataset (www.ga.gov.au/scientific-topics/national-location-information/dimensions/area-of-australia-states-and-territories).

Table 1.2: Australia's forest areas by category and type

Native forest type	Area ('000 hectares)	Proportion of total native forest area (%)	Proportion of total forest area (%)
Acacia	10,813	8.2	8.1
Callitris	2,011	1.5	1.5
Casuarina	1,236	0.9	0.9
Eucalypt	101,058	77	75
Mangrove	854	0.6	0.6
Melaleuca	6,382	4.8	4.8
Rainforest	3,581	2.7	2.7
Other native forest[a]	5,679	4.3	4.2
Total Native forest	**131,615**	**100**	**98**

Commercial plantation[b]	Area ('000 hectares)	Proportion of total commercial plantation area (%)	Proportion of total forest area (%)
Softwood	1,015	52	0.8
Hardwood	922	47	0.7
Unknown or mixed species[c]	11	0.6	0.01
Total Commercial plantation	**1,949**	**100**	**1.5**

Other forest[d]	Area ('000 hectares)	Proportion of total other forest area (%)	Proportion of total forest area (%)
Other forest	474	100	0.4
Total Other forest	**474**	**100**	**0.4**

Total	**134,037**		**100**

[a] Other native forest comprises a range of minor forest types, including Agonis, Atalaya, Banksia, Hakea, Grevillea, Heterodendron, Leptospermum, Lophostemon and Syncarpia (each named after its dominant genus), as well as native forests where the type is unknown.

[b] Determined from the National Forest Inventory spatial coverage. See footnote on Commercial plantation areas under Table 1.1.

[c] Plantations of mixed hardwood and softwood species, and plantations where the species type is not reported.

[d] Other forest comprises mostly non-commercial plantations, planted forests of various types, and non-planted forests dominated by trees of introduced species.

Note: Totals may not tally due to rounding.

Source: ABARES, National Forest Inventory, National Plantation Inventory.

This table, together with other data for Indicator 1.1a, is available in Microsoft Excel via www.doi.org/10.25814/5bda82c8d76d4

Forests are generally confined to regions where average rainfall exceeds 500 millimetres per year. Most forests are in the northern, eastern, south-eastern and south-western coastal zones of Australia, although woodland forests extend into drier areas in many parts of the country (Figure 1.1).

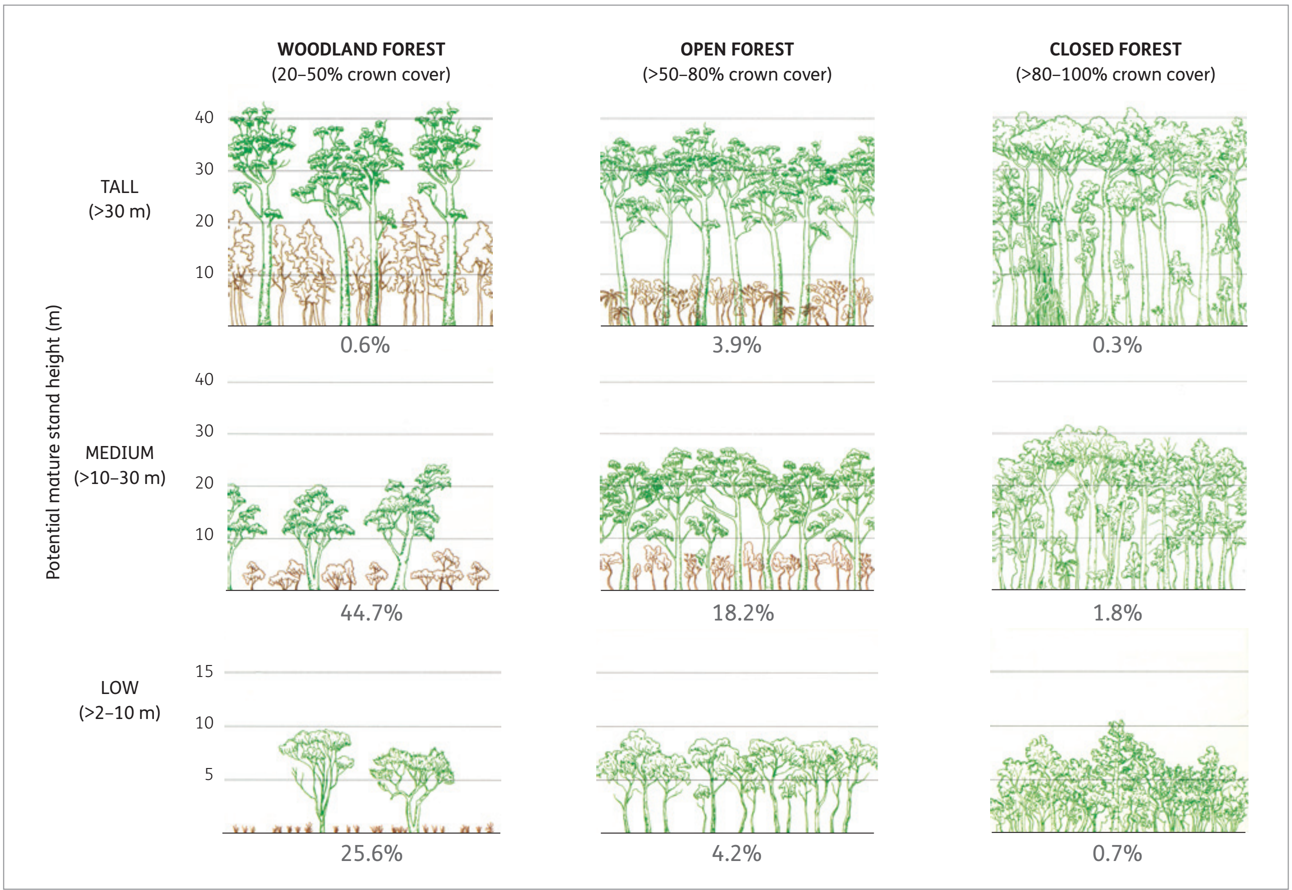
Forest classified as 'Eucalypt medium open' forest. This forest is dominated by eucalypts, and has a stand height of >10–30 metres and crown cover >50–80%. Northern New South Wales.

Crown cover, height and form

Australia's definition of forest specifies a minimum existing or potential crown cover of 20%, a minimum mature or potentially mature stand height exceeding 2 metres, and stands dominated by trees usually having a single stem. Within this definition, native forests are classified into nine structural classes, based on three crown cover classes (woodland forest, crown cover 20–50%; open forest, crown cover >50–80%; and closed forest, crown cover >80–100%) and three stand height classes (low, height >2–10 metres; medium, height >10–30 metres; and tall, height >30 metres), as shown in Figure 1.2. Australia's multi-stemmed eucalypt mallee associations are included in the definition of forest if they meet the criteria for height and crown cover.

Forest type and crown cover are reasonably well measured across Australia, but only limited forest height information is collected outside forests in which wood is harvested.

Figure 1.2: Native forest crown cover classes, height classes, and area proportions



Note: Percentages are area proportions of each height class/crown cover class combination in Australia's total native forest area, excluding 'Other native forest' for which height and cover class is unknown. In accordance with the definition of forest used for the National Forest Inventory, the crown cover values relate to existing or potential crown cover, and the height values relate to mature or potentially mature stand height.

Source: Adapted from Australian Land Information Group and JA Carnahan (1990). *Atlas of Australian Resources, Vegetation*. Australian Government Publishing Service, Canberra.

A higher resolution version of this graphic is available via www.doi.org/10.25814/5be3bc4321162

Land classified as non-forest comprises both land carrying other woody vegetation (defined as woody vegetation often but not necessarily containing a tree component, and with existing or potential crown cover less than 20% or with a mature or potentially mature stand height of 2 metres or less), and land not carrying other woody vegetation. 'Other woody vegetation' is sometimes referred to as 'Sparse woodland'.

A total of 91 million hectares (69%) of Australia's native forest area is classified as woodland forest of 20–50% crown cover (Table 1.3). Open forests of >50–80% crown cover comprise 34 million hectares (26%) of the native forest area. Closed forests of >80–100% crown cover comprise 3.7 million hectares (2.8%) of the native forest area. Eucalypt forest types are the largest component of both woodland forest (73 million hectares) and open forest (28 million hectares), while Rainforest is the largest component of closed forest (2.6 million hectares) (Table 1.3).

The distribution of Australia's native forest types, subtypes and crown cover classes varies across the continent, depending on climate, geology and soil type, and fire history. This distribution is closely related to soil moisture regimes and water availability, as well as past and present land management practices. Figure 1.3 shows the mapped distribution of native forest by crown cover class. Data from various sources including NPI 2016, NVIS 5.0, SOFR 2013 and new forest cover datasets provided by state and territory agencies were used to allocate NFI forest types to the SOFR 2018 forest extent (see Table 1.13). Tables 1.4 and 1.5 provide a breakdown of the areas of the various forest types and height and crown cover classes, by jurisdiction, and Figure 1.2 shows the area proportions of nine structural classes (three crown cover classes by three height classes) across Australia's native forests.

Woodland forest is the largest crown cover class of forest in all jurisdictions except Victoria and the Australian Capital Territory (Table 1.4). In South Australia, woodland forest represents 93% of the native forest area, in Western Australia 89%, and in Queensland 77%; there are 40 million hectares of woodland forest in Queensland alone. Open forests dominate in the Australian Capital Territory (71% of the native forest area in that jurisdiction) and Victoria (61%). Woodland and open forests occur in similar proportions in Tasmania and New South Wales, while Tasmania has the highest proportion of closed forests (0.67 million hectares, 20% of that state's native forest area).

Table 1.3: Australia's native forest area, by forest type and crown cover class

	Area ('000 hectares)					Proportion of total native forest area
Native forest type	Woodland	Open	Closed	Unknown	Total	(%)
Acacia	8,536	2,233	44	0	**10,813**	8.2
Callitris	951	1,060	0	0	**2,011**	1.5
Casuarina	1,070	150	16	0	**1,236**	0.9
Eucalypt	72,829	27,776	454	0	**101,058**	77
Eucalypt mallee	12,530	842	0	0	**13,372**	10
Eucalypt low	8,227	2,205	58	0	**10,490**	8.0
Eucalypt medium	51,326	19,783	256	0	**71,365**	54
Eucalypt tall	746	4,945	140	0	**5,830**	4.4
Mangrove	63	370	420	0	**854**	0.6
Melaleuca	5,416	938	28	0	**6,382**	4.9
Rainforest	0	1,006	2,574	0	**3,581**	2.7
Other native forest[a]	2,590	429	85	2,576	**5,679**	4.3
Total Native forest	**91,455**	**33,962**	**3,622**	**2,576**	**131,615**	**100**
Proportion of total native forest area (%)	**69**	**26**	**2.8**	**2.0**	**100**	

[a] Other native forest comprises a range of minor forest types, including Agonis, Atalaya, Banksia, Hakea, Grevillea, Heterodendron, Leptospermum, Lophostemon and Syncarpia (each named after its dominant genus), as well as native forests where the type is unknown.

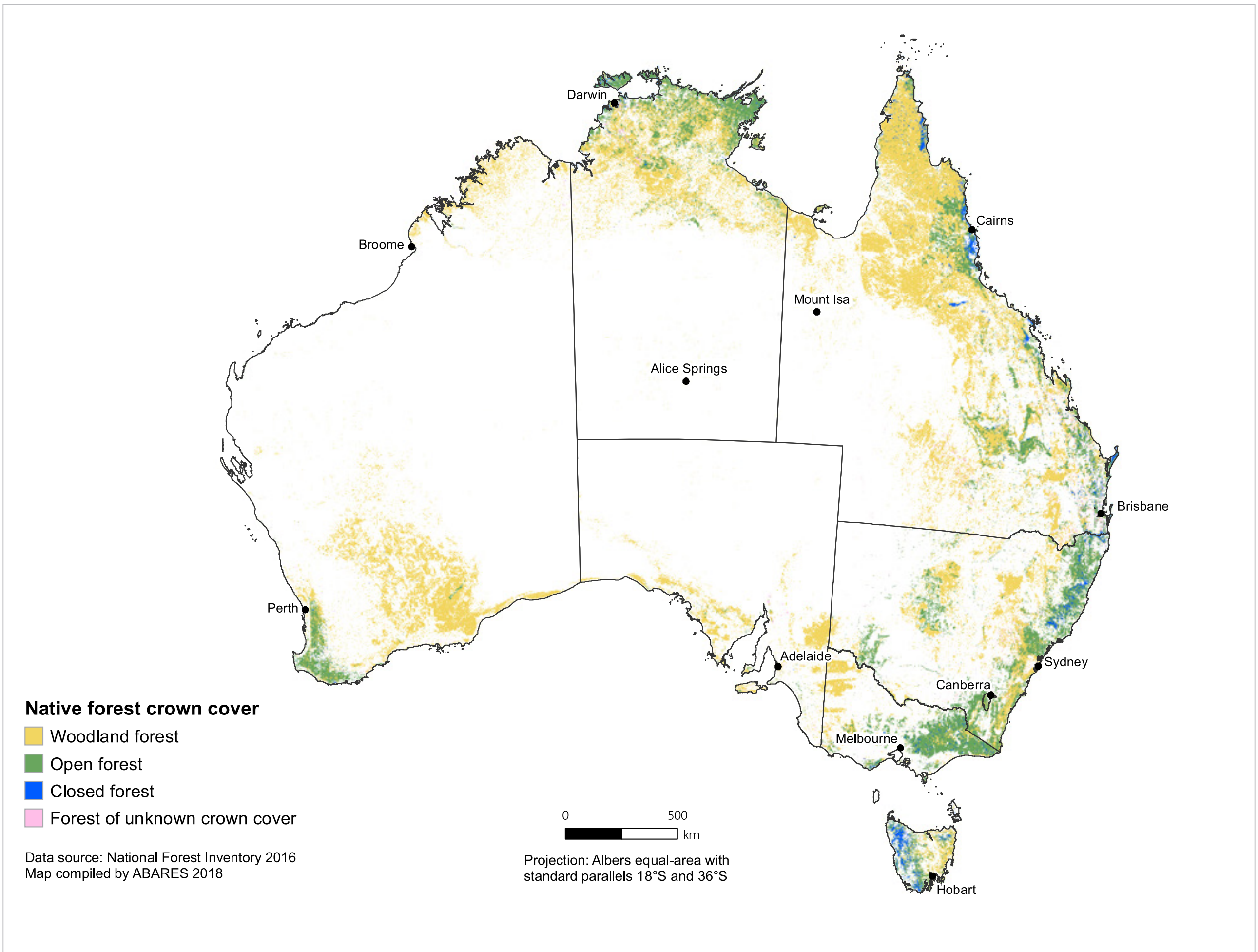
Notes: Totals may not tally due to rounding.

The area for 'Rainforest – Open' was originally published as 1,026 thousand hectares. The correct figure, as shown above, is 1,006 thousand hectares.

Source: ABARES, National Forest Inventory.

This table, together with other data for Indicator 1.1a, is available in Microsoft Excel via www.doi.org/10.25814/5bda82c8d76d4

Figure 1.3: Native forest, by crown cover class



A higher resolution version of this map is available via www.doi.org/10.25814/5be3bc4321162

Table 1.4: Area of native forest, by crown cover class and jurisdiction

Jurisdiction	Woodland forest		Open forest		Closed forest		Unknown		Total native forest	
	Area ('000 hectares), and proportion of jurisdiction's native forest area (%)									
ACT	38	29	92	71	0	0	0.1	0.1	130	100
NSW	9,479	48	9,233	46	507	3	707	4	19,925	100
NT	15,482	65	7,485	32	483	2	236	1	23,686	100
Qld	39,663	77	8,720	17	1,673	3	1,524	3	51,580	100
SA	4,534	93	261	5	1	0.02	61	1	4,856	100
Tas.	1,373	41	1,299	39	666	20	4	0.1	3,342	100
Vic.	2,771	36	4,641	61	233	3	0	0	7,645	100
WA	18,116	89	2,231	11	60	0.3	44	0.2	20,450	100
Australia	**91,455**	**69**	**33,962**	**26**	**3,622**	**3**	**2,576**	**2**	**131,615**	**100**

Note: Totals may not tally due to rounding.
Source: ABARES, National Forest Inventory.

This table, together with other data for Indicator 1.1a, is available in Microsoft Excel via www.doi.org/10.25814/5bda82c8d76d4

More than half (27 million hectares, 53%) of Queensland's native forests are classified as Eucalypt medium woodland (Table 1.5). Queensland also has the largest area of Acacia forest (5.1 million hectares, 47% of Australia's total) and Melaleuca forest (5.1 million hectares, 81% of Australia's total), which are both mostly woodland forests, as well as the largest area of Rainforest (2.0 million hectares, 55% of Australia's total).

Eucalypt forests dominate the Northern Territory (20 million hectares, 83% of the territory's native forest area). The largest components are Eucalypt low and medium woodland and medium open forests, together with significant amounts of Acacia and Melaleuca forests. There are no tall Eucalypt forests in the Northern Territory.

Western Australia's native forests are dominated by Eucalypt forests (16.6 million hectares, 79% of the state's native forest area) and Acacia forests (3.2 million hectares, 15%). Over half of Australia's Eucalypt mallee woodland is in Western Australia.

Over three-quarters of New South Wales native forests (15.5 million hectares) are Eucalypt forest types, with approximately equal areas of Eucalypt woodland forests and Eucalypt open forests.

Victoria's native forests are also dominated by Eucalypt forests (7.2 million hectares, 94% of the state's native forest area). Over 40% of Victoria's native forests are Eucalypt medium open forests (3.1 million hectares), with over 1 million hectares each of Eucalypt mallee woodland, Eucalypt medium woodland and Eucalypt tall open forests.

South Australia's native forests are dominated by Eucalypt mallee forests (78% of the state's native forest area). There are no tall Eucalypt forests or Rainforest in South Australia.

Although Tasmania and the Australian Capital Territory have the smallest areas of native forest of all the states and territories, they have the highest proportion of forest area (Table 1.1). Native forests in the Australian Capital Territory are almost completely Eucalypt forests (0.13 million hectares, 91% of the territory's native forest area), with the balance comprising Commercial plantations and Other forests (Table 1.5). Tasmania has the highest proportional area of Rainforest (20% of the state's native forest area, covering 0.7 million hectares), with most of the balance represented by Eucalypt forests (2.5 million hectares, 67%).

Australia has a total of 0.85 million hectares of Mangrove forests (Table 1.2). About 84% of these are in Queensland and the Northern Territory (Table 1.5).

Native forest managed for wood production occurs predominantly in the tall open and medium open Eucalypt forest types on public and private land in the 10 Regional Forest Agreement (RFA) regions and south-eastern Queensland (see Introduction and below). Across Australia, low and medium open forests and woodland forests, typically on leasehold and private land, are generally used for livestock grazing, with only occasional low-intensity wood production.

Eucalypt low woodland forest, Kalgoorlie, Western Australia.

Table 1.5: Forest area, by forest type and jurisdiction

	Area ('000 hectares)								
Forest type	**ACT**	**NSW**	**NT**	**Qld**	**SA**	**Tas.**	**Vic.**	**WA**	**Australia**
Acacia	0	730	1,522	5,121	104	77	37	3,222	10,813
Callitris[a]	0	1,394	0	527	66	1	23	0.1	2,011
Casuarina	1	512	38	272	252	10	48	103	1,236
Eucalypt	129	15,460	19,764	35,184	4,283	2,461	7,175	16,602	101,058
Eucalypt mallee open	0	617	0	0	208	0	11	6	842
Eucalypt mallee woodland	0	1,147	44	1	3,721	0.1	1,280	6,338	12,530
Eucalypt low closed	0	0	16	10	0	12	14	5	58
Eucalypt low open	0	76	624	1,295	8	52	69	83	2,205
Eucalypt low woodland	0	472	4,224	1,949	134	59	20	1,369	8,227
Eucalypt medium closed	0	17	72	42	0	0	97	28	256
Eucalypt medium open	1	4,669	5,673	4,434	17	197	3,092	1,700	19,783
Eucalypt medium woodland	8	6,015	9,111	27,052	195	1,050	1,037	6,859	51,326
Eucalypt tall closed	0	17	0	0	0	0	117	6	140
Eucalypt tall open	91	2,308	0	154	0	831	1,367	194	4,945
Eucalypt tall woodland	30	123	0	247	0	259	73	14	746
Mangrove	0	6	334	384	13	0	1	116	854
Melaleuca	0	67	1,038	5,141	34	25	19	58	6,382
Rainforest	0	594	287	1,981	0	699	20	0.2	3,581
Other native forest	0.2	1,162	702	2,970	104	69	322	350	5,679
Total Native forest	**130**	**19,925**	**23,686**	**51,580**	**4,856**	**3,342**	**7,645**	**20,450**	**131,615**
Softwood	7	294	1	196	127	76	216	98	1,015
Hardwood	0	86	44	34	51	233	198	276	922
Unknown or mixed species[b]	0	0.1	0	0	0.2	2	1	9	11
Total Commercial plantation[c]	**7**	**380**	**45**	**229[d]**	**178**	**311**	**415**	**383**	**1,949**
Other forest[d]	**5**	**62**	**4**	**21**	**25**	**46**	**162**	**148**	**474**
Total forest	**142**	**20,368**	**23,735**	**51,830**	**5,060**	**3,699**	**8,222**	**20,981**	**134,037**

a Stands of Callitris not sufficiently large to map at a 1 hectare scale are present in the ACT, NT and WA

b Plantations of mixed hardwood and softwood species, and plantations where the species type is not reported.

c Determined from the National Forest Inventory spatial coverage. See footnote on Commercial plantation areas under Table 1.1.

d Area figures for Queensland plantations reported here differ slightly from the figures reported by Queensland in 2016[27]. Area figures for 'Commercial plantations' reported in SOFR 2018 exclude plantations assessed as non-commercial plantations for the National Plantation Inventory, and which are reported in SOFR 2018 in the 'Other forest' category.

Note: Totals may not tally due to rounding.

Source: ABARES, National Forest Inventory, National Plantation Inventory.

This table, together with other data for Indicator 1.1a, is available in Microsoft Excel via www.doi.org/10.25814/5bda82c8d76d4

Tenure

Land tenure is an important attribute of forests, and one determinant of forest management. Different types of ownership are linked to who has the right to use and occupy land, the right to use forest resources, and the conditions that may be attached to these rights. Tenure of forest land cannot always be used to determine ownership of trees.

In the National Forest Inventory, forest ownership is reported in six national tenure classes that bring together the wide range of land tenures used by each jurisdiction across Australia (see Introduction for descriptions of tenure classes).

The dataset used in SOFR 2018 for forest tenure analysis is a combination of datasets from state and territory land titles registries and spatial data agencies, with national land tenure data from PSMA Australia Limited[28] and the Australian Government Department of Defence.

Table 1.6 shows the areas of forest in each tenure class by jurisdiction, Table 1.7 the areas of native forest in each tenure class by jurisdiction, and Table 1.8 the areas of forest by forest category, crown cover class and tenure. The distribution of forest by tenure type is mapped in Figure 1.4.

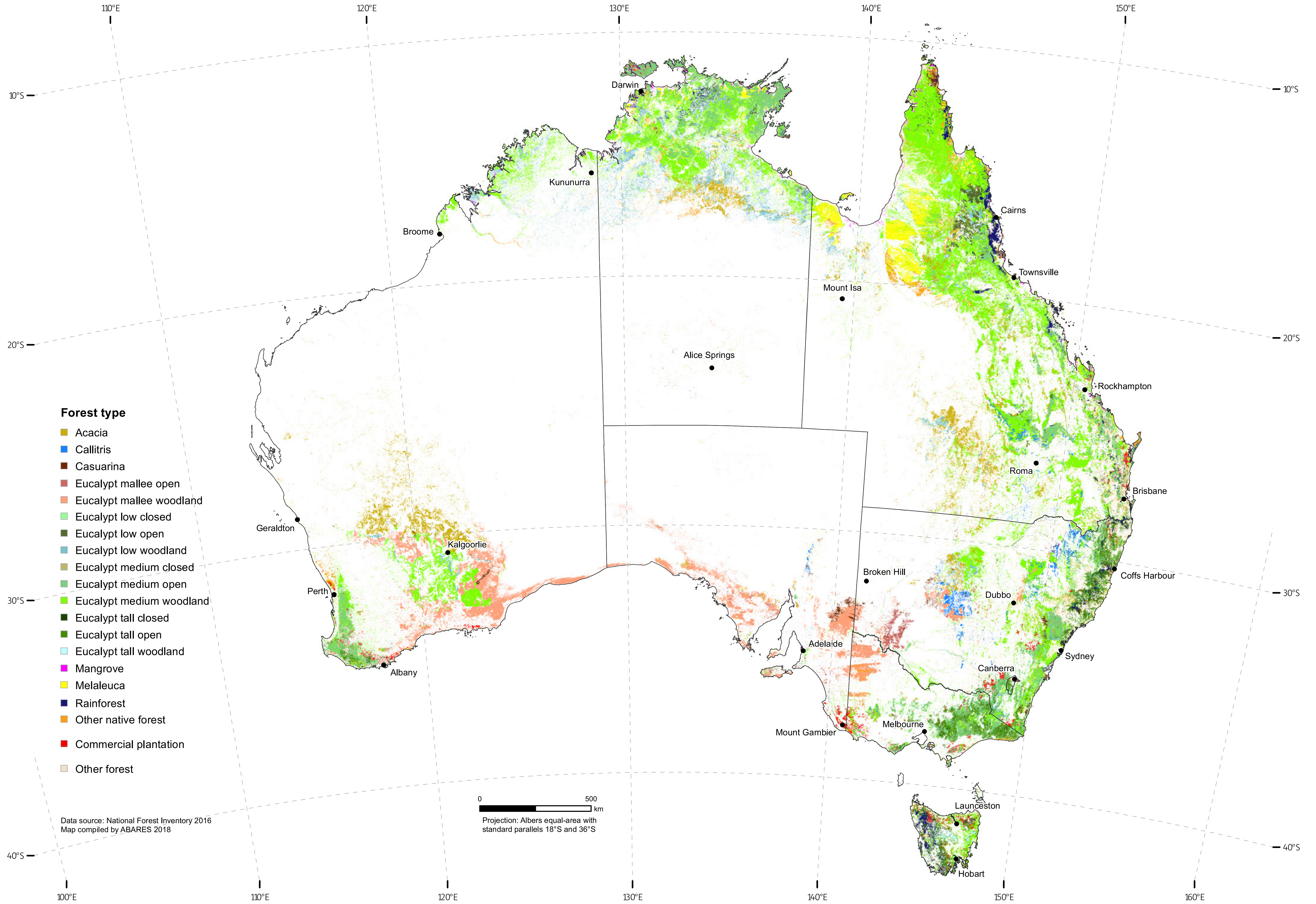
Of the 134 million hectares of forest in Australia, 47 million hectares (35%) are forest on leasehold land, and 42 million hectares (32%) are forest on land held under private freehold title (Table 1.6).

Of the 132 million hectares of native forest in Australia, 47 million hectares (36%) are native forest on leasehold land, and 41 million hectares (31%) are native forest on land held

27 www.daf.qld.gov.au/business-priorities/forestry/plantation/plantation-area

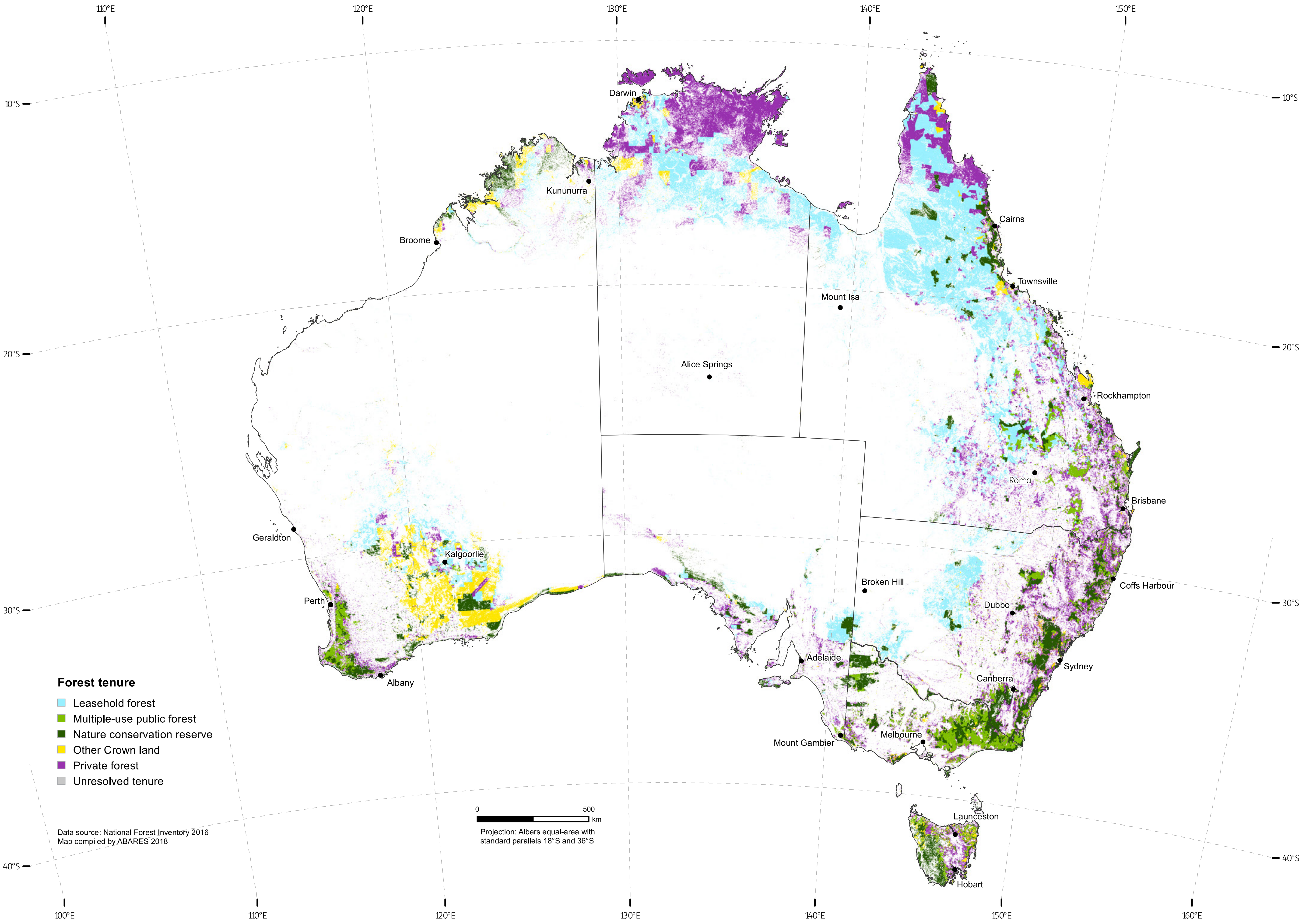
28 www.psma.com.au/products/land-tenure. Data were purchased from OMNILINK Pty Limited (www.omnilink.com.au).

Figure 1.1: Australia's forests, by forest type



A higher resolution version of this map is available via www.doi.org/10.25814/5be3bc4321162

Figure 1.4: Australia's forests, by tenure



A higher resolution version of this map is available via www.doi.org/10.25814/5be3bc4321162

under private freehold title (Table 1.7). A total of 88 million hectares (67%) of native forest are thus under either private or leasehold tenure. The Northern Territory (96% of native forest area), Queensland (82%) and New South Wales (59%) have the highest proportions of their native forest area under private or leasehold tenure, while Western Australia (33%), Victoria (13%) and Australian Capital Territory (6%) have the lowest proportions.

Queensland has the largest area of leasehold native forest (28 million hectares, 55% of Australia's total area of leasehold native forest)[29]. Other substantial areas of leasehold native forest are in the Northern Territory, New South Wales and Western Australia. Together, Queensland, New South Wales and the Northern Territory contain 85% of Australia's native forests under private or leasehold tenure, including large areas that are Indigenous owned and managed or Indigenous managed (see Indicators 6.4a and 6.4c).

The Australian Capital Territory (86%), Tasmania (46%) and Victoria (44%) have the highest proportions of their native forest area as nature conservation reserves. The Northern Territory (0.1%) and Queensland (8%) have the lowest proportions, noting that Kakadu National Park and some other national parks in these jurisdictions are classified as private tenure.

A total of 22 million hectares of forest (17% of Australia's native forest, and 16% of Australia's total forest), is in nature conservation reserve tenure (Tables 1.6 and 1.7). Additional forest areas in different formal land tenure categories have their legislated management intent as conservation, including Indigenous owned and managed or Indigenous managed lands classified as private, leasehold or other Crown land. Kakadu National Park in the Northern Territory, classified as private tenure, is an example of such an area managed for conservation (see Indicators 1.1c, 6.4a and 6.4c).

The area of native forests in formal nature conservation reserves in SOFR 2018 is 0.24 million hectares larger than the figure reported in SOFR 2013. However, the proportion of native forest that is in nature conservation reserves is 1.0% lower than the proportion reported in SOFR 2013. This reflects the increase in the reported area of total native forest in SOFR 2018, with much of this increase occurring in the Northern Territory, where

Table 1.6: Area of forest, by tenure and jurisdiction

	Area ('000 hectares)									Proportion of total forest area (%)
Tenure class	ACT	NSW	NT	Qld	SA	Tas.	Vic.	WA	Australia	
Leasehold forest	9	4,249	9,318	28,135	1,462	0	0	4,095	47,268	35
Multiple-use public forest	15	2,138	0	3,074	117	733	3,190	1,405	10,673	8.0
Nature conservation reserve	113	5,570	15	4,379	1,698	1,545	3,377	5,056	21,752	16
Other Crown land	7	757	889	1,308	91	381	252	7,419	11,102	8.3
Private forest	0	7,572	13,476	14,269	1,671	1,040	1,402	3,006	42,436	32
Unresolved tenure	0	82	38	666	20	0	0.2	0	806	0.6
Total forest	**142**	**20,368**	**23,735**	**51,830**	**5,060**	**3,699**	**8,222**	**20,981**	**134,037**	**100**

Note: Totals may not tally due to rounding.
Source: ABARES, National Forest Inventory, PSMA Australia Ltd.

This table, together with other data for Indicator 1.1a, is available in Microsoft Excel via www.doi.org/10.25814/5bda82c8d76d4

Table 1.7: Area of native forest, by tenure and jurisdiction

	Area ('000 hectares)									Proportion of total native forest area (%)
Tenure class	ACT	NSW	NT	Qld	SA	Tas.	Vic.	WA	Australia	
Leasehold forest	8	4,249	9,318	28,135	1,447	0	0	4,089	47,246	36
Multiple-use public forest	5	1,856	0	2,881	22	612	3,052	1,344	9,772	7.4
Nature conservation reserve	113	5,569	15	4,378	1,698	1,544	3,367	5,035	21,719	17
Other Crown land[a]	5	755	881	1,308	91	380	241	7,382	11,042	8.4
Private forest	0	7,414	13,435	14,213	1,580	806	984	2,600	41,031	31
Unresolved tenure	0	81	38	666	20	0	0	0	805	0.6
Total native forest	130	19,925	23,686	51,580	4,856	3,342	7,645	20,450	131,615	100

[a] A total of 1.3 million hectares of native forest on Other Crown land tenure is managed by the Australian Government Department of Defence. A breakdown of this area by jurisdiction is given in Table 1.27, Indicator 1.1c.
Note: Totals may not tally due to rounding.
Source: ABARES, National Forest Inventory, PSMA Australia Ltd.

This table, together with other data for Indicator 1.1a, is available in Microsoft Excel via www.doi.org/10.25814/5bda82c8d76d4

[29] Not all forest on leasehold land is privately managed. In Queensland, under the *Forestry Act 1959* the state owns forest products on certain parcels of state land leased under the *Land Act 1994*, such as grazing leases.

Table 1.8: Area of forest, by tenure and crown cover[a]

	Area ('000 hectares)						
Crown cover class	Leasehold forest	Multiple-use public forest	Nature conservation reserve	Other Crown land	Private forest	Unresolved tenure	Total
Woodland	40,217	3,591	12,445	9,649	25,090	463	91,455
Open forest	6,277	5,699	7,666	1,084	13,019	217	33,962
Closed forest	277	419	1,528	206	1,120	72	3,622
Unknown	475	63	79	103	1,802	53	2,576
Total native forest	**47,246**	**9,772**	**21,719**	**11,042**	**41,031**	**805**	**131,615**
Commercial plantation[a]	**18**	**810**	**4**	**14**	**1,102**	**0.4**	**1,949**
Other forest	**4**	**91**	**30**	**46**	**303**	**0.3**	**474**
Total forest	**47,268**	**10,673**	**21,752**	**11,102**	**42,436**	**806**	**134,037**

[a] Determined from the National Forest Inventory spatial coverage. See footnote on Commercial plantation areas under Table 1.1.
Note: Totals may not tally due to rounding.
Source: ABARES, National Forest Inventory, National Plantation Inventory, PSMA Australia Ltd.

This table, together with other data for Indicator 1.1a, is available in Microsoft Excel via www.doi.org/10.25814/5bda82c8d76d4

98% of native forest is under private or leasehold land tenure and relatively little is in nature conservation reserves.

Multiple-use public forests comprise 9.8 million hectares of native forest (7.4% of Australia's native forest area). Wood harvesting is permitted in some of this area, but not in informal reserves, and not in areas such as steep areas, riparian zones or special habitat zones where harvesting is restricted by jurisdictional code of practices (see Indicator 2.1a). Wood harvesting in multiple-use public native forest is not permitted in the Australian Capital Territory or South Australia[30] (see Indicators 1.1c and 2.1a). Victoria has the largest area of multiple-use public forest (3.1 million hectares, 31% of the national area) followed by Queensland (2.9 million hectares, 29%) and New South Wales (1.9 million hectares, 19%).

The total area of multiple-use public forest reported in SOFR 2018 is 0.45 million hectares less than that reported in SOFR 2013. A substantial portion of the decrease in area is in Tasmania, where areas of forest previously reported as multiple-use public forest are now classified as either 'Future Potential Production Forest' and reported in the tenure category 'Other Crown land'[31], or as nature conservation reserve. A decrease in the reported area of multiple-use public forest has also occurred in New South Wales resulting from the use of tenure data from the NSW Spatial Cadastre database, with areas of plantation on private freehold land that are managed by state agencies being reclassified as private tenure.

Victoria (40%) and Tasmania (18%) have the highest proportions of their native forest area as multiple-use public forests. The proportion of multiple-use public forest area in each of the other jurisdictions is less than 10% of their native forest area.

A total of 0.8 million hectares of forest is of unresolved tenure. Most of this area is in Queensland, and is land for which insufficient tenure information is available in the Queensland cadastral database to allow translation to an NFI tenure class. It mostly comprises forest (including mangrove forest) on intertidal zones, wetlands and mudflats, and forest on road easements and watercourse corridors.

There are notable differences in the distribution of forest with different crown cover classes (woodland forest, open forest and closed forest) across the six tenure categories used in SOFR 2018 (Table 1.8). The majority (40 million hectares, 85%) of leasehold native forest land carries woodland forests, with almost all the remainder carrying open forest; this is because leasehold forest is predominantly in the drier parts of the forest estate (Figure 1.4). Native forest on private land is also primarily (93% by area) woodland and open forests. However, woodland forest comprises only 38% of all multiple-use public native forests. Closed forest comprises only 2.6% of the total native forest area, but comprises 6.9% of native forest in nature conservation reserves.

Mallee-form eucalypt, Western Australia.

[30] There is no multiple-use public native forest in the Northern Territory.

[31] 'Future Potential Production Forest' (FPPF) is an area of Crown land in Tasmania for which administration was transferred from the former Forestry Tasmania to the Tasmanian Department of Primary Industries, Parks, Water and Environment (DPIPWE) under *The Forestry Act 2014*. Generally, no native forest harvesting is permitted in FPPF, but after 08 April 2020 FPPF land can be converted to 'Permanent Timber Production Zone' land, subject to Parliament approval and a range of legislated conditions.

Commercial plantations

Commercial plantations are stands of trees of either native or exotic species, created by the regular placement of seedlings or seeds, and managed primarily for commercial wood production (mainly sawlogs, veneer logs and pulplogs). Commercial plantations are identified in the National Plantation Inventory (NPI), and were reported as 'Industrial plantations' in SOFR 2013. Planted trees managed for other purposes, including oil production (e.g. sandalwood oil, eucalyptus oil and tea-tree oil), environmental services or bioenergy, are reported under the 'Other forests' category.

Commercial plantation areas reported in Indicator 1.1a of SOFR 2018 are derived from the most recent update of the National Plantation Inventory spatial dataset, dated June 2015, as reported in *Australian plantation statistics 2016* (ABARES 2016b). The spatial dataset used in *Australian plantation statistics 2016* is in vector format, and conversion of this to the raster (grid) format dataset used in SOFR 2018 resulted in the area figure for Commercial plantations reported in Table 1.1a (1.95 million hectares) being slightly (1.3%) lower than the area figure (1.97 million hectares) reported in *Australian plantation statistics 2016*. More recent tabular data on plantation areas as at June 2016 are available in *Australian plantation statistics 2017 update* (Downham and Gavran 2017) (area of 1.97 million hectares), and as at June 2017 in *Australian plantation statistics 2018* update (Downham and Gavran 2018) (area of 1.96 million hectares), and again differ only slightly from the figures reported here.

Determined from the National Forest Inventory spatial coverage, Australia has 1.95 million hectares of Commercial plantations, accounting for 1.5% of Australia's total forest area (Tables 1.1, 1.2, 1.5 and 1.8). They comprise 1.02 million hectares of softwoods, 0.92 million hectares of hardwoods, and 0.01 million hectares of other, unknown or mixed species. The area of Commercial plantations has decreased slightly over the last 5 years mainly due to plantation land being returned to agriculture or other uses on the expiration of hardwood plantation lease arrangements, and only a small area of new plantation establishment. Plantations deemed non-commercial are reported in the 'Other forest' category. Details of changes in Commercial plantation areas over time are given in *Australian plantation statistics 2016* (ABARES 2016b) and *Australian plantation statistics 2017 update* (Downham and Gavran 2017).

Victoria, Western Australia, New South Wales and Tasmania have the largest areas of commercial plantations, at 0.42 million hectares, 0.38 million hectares, 0.38 million hectares and 0.31 million hectares, respectively, each contributing more than 15% of the total area of Australia's commercial plantations (Tables 1.1 and 1.5). New South Wales, Victoria and Queensland have the highest proportions of Australia's commercial softwood plantation areas (29%, 21% and 19%, respectively). Western Australia, Tasmania and Victoria have the highest proportions of Australia's commercial hardwood plantation area (30%, 25% and 21%, respectively).

The majority of the area of Commercial plantations is on private tenure (57%) and multiple-use public forest (42%) (Table 1.8). Relatively more commercial plantations are on multiple-use public forest in New South Wales, Queensland and South Australia. Nationally, Commercial plantations comprise 7.6% of the area of multiple-use public forest, and 2.6% of the area of private tenure forest.

Taken together, the 'Commercial plantation' category, plus the 'Other forest' category excluding areas of forest dominated by introduced trees established without human intervention, comprise the 'Planted forests' category used by the Food and Agriculture Organization of the United Nations for the Global Forest Resources Assessment[32], and are reported as such in Australia's Country Reports to the five-yearly Global Forest Resources Assessment[33].

Other forest

SOFR 2018 shows that Australia has 0.47 million hectares of 'Other forests'. This National Forest Inventory category includes all forest that is not native forest or commercial plantation, and so comprises mostly non-commercial plantations, planted forests of various types, and non-planted forests dominated by trees of introduced species, none of which are reported through the National Plantation Inventory.

The planted forests in 'Other forests' include environmental plantings, farm forestry and agroforestry plantations (small woodlots typically less than 1000 hectares), sandalwood (*Santalum* spp.) plantations (which are generally not intended for sawlog or fibre production), plantations within the reserve system (such as plantations in New South Wales where the land tenure has changed to nature conservation reserve), and plantations regarded as not commercially viable. Areas of forest dominated by trees of introduced (exotic) species established without human intervention (that is, not planted) are also included in this category.

The largest areas of 'Other forest' are in Victoria (0.16 million hectares) and Western Australia (0.15 million hectares) (Table 1.1), with these states having the largest increases in reported area of 'Other forest' since SOFR 2013. These areas are dominated by plantations not reported in the National Plantation Inventory because they are not deemed to be or not reported to be commercial plantations.

The majority of the 'Other forest' category occurs on private tenure (64%) and multiple-use public forest (19%) (Table 1.8).

32 www.fao.org/forestry/fra/en/
33 www.fao.org/3/a-az156e.pdf

Forest cover in Regional Forest Agreement regions

Regional Forest Agreements (RFAs) were established to provide a framework for sustainable forest management and conservation in regions containing substantial forestry activities. Australia's 10 RFAs cover 11 RFA regions (in New South Wales, the Upper North East and Lower North East regions are covered by a single RFA) and 39.2 million hectares of south-western and south-eastern Australia, and total 5% of Australia's land area (see Introduction). Within these RFA regions, forests cover 21.9 million hectares, which is 16% of Australia's total forest area, and 56% of the total land area of the RFA regions (Table 1.9). The forest area in RFA regions comprises 20.4 million hectares of native forest, 1.2 million hectares of commercial plantations and 0.3 million hectares of 'Other forest'.

The national forest types are not evenly distributed between forest in RFA regions and forest outside RFA regions (Table 1.10). Although only 16% of Australia's forest area is within the RFA regions, these regions contain 92% of the area of Eucalypt tall open forests, and 41% of the area of the Eucalypt medium open forests, which are major wood-production forest types. On the other hand, the RFA regions contain only 1.5% of the area of Acacia forests, and 0.6% of Eucalypt mallee woodland forests. A total of 61% of Australia's commercial plantations is in the RFA regions (Table 1.10).

Similarly, forests on different tenures are not evenly distributed between forest in RFA regions and forest outside RFA regions. Although the combined RFA regions contain 16% of Australia's forest area, they contain 60% of the area of multiple-use public forest, 37% of the area of forest in nature conservation reserves, and 16% of the area of forest on private tenure, but only 0.1% of the area of forest on leasehold land (Table 1.11). This is again consistent with large areas of drier inland forest on private or leasehold tenure not being included in RFA regions.

Across all the RFA regions, 29% of forest is multiple-use public forest, 36% is forest in nature conservation reserve and 30% is forest on private tenure. However, the tenure composition of the forest differs between RFA regions. Three RFA regions in New South Wales (Southern, Upper North East and Lower North East) contain smaller proportions of their area as multiple-use public forest (15%, 18% and 14% respectively), and larger proportions of their areas as either forest in nature conservation reserve (Southern, 47%) or forest on private tenure (Upper North East and Lower North East, 52% and 44% respectively). This contrasts with four RFA regions in Victoria (Central Highlands, East Gippsland, Gippsland and North East), which contain larger proportions of their area as multiple-use public forest (55%, 52%, 53% and 54%, respectively) and smaller proportions of their area as forest on private tenure (17%, 6%, 14% and 12% respectively).

Table 1.9: Areas of forest in Regional Forest Agreement regions, by state

RFA region	Region area ('000 hectares)	Native forest		Commercial plantation		Other forest		Total forest	
		Forest area ('000 hectares)	Proportion of area of RFA region (%)	Forest area ('000 hectares)	Proportion of area of RFA region (%)	Forest area ('000 hectares)	Proportion of area of RFA region (%)	Forest area ('000 hectares)	Proportion of area of RFA region (%)
Eden	814	550	68	41	5	5	1	596	73
Upper North East	3,910	2,297	59	71	2	22	1	2,390	61
Lower North East	5,786	3,404	59	38	1	7	0.1	3,449	60
Southern NSW	4,512	2,510	56	141	3	18	0.4	2,668	59
Total RFA regions in NSW	**15,023**	**8,761**	**58**	**290**	**2**	**52**	**0.3**	**9,104**	**61**
Tasmanian[a]	6,796	3,319	49	310	5	46	1	3,676	54
Total RFA regions in Tasmania[a]	**6,796**	**3,319**	**49**	**310**	**5**	**46**	**1**	**3,676**	**54**
Central Highlands	1,125	699	62	12	1	8	1	719	64
East Gippsland	1,225	1,104	90	6	0.5	2	0.2	1,112	91
Gippsland	2,662	1,480	56	89	3	26	1	1,595	60
North East	2,318	1,281	55	56	2	18	1	1,355	58
West Victoria	5,779	1,074	19	251	4	80	1	1,404	24
Total RFA regions in Victoria	**13,109**	**5,638**	**43**	**412**	**3**	**135**	**1**	**6,185**	**47**
South-West Forest Region of WA	4,257	2,698	63	181	4	41	1	2,920	69
Total RFA regions in WA	**4,257**	**2,698**	**63**	**181**	**4**	**41**	**1**	**2,920**	**69**
Total RFA regions in Australia	**39,185**	**20,416**	**52**	**1,194**	**3**	**274**	**1**	**21,884**	**56**

[a] Areas for Tasmania are derived from the spatial boundary of the Tasmanian RFA region held by ABARES, and differ slightly from the areas derived from the spatial boundary of the state of Tasmania used in other tables.

RFA, Regional Forest Agreement. In NSW, the Upper North East and Lower North East regions are covered by a single RFA.

Note: Totals may not tally due to rounding.

Source: ABARES, National Forest Inventory, National Plantation Inventory.

This table, together with other data for Indicator 1.1a, is available in Microsoft Excel via www.doi.org/10.25814/5bda82c8d76d4

Differences in RFA forest areas reported in SOFR 2013 and in SOFR 2018

The total forest area for each RFA region remained largely unchanged between that reported in SOFR 2013 and that reported in SOFR 2018. The exceptions are the combined Upper and Lower North East RFA regions in New South Wales where the reported forest area in SOFR 2018 is 425 thousand hectares less than that reported in SOFR 2013, and the Southern RFA region in New South Wales where the reported forest area in SOFR 2018 is 63 thousand hectares less.

These changes in reported areas result from the use of new and more accurate datasets (such as SPOT5 FPC and NGGI), and applying the CRAFTI dataset to identify ecosystems that are naturally non-forest, together with validation with high-resolution imagery. This allowed the reclassification to non-forest of areas previously misclassified as forest; there have been only small actual on-ground forest area changes in these RFA regions. Details and examples are given in a subsequent section of this indicator (see Figures 1.8–1.10).

In the Upper and Lower North East RFA regions, the vast majority of the difference in the reported areas derives mainly from reclassification to non-forest of areas of heathlands, shrublands, wetlands and grasslands in coastal ecosystems, and areas of shrubland on western hill slopes. Minor areas of actual, on-ground forest loss derive from loss of woodland forest adjacent to mining areas in the Hunter Valley, and conversion of plantations to grazing land to the east of the Tia River in the northern tablelands.

In the Southern RFA region, the majority of the difference in the reported areas derives from reclassification to non-forest of areas of alpine grasslands, shrublands, sedgelands and heathlands; areas of coastal heathlands, shrublands and grasslands; and areas of tableland heathlands and shrublands.

Table 1.10: Areas of forest in Regional Forest Agreement regions, by forest type

Forest type	Area in RFA regions ('000 hectares)	Area in Australia ('000 hectares)	Area in RFA regions as proportion of area in Australia (%)
Acacia	167	10,813	2
Callitris	128	2,011	6
Casuarina	98	1,236	8
Eucalypt	17,761	101,058	18
Eucalypt mallee open	0.3	842	0.03
Eucalypt mallee woodland	72	12,530	0.6
Eucalypt low closed	26	58	46
Eucalypt low open	220	2,205	10
Eucalypt low woodland	231	8,227	3
Eucalypt medium closed	141	256	55
Eucalypt medium open	8,208	19,783	41
Eucalypt medium woodland	4,572	49,326	7
Eucalypt tall closed	139	140	100
Eucalypt tall open	4,572	4,945	92
Eucalypt tall woodland	439	746	59
Mangrove	4	854	0.5
Melaleuca	146	6,382	2
Rainforest	1,258	3,581	35
Other native forest	854	5,679	15
Total native forest	**20,416**	**131,615**	**16**
Softwood	545	1,015	54
Hardwood	645	922	70
Unknown or mixed species	4	11	33
Total Commercial plantation[a]	**1,194**	**1,949**	**61**
Other forest	**274**	**474**	**58**
Total forest	**21,884**	**134,037**	**16**

RFA, Regional Forest Agreement.

[a] Determined from the National Forest Inventory spatial coverage. See footnote on Commercial plantation areas under Table 1.1.

Note: Totals may not tally due to rounding.

Source: ABARES, National Forest Inventory, National Plantation Inventory.

This table, together with other data for Indicator 1.1a, is available in Microsoft Excel via www.doi.org/10.25814/5bda82c8d76d4

Table 1.11: Areas of forest by tenure in Regional Forest Agreement regions, by state

	Area ('000 hectares)						
RFA region	Leasehold forest	Multiple-use public forest	Nature conservation reserve	Other Crown land	Private forest	Unresolved tenure	Total forest
Eden	1	204	251	7	134	0.3	596
Upper North East	13	428	631	61	1,252	5	2,390
Lower North East	10	489	1,320	101	1,525	6	3,449
Southern NSW	13	411	1,266	85	887	5	2,668
Total RFA regions in NSW	**36**	**1,532**	**3,467**	**254**	**3,797**	**17**	**9,104**
Tasmanian[a]	0	733	1,532	380	1,032	0	3,676
Total RFA regions in Tasmania[a]	**0**	**733**	**1,532**	**380**	**1,032**	**0**	**3,676**
Central Highlands	0	398	179	21	121	0	719
East Gippsland	0	580	455	5	72	0	1,112
Gippsland	0	845	481	41	229	0	1,595
North East	0	733	412	42	168	0.1	1,355
West Victoria	0	302	475	83	544	0.1	1,404
Total RFA regions in Victoria	**0**	**2,859**	**2,001**	**191**	**1,134**	**0**	**6,185**
South-West Forest Region of WA	17	1,250	950	49	654	0	2,920
Total RFA regions in WA	**17**	**1,250**	**950**	**49**	**654**	**0**	**2,920**
Total RFA regions	**53**	**6,373**	**7,950**	**874**	**6,617**	**17**	**21,884**
Proportion of total forest in RFA regions (%)	**0.2**	**29**	**36**	**4**	**30**	**0**	**100**
Proportion of area of that tenure in all Australia's forests (%)	**0.1**	**60**	**37**	**8**	**16**	**2**	**16**

RFA, Regional Forest Agreement.

[a] Areas for Tasmania are derived from the spatial boundary of the Tasmanian RFA region held by ABARES, and differ slightly from the areas derived from the spatial boundary of the state of Tasmania used in other tables.

Note: Totals may not tally due to rounding.

Source: ABARES, National Forest Inventory, National Plantation Inventory.

This table, together with other data for Indicator 1.1a, is available in Microsoft Excel via www.doi.org/10.25814/5bda82c8d76d4

Change in total forest cover over time

The NFI forest cover dataset reported in the five reports in the SOFR series (from SOFR 1998 to SOFR 2018) provides the best available and most accurate representation of Australia's forest extent at the time of each publication. However, the methodology used for collecting forest area data, and for compiling the data into a single national dataset, has improved substantially through the SOFR series. The continual improvements in the accuracy and resolution of the input datasets mean that comparison of the total forest area figures published in different SOFRs cannot be used to measure actual, on-ground change in forest area over time.

The change between the forest area reported in SOFR 2013 and that reported in SOFR 2018 (Table 1.14) is therefore a combination of improvements in the forest area datasets and analysis methods (Figures 1.8–1.10, below), and on-ground change in forest cover (Figures 1.11–1.13).

The best quantitative measure of the actual change over time in Australia's total forest area is obtained from the annual forest area figures produced for the National Greenhouse Gas Inventory (NGGI) for the purposes of calculating net emissions from forest lands (see Indicator 5.1a). These figures are published by the Australian Government Department of the Environment and Energy (DoEE) in annual National Inventory Reports (NIRs). The NGGI area figures are derived from a remotely sensed Landsat satellite dataset that has been collected consistently since 1972, and analysed using a national methodology, thus giving a time-consistent dataset that allows calculation of forest area change over time.

The most recent NGGI data (from the National Inventory Report 2016, Volume 2; DoEE 2018a) were used to determine figures for forest area change over time (Figure 1.5a). Those change figures were then applied to Australia's total forest area of 134.0 million hectares as at June 2016, to show the best estimate of the trend over time in Australia's total forest area since 1990 (Figure 1.5b).

These data show that there was a gradual decline in Australia's forest area through the 1990s continuing until approximately 2008. This decrease was driven by a greater extent of land clearing than regrowth or plantation establishment. However, since 2008 Australia's forest area has increased, with a net increase of 3.9 million hectares between 2011 and 2016, the reporting period for SOFR 2018. This increase was driven by an increase in the regrowth of cleared forest and a slowing in the rate of first-time forest clearing (Figure 5.3, Indicator 5.1a), together with an expansion of forest onto previously cleared areas, and establishment of environmental plantings and commercial plantations.

Improvements in NGGI data

There have been substantial improvements in the methodologies and algorithms used to produce the forest area change figures for Australia's NGGI since the forest area change figures reported in SOFR 2013. The improved methodologies and algorithms are described in Volume 2 of various National Inventory Reports (DoE 2015, DoEE 2017d, DoEE 2018a), and include:

- Improvements in processing of remotely sensed data, and adoption of a new, 3-class algorithm to determine the boundary between woodland forest and sparse woodland (a non-forest category).
- Inclusion only of human-induced change in forest area due to permanent alterations in land use or land cover, without incorporating short-term (transient) changes in forest area or canopy cover due to natural events such as dieback, drought, cyclone damage and subsequent regrowth, wildfire and subsequent regrowth, or forest harvesting and regeneration. This identification only of long-term changes in forest cover is consistent with the definition of forest used in the NFI.
- Identification and inclusion of the natural expansion of forest onto land that did not carry forest in 1972.

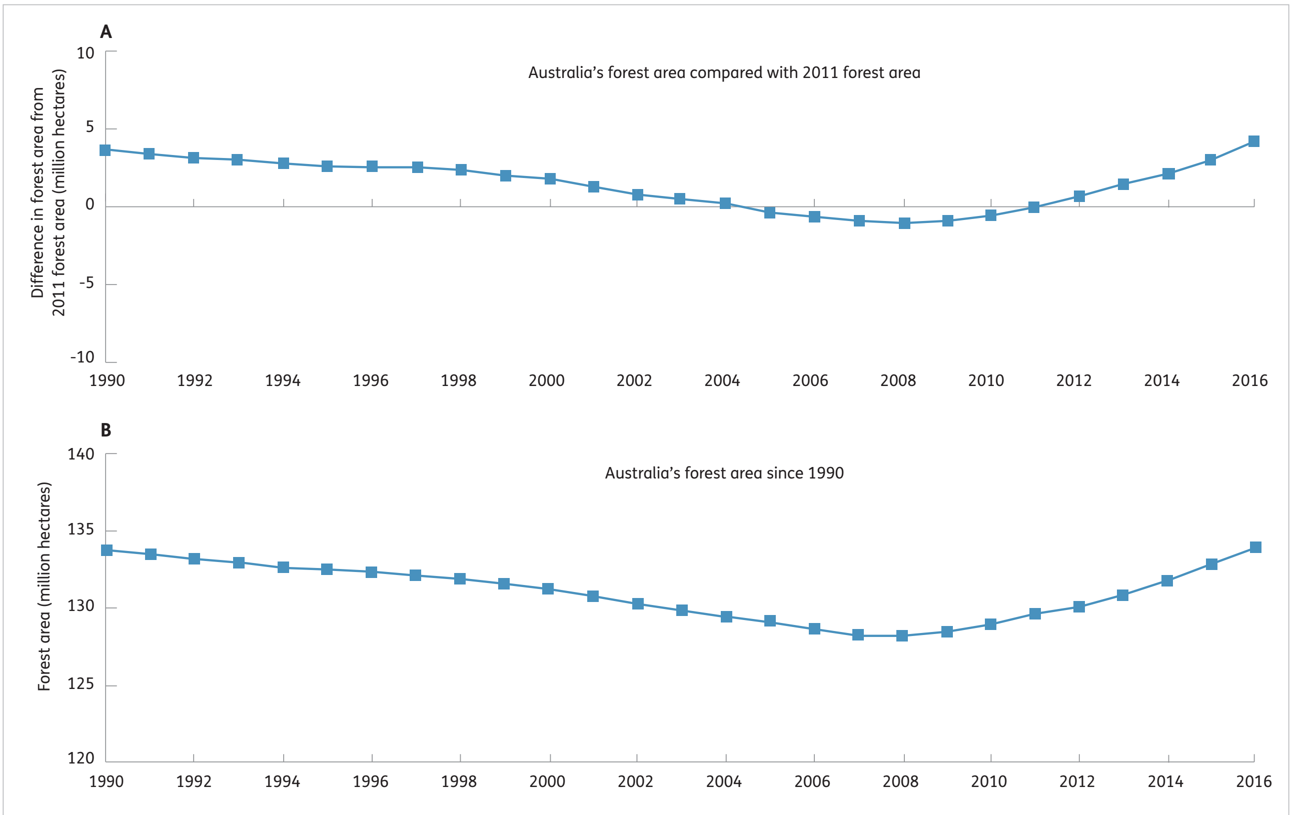
Each of these improvements is applied to the entire time-series of Landsat data. This allows the time-series to continue to be used for determination of forest area changes over time.

These improvements have also resulted in the total forest area reported in the NGGI data for 2016 (138.9 million hectares; DoEE 2018a) being similar to the total forest area reported for 2016 in SOFR 2018 through the NFI (134.0 million hectares; Table 1.1). This is the case even though the two spatial coverages differ, being derived from different datasets (Landsat satellite data for the NGGI, and multiple datasets for the NFI: see Table 1.12).

Forest clearing and regrowth

The NGGI data on the extent of forest clearing, regrowth and reclearing, for land on which clearing has occurred at some point since 1972, and published in Volume 2 of National

Figure 1.5: Australia's forest area change over time



Source: **A**, calculated by ABARES from data in the *National Inventory Report 2016* (DoEE 2018a). The forest area as at June 2011 is set at zero as this date is the start of the SOFR 2018 five-year reporting period. **B**, calculated by applying the change data in **A** to Australia's total forest area of 134.0 million hectares (Table 1.1).

These figures include data on annual clearing, regrowth and reclearing (Figure 5.3), plus data on the expansion of native forest onto areas that did not carry forest in 1972, and establishment of plantations and environmental plantings.

The data used to create this figure, together with other data for Indicator 1.1a, are available in Microsoft Excel via www.doi.org/10.25814/5bda82c8d76d4

Inventory Report 2016 (DoEE 2018a), were assembled to underpin calculations of greenhouse gas emissions by the Land-use, Land-Use Change and Forestry sector[34]. The time-series of annual forest area changes due to clearing, regrowth and reclearing is shown in Indicator 5.1a, Figure 5.3. For the NGGI dataset, 'clearing' includes clearing of native forest that has grown on previously cleared land, and harvesting of plantations that are not replanted; and 'regrowth' includes regrowth of native forests on cleared land.

For the period 2011–16, the NGGI data show:

- first-time clearing of 0.29 million hectares of forest
- regrowth of 2.69 million hectares of forest on land that has been cleared at some point since 1972
- re-clearing of 1.86 million hectares of forest that has regrown on land cleared at some point since 1972 (giving a total of 2.16 million hectares of forest cleared), and
- a net increase of 0.53 million hectares of forest due to clearing, regrowth and reclearing.

In the year 2015–16, the NGGI data show:

- first-time clearing of 60 thousand hectares of forest
- regrowth of 564 thousand hectares of forest on land that has been cleared at some point since 1972
- re-clearing of 395 thousand hectares of forest that has regrown on land cleared at some point since 1972 (giving a total of 455 thousand hectares of forest cleared), and
- a net increase of 108 thousand hectares of forest due to clearing, regrowth and reclearing.

However, these data on clearing, regrowth and reclearing do not equate to the total net change in Australia's forest area over this period, as they do not take account of forest expansion (which occurs when native forests grow on land that did not carry forest in 1972) or the smaller areas of newly established plantations and environmental plantings. Over the period 2011–16, the total area of forest expansion plus establishment of plantations and environmental plantings was 3.38 million hectares.

Summing these area changes for the period 2011–16 gives a total increase in Australia's total forest area over this period of 3.9 million hectares, as reported in Figure 1.5.

[34] Figure 6.5a of *National Inventory Report 2016 Volume 2* shows gross annual clearing and reclearing area data, as presented in Indicator 5.1a, Figure 5.3. However, Figure 6.5b of *National Inventory Report 2016 Volume 2* shows cumulative regrowth area data after accounting for any reclearing of that regrowth, and those area data are therefore different to the gross regrowth areas presented in Indicator 5.1a, Figure 5.3.

Forest mapping for SOFR 2018

Continual improvement in measuring the extent of Australia's forests, and in the reporting of forest area, has occurred since national figures were first reported in 1974 (Forwood 1975). Australia's reported forest area has fluctuated between 105 million hectares and 164 million hectares since that date. These historic fluctuations in reported areas did not represent actual changes in on-ground forest cover, but instead were largely due to changes in the area basis reported (from only commercial forests to all forests), changes prior to 1998 in the definition of forest, variability in state and territory data, correction of mapping errors, the progressive incorporation of a variety of remotely sensed datasets, and recent validation with high-resolution aerial and satellite imagery.

At 134.0 million hectares, Australia's forest area reported in SOFR 2018 differs from the forest area of 124.8 million hectares reported in SOFR 2013. The majority of this difference reflects the incorporation of new and updated data for all states and territories, delivered as a result of technological advances, including greater coverage of recent high-resolution imagery for validation of areas as forest or non-forest where confidence in other input datasets was low. The SOFR 2018 area statement also incorporates some updates due to on-ground change in forest cover over time when this is detected with the new datasets and imagery.

The Multiple Lines of Evidence process

A Multiple Lines of Evidence (MLE) process was used by ABARES to examine and combine forest cover data from multiple sources to produce the forest cover data reported in SOFR 2018. Appropriate independent datasets were intersected using analytical spatial (GIS) software, and the outputs validated using high-resolution aerial and satellite imagery. Input datasets for the MLE process included forest cover data sourced from relevant state or territory agencies, forest cover data from other national programs such as the National Greenhouse Gas Inventory (NGGI), and the forest cover dataset developed for SOFR 2013. Table 1.12 lists these datasets.

Forest of *Eucalyptus regnans* (mountain ash), Victoria.

Table 1.12: Key MLE input datasets

Dataset	Description
Forests of Australia (2013) v2.0	Forests of Australia (2013) v2.0 is an updated version of the forest cover dataset that was used in SOFR 2013. It is a continental dataset of forest extent by national forest categories and types, and was developed by a Multiple Lines of Evidence process from multiple forest, vegetation and land cover spatial data inputs, including contributions from relevant Australian, state and territory government agencies and external sources.
Landsat Foliage Projective Cover – Queensland; also known as QLD State-wide Land and Tree Study (SLATS), 2014–15.	The Queensland government SLATS method calculates Foliage Projective Cover (FPC) values from Landsat satellite Thematic Mapper™ and Enhanced Thematic Mapper Plus (ETM+) images. ABARES uses an empirically derived relationship between FPC and crown-cover values (Scarth et al. 2008) to delineate the landscape into forest and non-forest areas (an FPC of 11% is approximately equivalent to a crown cover of 20%). The SLATS dataset is produced at 30 m × 30 m resolution, and is supported by extensive on-ground validation. The dataset covers the whole of Queensland, was developed to support land-clearance legislation and monitoring of change, and is frequently updated using a consistent methodology and data source (data.qld.gov.au/dataset/statewide-landcover-and-trees-study-queensland-series)
NGGI 2016	NGGI datasets are produced from Landsat satellite Thematic Mapper™, Enhanced Thematic Mapper Plus (ETM+) and Operational Land Image (OLI) images for the Australian Government Department of the Environment and Energy, and identifies woody vegetation of height or potential height greater than 2 metres, crown cover greater than 20%, and with a minimum patch size of 0.2 hectares (DoEE 2017d). The dataset is compiled using time-series data since 1972, and is produced at a 25 m × 25 m resolution. It was designed for national carbon accounting and for monitoring changes in Kyoto-compliant forests over long time-periods, and is updated annually using a consistent methodology and data source. The NGGI dataset used was the 2016 data from the 'Woody Extent & Change (version 1.0)' spatial dataset from the Australian Government Department of the Environment and Energy, published in March 2017, which was produced using the algorithms for land-use change allocation developed for the *National Inventory Report 2015* (DoEE 2017d).
SPOT5 Foliage Projective Cover (FPC) – New South Wales; also known as the NSW SLATS 2012	The New South Wales Foliage Projective Cover (FPC) dataset is derived from Satellite Pour l'Observation de la Terre 5 (SPOT5) High Resolution Geometric satellite imagery, using the SLATS methodology described in Scarth et al. (2008). The SPOT5 FPC product used to derive forest cover is produced at 5 m x 5 m resolution. ABARES uses an empirically derived relationship between FPC and crown cover values (Scarth et al. 2008) to delineate the landscape into forest and non-forest areas (an FPC of 11% is approximately equivalent to a crown cover of 20%). The dataset is supported by extensive on-ground validation, and covers the whole of New South Wales. It was developed to support land-clearance legislation and monitoring of change, and is frequently updated using a consistent methodology and data source (datasets.seed.nsw.gov.au/dataset/nsw-woody-vegetation-extent-fpc-20119bb42)
Persistent Green-Vegetation Fraction (PGVF) (TERN)	PGVF is a national Foliage Projective Cover (FPC) dataset derived from Landsat 5 TM and Landsat 7 ETM+ satellite imagery using an algorithm developed by the Terrestrial Ecosystem Research Network (TERN) (www.auscover.org.au/xwiki/bin/view/Product+pages/Persistent+Green-Vegetation+Fraction)
Catchment Land Use Mapping (CLUM) 2017 land-use mask	The CLUM land-use mask was used to exclude from the MLE forest cover dataset land uses deemed to be not suitable to carry forests, for example urban residential, industrial, mining, horticulture and intensive agriculture. CLUM dataset is produced by ABARES.
NPI 2016 spatial dataset	NPI data were used to identify the area of Commercial plantations. The spatial vector dataset was converted to a raster format before being integrated with the MLE forest cover raster dataset. The NPI dataset is produced by ABARES.
Google Earth Pro and Bing Maps	The most recent high-resolution imagery from Google Earth Pro and Bing Maps were used for validation of forest and non-forest allocation in areas where confidence in other datasets was low.
Qld 2007–2016 Land Clearing dataset	This dataset is produced by the Queensland government for the purposes of tracking vegetation clearing in the state. It was used by the NFI to identify and classify as non-forest cleared areas that would otherwise have been incorrectly reported as forest in SOFR 2018.
ACT 2016 Vegetation Map	This spatial vegetation dataset, including forest cover, was provided by the Australian Capital Territory government for use in SOFR 2018.
Western Australia South West Forest Management Area dataset	This spatial forest cover dataset was provided by the Western Australia government for use in SOFR 2018. The dataset covers only the south-west region of the state.
Tasmania 2016 Forest Cover	This statewide forest cover dataset was provided by the Tasmanian government for use in SOFR 2018.
Victoria SOFR 2013 Forest Cover dataset	This spatial forest cover dataset (developed for the Victorian SOFR 2013) was provided by the Victorian government for use in the national SOFR 2018. It was developed for Victoria's SOFR 2013 from Landsat satellite data using Victoria's Machine Learning Algorithm.
NSW CRAFTI Upper and Lower North East (1999), Eden CRA Forest Ecosystems (1998) and Southern CRA Forest Ecosystems (2000)	These datasets, developed for the Comprehensive Regional Assessment (CRA) process, were used to delineate and mask naturally treeless areas (grasslands, heathlands and shrublands). Such areas are often classified as tree cover by remote-sensing datasets including SLATS and NGGI.

CLUM, Catchment Scale Land Use of Australia – Update September 2017[35]; CRA, Comprehensive Regional Assessment; CRAFTI, Comprehensive Regional Assessment Aerial Photographic Interpretation; FPC, Foliage Projective Cover; MLE, Multiple Lines of Evidence; NFI, National Forest Inventory; NGGI, National Greenhouse Gas Inventory; NPI, National Plantation Inventory; NIR, National Inventory Report; SPOT, Satellite Pour l'Observation de la Terre.

Note: Forest area, cover and extent are used interchangeably in this work.

[35] data.gov.au/dataset/catchment-scale-land-use-of-australia-update-2017

In the MLE process, intersection of the datasets identifies areas where datasets agree on the allocation of land as forest or non-forest. For areas for which the datasets disagree, allocation as forest or non-forest is made through an assessment of the accuracy and/or currency of individual datasets, through using ancillary data from the National Vegetation Information System, and through validation with recent high-resolution aerial and satellite imagery. Validation also involves input from and checking by the relevant state and territory agencies. The product from the most recent MLE process is a 100-m resolution forest/non-forest binary raster (grid) at 100 metre resolution (each cell or pixel thus being 1 hectare in area), and is the NFI forest cover dataset as at June 2016 that is used for reporting in SOFR 2018.

Attribution of the forest area dataset for SOFR 2018

The updated forest cover dataset is given a number of attributes, most important being forest type and tenure. The datasets used for this attribution are described in Table 1.13.

Forest area differences between SOFR 2013 and SOFR 2018

Australia's forest area determined by the above MLE process for SOFR 2018 was 134 million hectares, which is 9.3 million hectares (7.4%) greater than the forest area reported in SOFR 2013 (Table 1.14). This increase occurred for all jurisdictions excepting New South Wales and Tasmania, but the majority of the increase (8.5 million hectares, 92%) was in the Northern Territory. The majority of these area differences do not reflect actual changes of forest area (whether gain or loss), but instead reflect improved forest cover data, and improved coverage of the high-resolution aerial and satellite imagery used for validation.

This net increase in reported area of 9.3 million hectares is the sum of 16.1 million hectares identified as forest for SOFR 2018 that was reported as non-forest in SOFR 2013, and 6.8 million hectares that was been reported as forest in SOFR 2013 but identified as non-forest for SOFR 2018 (Table 1.14). These changes are generally driven by different factors in the different jurisdictions.

Table 1.13: Data sources for forest area attribution

Parameter	Data sources	Notes
Forest type	• NPI 2016, then • TASVEG, or ACT 2016 Vegetation Map, then • NVIS 5.0 or Forests of Australia (2013) v2.0, as used for SOFR 2013	A hierarchical approach was used to derive and allocate NFI forest types to the NFI 2016 forest cover dataset in the following order as applicable: 1. the NPI 2016 spatial dataset was used to allocate types to Commercial plantations 2. native forest types were allocated as follows: • Tasmania, from floristics information in TASVEG • ACT, from floristics information in the ACT 2016 Vegetation Map • for Victoria, and NSW Lower and Upper North East RFA regions, from SOFR 2013 forest cover dataset 'Forests of Australia (2013) v2.0' (and from NVIS 5.0 where appropriate information could not be derived from SOFR 2013 dataset) • for all other states and territories, from Major Vegetation Subgroup (MVS), Major Vegetation Group (MVG), Level V and Level VI categories of the NVIS 5.0 dataset. 3. where forest types could not be allocated from the above sources, forest types used in the SOFR 2013 forest cover dataset were allocated 4. any remaining native forest areas not allocated a forest type were allocated as "Other native forest". Planted forest areas not allocated a type were also allocated as "Other forest".
Forest tenure	• Jurisdictional land tenure datasets from relevant land titles registries and spatial data agencies • National land tenure data from PSMA Australia Limited • Australian Government Department of Defence • Tenure of Australia's Forests (2013) v2.0, as used for SOFR 2013	The process to allocate tenure categories to the NFI 2016 forest cover dataset used a combination of national tenure information from PSMA, data from the Australian Government Department of Defence, and data from all jurisdictions except South Australia. Data sources used for each jurisdiction were prioritised based on the assessed accuracy of each dataset.
Forest height and cover	• NVIS 5.0 • ACT 2016 Vegetation Map • Tasmania 2016 Forest Cover • SOFR 2013	

NFI, National Forest Inventory; NPI, National Plantation Inventory; NVIS, National Vegetation Information System; PSMA, PSMA Australia Ltd; TASVEG, Tasmanian Vegetation Monitoring and Mapping Program.

Table 1.14: Forest area differences between SOFR 2013 and SOFR 2018

Jurisdiction	SOFR 2013 Area ('000 ha)	SOFR 2018 Area ('000 ha)	SOFR 2018 difference from SOFR 2013 Area ('000 ha)	SOFR 2018 difference from SOFR 2013 % of SOFR 2013 area	Non-forest in SOFR 2013 but forest in SOFR 2018 Area ('000 ha)	Non-forest in SOFR 2013 but forest in SOFR 2018 % of total	Forest in SOFR 2013 but non-forest in SOFR 2018 Area ('000 ha)	Forest in SOFR 2013 but non-forest in SOFR 2018 % of total	Forest in SOFR 2013 and forest in 2018 Area ('000 ha)	Forest in SOFR 2013 and forest in 2018 % of SOFR 2013 area	Forest in SOFR 2013 and forest in 2018 % of SOFR 2018 area
ACT	139	142	4	3	9	0.1	6	0.1	133	96	93
NSW	22,682	20,368	-2,314	-10	343	2	2,657	39	20,024	88	98
NT	15,207	23,735	8,528	56	9,293	58	765	11	14,442	95	61
Qld	51,036	51,830	795	2	3,017	19	2,222	33	48,814	96	94
SA	4,563	5,060	496	11	595	4	99	1.4	4,464	98	88
Tas.	3,706	3,699	-8	-0.2	96	0.6	104	1.5	3,603	97	97
Vic.	8,192	8,222	30	0.4	629	4	599	9	7,593	93	92
WA	19,223	20,981	1,758	9	2,140	13	382	6	18,841	98	90
Australia	**124,748**	**134,037**	**9,289**	**7**	**16,123**	**100**	**6,834**	**100**	**117,915**	**95**	**88**

This table, together with other data for Indicator 1.1a, is available in Microsoft Excel via www.doi.org/10.25814/5bda82c8d76d4

Table 1.14 also shows that, nationally, 118 million hectares reported as forest in SOFR 2013 (95% of the SOFR 2013 forest area) is again reported as forest in SOFR 2018. Furthermore, both nationally and in all jurisdictions with the exception of the Northern Territory, 88% or more of the area reported as forest in SOFR 2018 was also as reported as forest in SOFR 2013. These results give a high level of confidence in the areas classified as forest by the MLE process, and demonstrate the improved consistency that the MLE methodology has brought to the mapping of Australia's forest cover.

Identification of additional forest areas in northern Australia

The largest area identified as forest for SOFR 2018 that had been reported as non-forest in SOFR 2013 is in the Northern Territory (9.3 million hectares). Allocation of these areas as non-forest for SOFR 2013 was driven by the absence of datasets delineating areas of tree cover within otherwise large NVIS polygons, and by the poor coverage at that time of high-resolution imagery. The availability of Foliage Projective Cover (FPC) data from the Persistent Green-Vegetation Fraction dataset produced by TERN, the 2015 NGGI forest cover dataset, and supporting high-resolution imagery (Bing Maps and Google Earth Pro), has enabled delineation of these areas as forest for reporting in SOFR 2018.

Figure 1.6 shows the extent of the additional forest areas identified across the Northern Territory, and Figure 1.7 tracks the reallocation of non-forest to forest of an example area in the Northern Territory.

These new datasets also account for much of the additional 2.1 million hectares in Western Australia that were reported as non-forest in SOFR 2013 but identified as forest for SOFR 2018. Similarly, in Queensland, a total of 3.0 million hectares were reported as non-forest in SOFR 2013 but identified as forest for SOFR 2018 as a result of new data from the Landsat FPC dataset (as the Queensland State-wide Land and Tree Study (SLATS) dataset) and the 2015 NGGI forest cover dataset, supported by validation using recent high-resolution imagery.

Reallocation to non-forest of areas previously reported as forest, and to forest of areas previously reported as non-forest

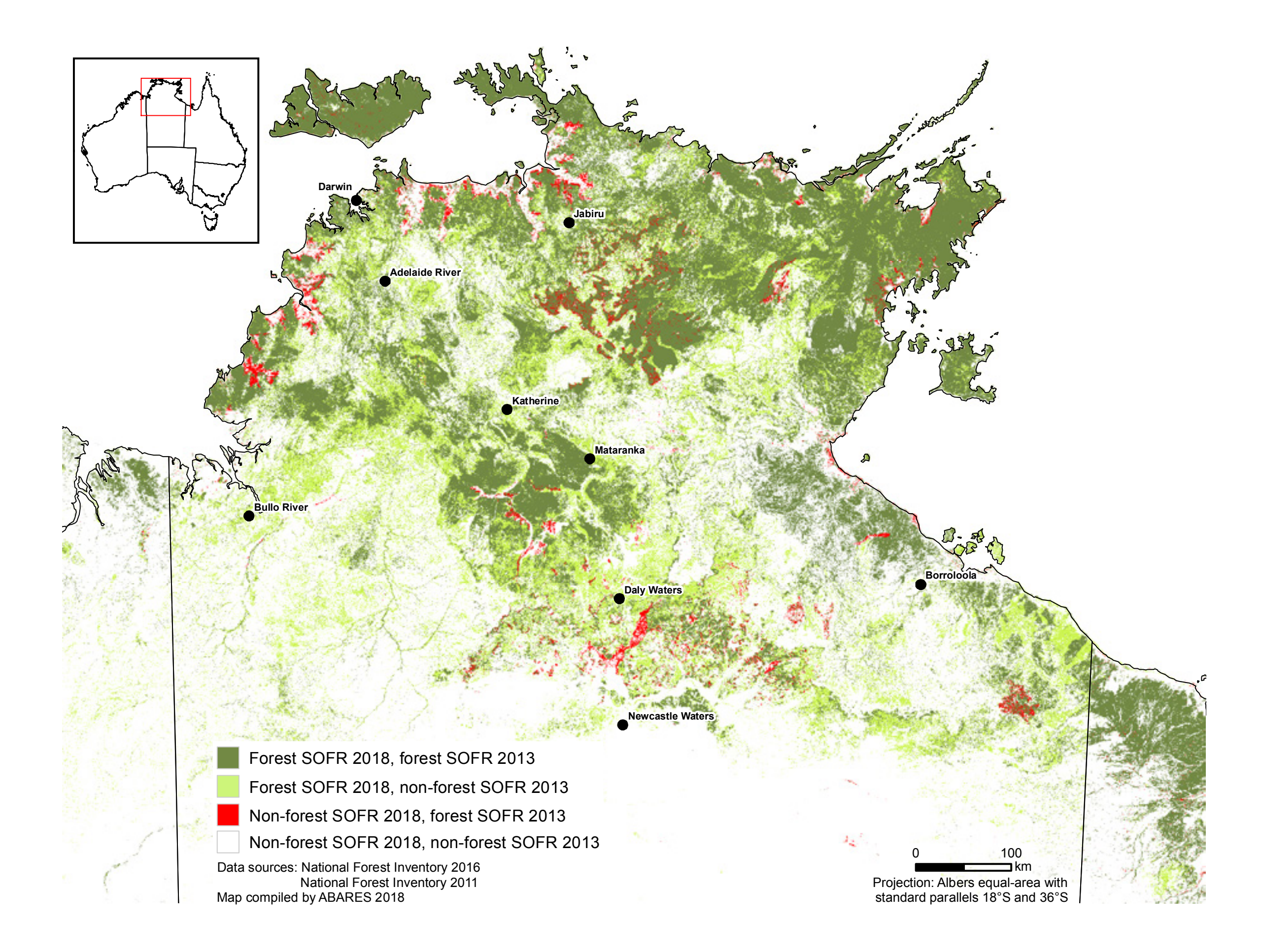
Access to a wider range of datasets, more accurate datasets, and high-resolution imagery, identified areas that were incorrectly mapped in SOFR 2013. Also identified were areas mapped as forest in SOFR 2013 but reported as non-forest in SOFR 2018, and where clearing of forest has occurred since the SOFR 2013 reporting period. It was more difficult to identify specific areas that were mapped as non-forest in SOFR 2013 but are reported as forest in SOFR 2018 specifically due to forest regrowth or forest expansion, probably because transitions from non-forest to forest are generally gradual, whereas transitions from forest to non-forest are generally abrupt.

Firstly, reallocation as non-forest of areas incorrectly mapped as forest in SOFR 2013 occurred for naturally treeless areas (grasslands, heathlands and shrublands) in coastal and alpine landscapes, mostly in RFA regions (see section above); areas of historical land clearing in New South Wales and Queensland; and areas of historical urban, mining and residential development (see Figures 1.8–10).

Secondly, reallocation to non-forest due to clearing of forest during the reporting period of SOFR 2018 occurred due to agriculture, mining or urban residential development (see Figures 1.11–13). A more detailed national view of the extent of forest clearing is covered in Indicator 5.1a (see above and Figure 5.3).

The largest areas reported as forest in SOFR 2013 but identified as non-forest in SOFR 2018 are in New South Wales (2.7 million hectares) and Queensland (2.2 million hectares). In New South Wales, this is due to incorporation of FPC data from the SPOT5 (Satellite Pour l'Observation de la Terre 5) dataset, and the 2015 NGGI forest cover data, as well as better coverage of high-resolution imagery, considered alongside the late 1990s and early 2000s Comprehensive Regional Assessments (CRA) datasets. In Queensland, this is due to incorporation of FPC data from the SLATS dataset, the 2015 NGGI forest cover data, and the Queensland 2007–2016 Land Clearing dataset, as well as the improved availability of high-resolution imagery.

Figure 1.6: Differences between forest mapping in SOFR 2018 and SOFR 2013 in the northern part of the Northern Territory



A higher resolution version of this map is available via www.doi.org/10.25814/5be3bc4321162

Three examples (Figures 1.8–1.10) are provided for areas of forest incorrectly reported as forest in SOFR 2013 that have been reallocated to non-forest in SOFR 2018.

The Upper and Lower North East CRA, Southern CRA and Eden CRA datasets, supported by high-resolution imagery, were used to identify ecosystems in New South Wales that do not support tree cover and that were incorrectly classified as forest in the SOFR 2013 dataset but are correctly classified as non-forest for SOFR 2018. These included ecosystems described as natural grasslands, herblands, sedgelands or rushlands, occurring both along the New South Wales coast and in alpine areas (see section above), and are mainly in RFA regions of New South Wales. Figures 1.8 and 1.9 track the reallocation of forest to non-forest for two example areas.

In the coastal areas of Queensland, the NVIS 5.0 dataset was used to identify non-forest ecosystems incorrectly classified as forest in the SOFR 2013 dataset, and that are correctly classified as non-forest for SOFR 2018. These include ecosystems described as in NVIS 5.0 as natural grasslands, herblands, sedgelands or rushlands and shrublands.

In New South Wales, the SPOT5 and NGGI datasets identified areas of isolated trees and green pastures in grazing landscapes (in the Upper Hunter, Namoi and Border Rivers-Gwydir Natural Resource Management (NRM) regions) that were reported as forest in SOFR 2013. The SPOT5 dataset, and inspection of new and historical high-resolution imagery, identified cleared forest areas in the Western NRM region of New South Wales with complex vegetation management regimes involving various intensities of tree clearing followed by periods of regrowth; these areas were reported as forest in SOFR 2013 but classified as non-forest in SOFR 2018. It is not yet clear how the land management regime in these systems (cycles of clearing followed by regrowth: see Figure 5.3) affects their long-term status as forest or non-forest.

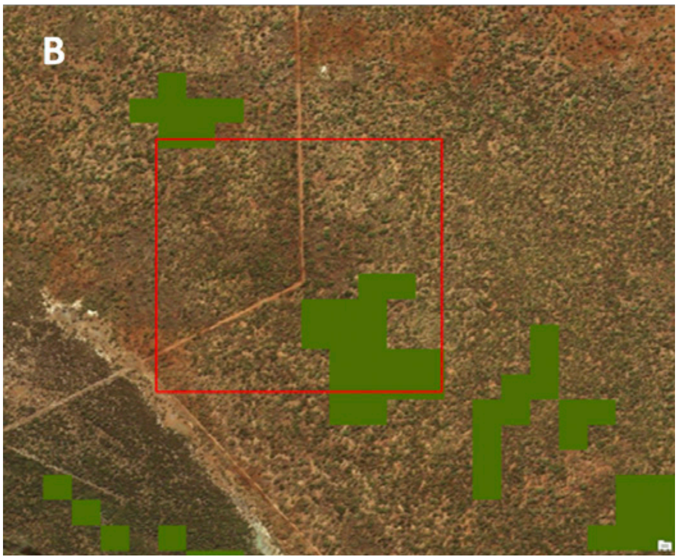
In Queensland, the SLATS FPC dataset and the 2015 NGGI forest cover dataset, supported by the Queensland Land Clearing dataset (2007–2016) and new and historical high-resolution imagery, identified areas reported as forest in SOFR 2013 that were classified as non-forest in SOFR 2018. Significant areas of cleared forest were identified mainly in inland Queensland NRM regions including Northern Gulf (Gilbert River), Burdekin, Fitzroy, Maranoa Balonne and Border Rivers and South West Queensland. Clearing in the Maranoa Balonne and Border Rivers NRM and the South West Queensland NRM shows complex vegetation management regimes involving various intensities of tree clearing followed by periods of regrowth, similar to clearing in western New South Wales as discussed above.

Figure 1.7: Example of an area reported as non-forest in SOFR 2013 but as forest in SOFR 2018 due to new datasets and high-resolution imagery. Mataranka, central Northern Territory. Area in image **A** is shown in red square on images **B** and **C**. Individual mid-green and pale-green squares on images **B** and **C** have an area of 1 hectare (100 m x 100 m).

A High-resolution Google Earth Pro imagery (2016).

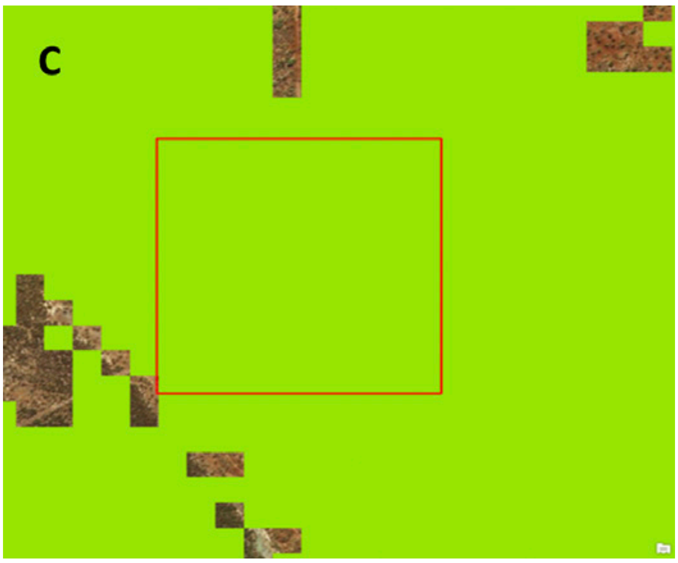
NVIS Major Vegetation Subgroup (MVS) for this area is 'Eucalyptus woodlands with a tussock grass understorey'. Upper stratum tree height code is '7' indicating a height range of 10–30 m, and cover code is 'i' indicating a crown cover range of 20–50%. Both codes are consistent with allocation of the area as forest, validated by imagery.

Area in this image is shown in red square on images **B** and **C**.



B Bing Maps imagery (circa 2011). Mid-green squares, areas reported as forest in SOFR 2013.

Red square in this image shows area depicted in image **A**. Large areas of woodland forest were incorrectly reported as non-forest in SOFR 2013.

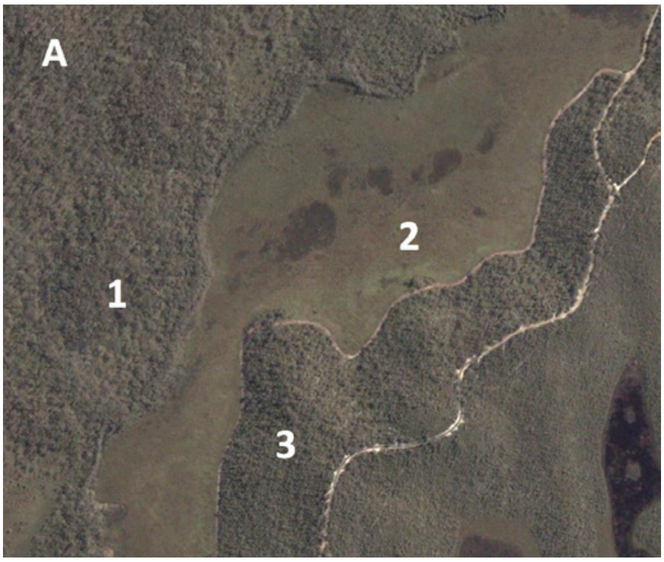


C Bing Maps imagery (circa 2011). Pale green squares, areas reported as forest in SOFR 2018.

Reclassification of areas to forest supported by NGGI 2015 and TERN PGF datasets in conjunction with NVIS data and high-resolution imagery.

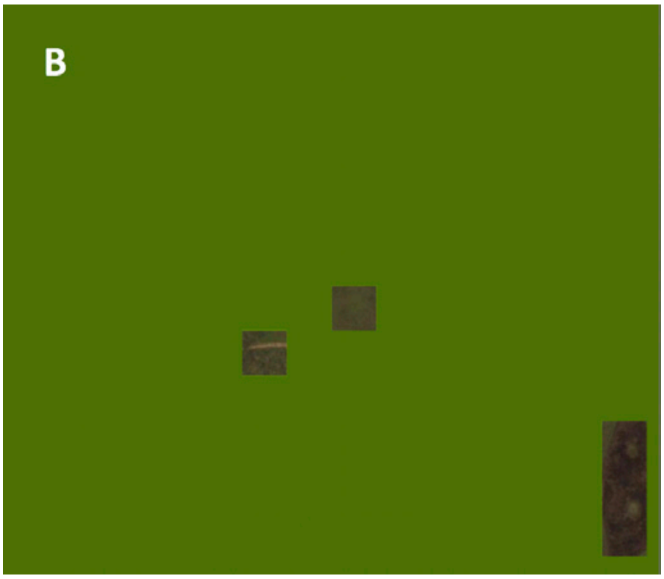
Red square in this image shows area depicted in image **A**.

Figure 1.8: Example of an area reported as forest in SOFR 2013 but as non-forest in SOFR 2018 due to better floristics information and high-resolution imagery. Evans Head, north coast New South Wales. Individual mid-green and pale green squares on images **B** and **C** have an area of 1 hectare (100 m x 100 m).



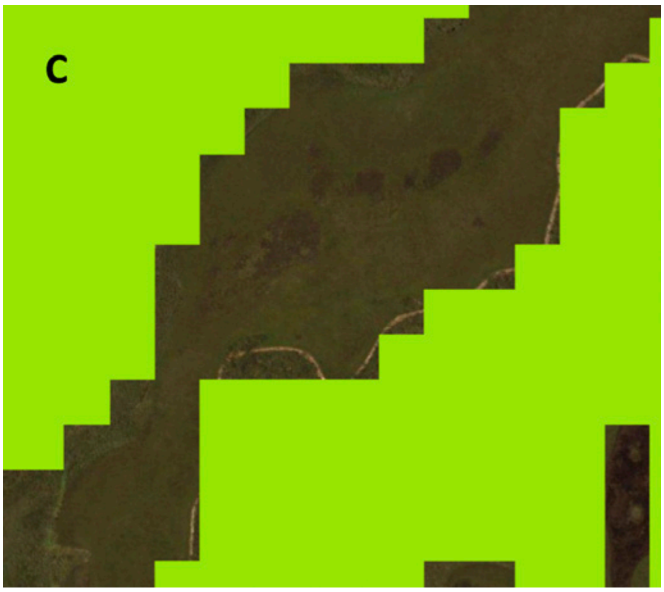
A High-resolution Google Earth Pro imagery (2013), showing areas of heath, shrub and sedge within the wider forest landscape.

NVIS Major Vegetation Subgroup (MVS) for area 1 is 'Eucalyptus open forests with fine shrubby understorey', for area 2 is 'Heathlands', and for area 3 is 'Eucalyptus tall open forest with a shrubby understorey'. Upper stratum tree height and cover codes are consistent with forest in areas 1 and 3 but not area 2.



B Bing Maps imagery. Mid-green squares, areas reported as forest in SOFR 2013.

Areas of heathlands were incorrectly reported as forest in SOFR 2013.



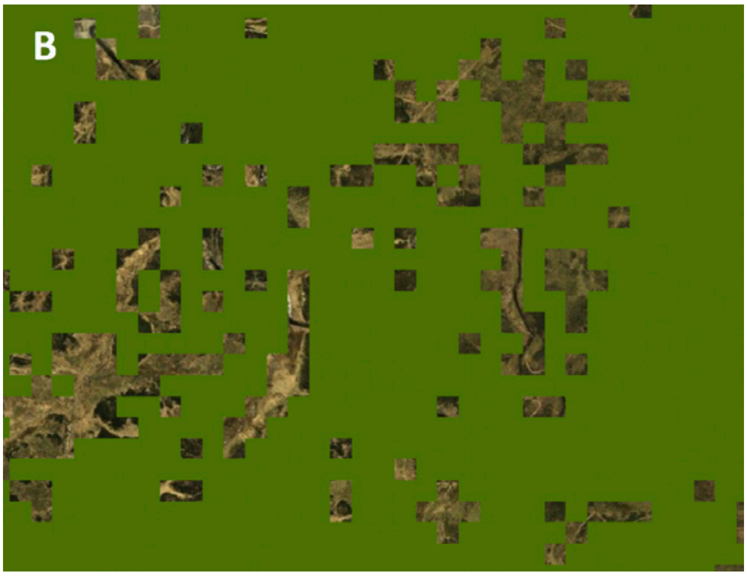
C Bing Maps imagery. Pale green squares, areas reported as forest in SOFR 2018.

Areas of heathland, shrub and sedge, as described in the Upper and Lower North East CRAFTI datasets, are correctly reported as non-forest in SOFR 2018.

Figure 1.9: Example of an area reported as forest in SOFR 2013 but as non-forest in SOFR 2018 due to better floristics information and high-resolution imagery. Khancoban, New South Wales. Individual mid-green and pale green squares on images **B** and **C** have an area of 1 hectare (100 m x 100 m).

A High-resolution Google Earth Pro imagery (2015), showing forest and non-forest areas.

NVIS Major Vegetation Subgroup (MVS) for area 1 is ‘Eucalyptus tall open forests and open forests with ferns, herbs, sedges, rushes or wet tussock grasses’, for area 2 is ‘Eucalyptus open forests with shrubby understorey’, and for area 3 is ‘Other tussock grassland’. Upper stratum tree height and cover codes are consistent with forest in areas 1 and 2 but not consistent with forest in area 3.



B Bing Maps imagery. Mid-green squares, areas reported as forest in SOFR 2013.

Areas of grassland were incorrectly reported as forest in SOFR 2013.

C Bing Maps imagery. Pale green squares, areas reported as forest in SOFR 2018.

Non-forest areas of ‘Grassland’ and ‘Sub-alpine Herbfield’, as described in the Southern CRA Forest Ecosystems dataset, are correctly reported as non-forest in SOFR 2018.

The NVIS dataset was used in a similar way in other jurisdictions to identify and mask out ecosystems that do not support tree cover and that were incorrectly classified as forest in the SOFR 2013 dataset.

In addition, a new land-use mask, based on the *Catchment Scale Land Use of Australia—Update September 2017* dataset[36], identified as residential and urban land-use some areas that were incorrectly reported as forest in SOFR 2013 (Figure 1.10).

Three examples are also provided for areas of forest reallocated as non-forest due to detection of actual on-ground change in forest cover.

Figure 1.11 shows an example of an area that was correctly reported as forest in SOFR 2013, but subsequently cleared for agriculture and therefore reported in SOFR 2018 as non-forest. This type of on-ground forest cover change is more common in northern and western New South Wales and southern and western Queensland, and less common in other states and territories. New datasets (QLD SLATS FPC 2014–15 and NSW SPOT5 FPC 2012), supported by the improved coverage of high-resolution imagery (Bing maps and Google Earth Pro) enabled the identification of this type of cover change, and allowed reallocation of forest areas to non-forest.

Figure 1.12 shows a mining development in an area that was correctly reported as forest in SOFR 2013. Expansion over time of the mine and associated infrastructure resulted in forest being cleared. The cleared areas are reported as non-forest in SOFR 2018.

Figure 1.13 shows the detection of on-ground forest cover change due to urban development, resulting from consideration of new forest cover datasets and an updated land-use mask. Such areas are reported as non-forest in SOFR 2018. This type of forest clearance occurs more commonly on the fringes of capital cities and also coastal towns. An area of 34 thousand hectares allocated as forest in SOFR 2013 was removed from the SOFR 2018 dataset with the application of the updated (September 2017) Catchment Land Use Mapping mask.

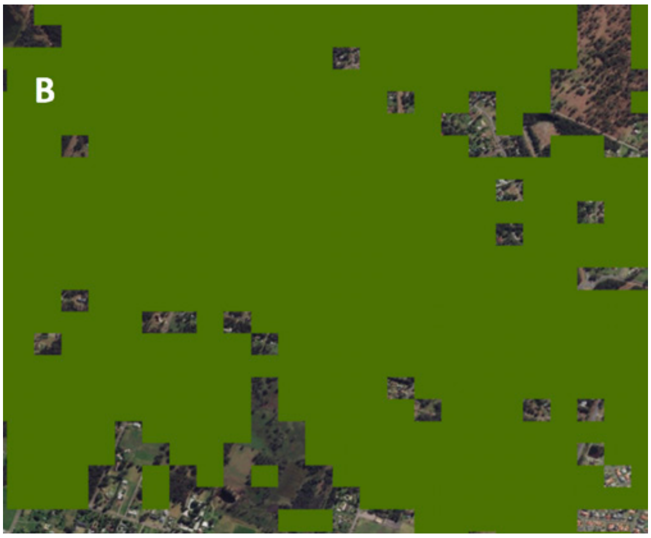
Forest of *Eucalyptus camaldulensis* (river red gum), Woohlpooer State Forest, Victoria. This forest is predominantly even-aged open forest of river red gum with a grassy understorey. The majority of trees established following the removal of grazing in 1890. (DNRE 2002: vhd.heritagecouncil.vic.gov.au/places/23412/download-report).

[36] data.gov.au/dataset/catchment-scale-land-use-of-australia-update-2017

Figure 1.10: Example of an area reported as forest in SOFR 2013 but as non-forest in SOFR 2018 due to application of an updated land-use mask. Medowie, north coast New South Wales. Individual mid-green and pale green squares on images **B** and **C** have an area of 1 hectare (100 m x 100 m).

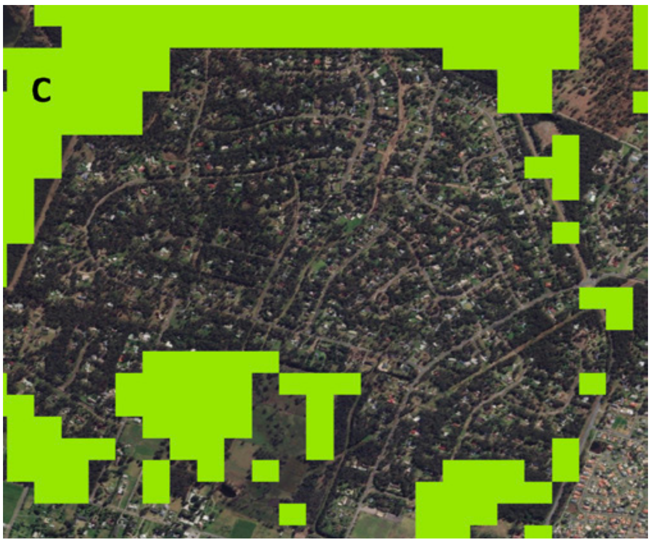
A High-resolution Google Earth Pro imagery (2011), showing urban and residential areas with patches of remaining forest.

Area 1, high-density residential. Area 2, low-density residential. Area 3, NVIS Major Vegetation Subgroup (MVS) is 'Eucalyptus open forests with a shrubby understorey', with height and cover codes consistent with the definition of forest.



B Bing Maps imagery. Mid-green squares, areas reported as forest in SOFR 2013.

Land-use mask used from *Catchment Scale Land Use of Australia—Update May 2012* (ABARES, unpublished), resulting in urban areas being incorrectly reported as forest in SOFR 2013.



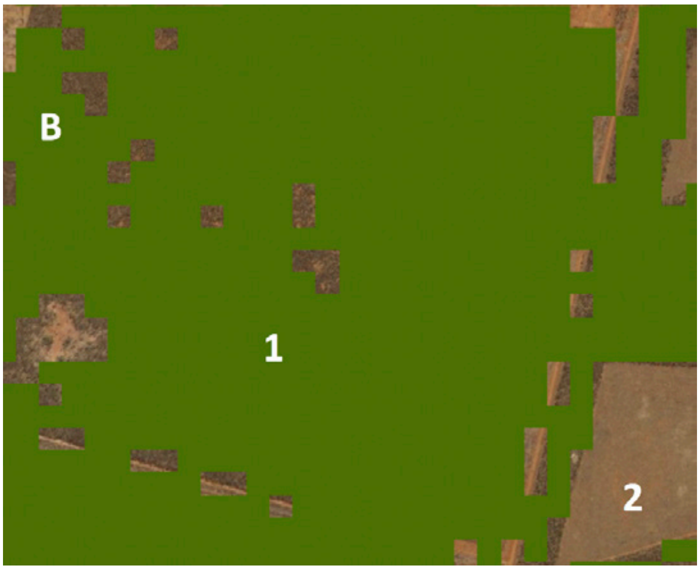
C Bing Maps imagery. Pale green squares, areas reported as forest in SOFR 2018.

Updated land-use mask from *Catchment Scale Land Use of Australia—Update September 2017* now correctly identifies urban and residential areas. Urban areas are correctly reported as non-forest in SOFR 2018.

Figure 1.11: Example of an area reported as forest in SOFR 2013 but as non-forest in SOFR 2018 due to land clearing. St George, central southern Queensland. Individual mid-green and pale green squares on images **B** and **C** have an area of 1 hectare (100 m x 100 m).

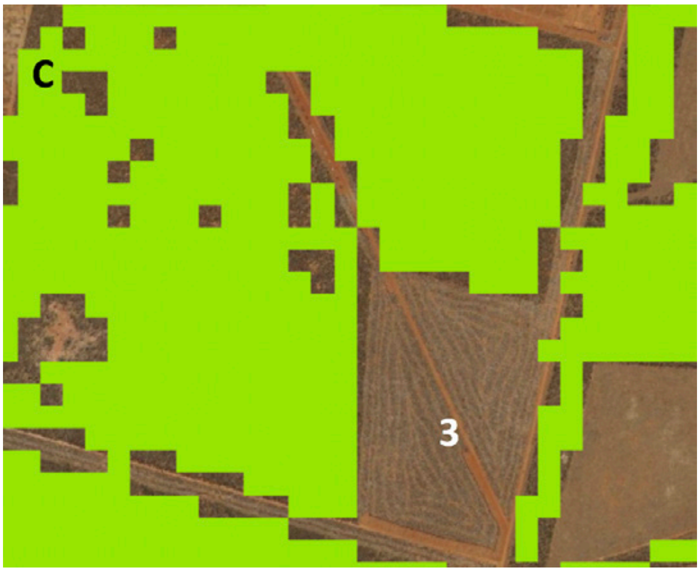
A High-resolution Google Earth Pro imagery (2012), showing landscape before land clearing.

Area 1, NVIS Major Vegetation Subgroup (MVS) is 'Mulga (*Acacia aneura*) woodlands and shrublands +/- tussock grass +/- forbs (with Eucalypt emergents)', with height and cover codes consistent with the definition of forest. Area 2 was cleared prior to 2012.



B Bing Maps imagery. Mid-green squares, areas reported as forest in SOFR 2013.

SOFR 2013 correctly reports area 1 as forest and area 2 as non-forest.



C Bing Maps imagery. Pale green squares, areas reported as forest in SOFR 2018.

SOFR 2018 correctly reports only the forest remaining after clearing, and reports cleared areas (such as area 3) as non-forest. Allocation is supported by QLD SLATS Land Clearing (2012–16) dataset. Clearing occurred in the 5-year reporting period for SOFR 2018.

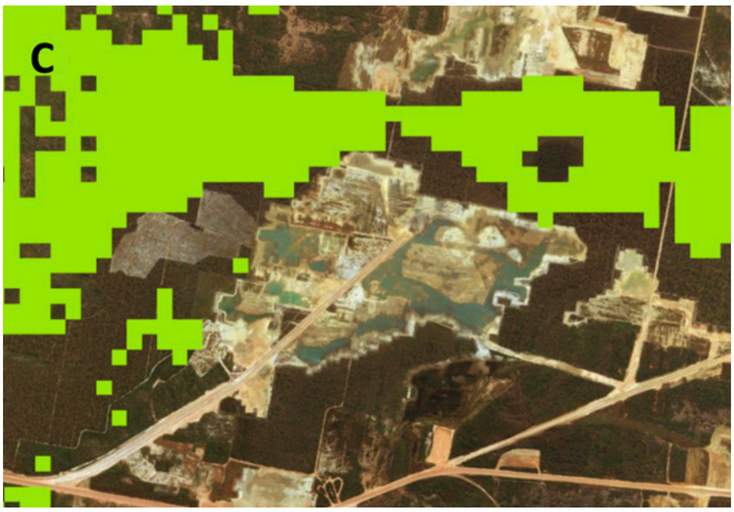
Figure 1.12: Example of an area reported as forest in SOFR 2013 but as non-forest in SOFR 2018 due to mining development or expansion. Weipa, north Queensland. Individual mid-green and pale green squares on images **B** and **C** have an area of 1 hectare (100 m x 100 m).

A High-resolution Google Earth Pro imagery (after 2005 but before 2012), showing a small area of mining development.

Area 1 NVIS Major Vegetation Subgroup (MVS) is 'Eucalyptus woodlands with a tussock grass understorey'. Upper stratum tree height code is '7' indicating a height range of 10–30 m, and cover code is 'i' indicating a crown cover range of 20–50%. Both codes are consistent with allocation as forest, validated by imagery.

B Bing Maps imagery (2012–16). Mid-green squares, areas reported as forest in SOFR 2013

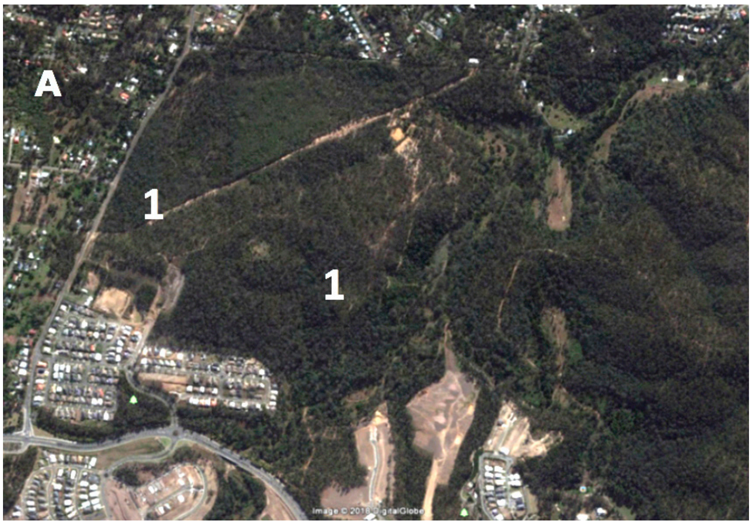
Forest areas identified from QLD SLATS 2010 and NGGI 2011 datasets. Forest clearing for mining commenced before 2012. The areas of forest and non-forest were correctly reported in SOFR 2013.



C Bing Maps imagery (2012–16). Pale green squares, areas reported as forest in SOFR 2018.

Expansion of mining development has resulted in further clearing of forest. Following incorporation of the SLATS 2014–15 and NGGI 2015 datasets, SOFR 2018 reports these additional cleared areas as non-forest.

Figure 1.13: Example of an area reported as forest in SOFR 2013 but as non-forest in SOFR 2018 due to urban residential expansion. Redbank Plains, Ipswich, south-east Queensland. Red square shows same area on all maps. Individual pale green squares on image **C** have an area of 1 hectare (100 m x 100 m).



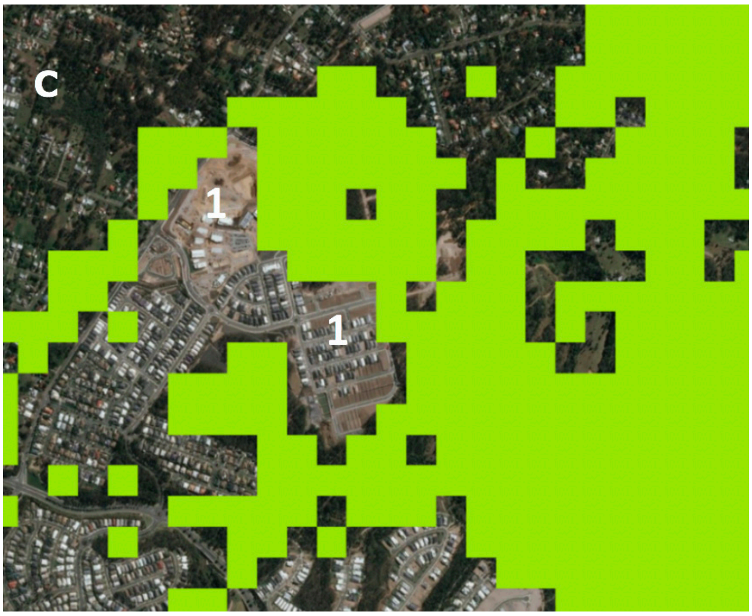
A High-resolution Google Earth Pro imagery (2011).

SOFR 2013 correctly reports area 1 as forest.

Landscape contains forest and urban components. Land-use mask from *Catchment Scale Land Use of Australia—Update May 2012* (ABARES, unpublished) allowed areas of forest to be correctly reported in SOFR 2013.

B High-resolution Google Earth Pro imagery (2016).

Forest has been cleared for urban residential development from area 1.



C Bing Maps Imagery (after 2011 but before 2017)

Area 1 correctly reported as non-forest in SOFR 2018.

Expansion of urban residential development has resulted in further clearing of forest. Updated land-use mask from *Catchment Scale Land Use of Australia —Update September 2017* has allowed SOFR 2018 to correctly report additional cleared areas as non-forest.

Indicator 1.1b

Area of forest, by growth stage

Rationale

This indicator measures the change in area of forest by growth stage to reflect how ecological processes and species associated with those processes change as forests grow. The age and size of trees is important in maintaining forest biodiversity.

Key points

- Australia's native forests comprise stands at regeneration, regrowth, mature and senescent growth stages, as well as stands of uneven-aged forest. Old-growth forest is not a specific growth stage, but is defined in relation to stand structure, as 'ecologically mature forest where the effects of disturbance are now negligible'.
  - Current information on native forest growth stage is available only for Tasmania, and current information on the area of old-growth forest is available only for Tasmania and Western Australia.
- Data collected over the period 1995–2000 as part of Comprehensive Regional Assessments in eleven forested regions of five states showed that all forest growth stages were present on all tenures.
  - On average, multiple-use public forest had a greater proportion of younger growth stages (regeneration and regrowth) and uneven-aged forest than did forest in nature conservation reserves, which had a greater proportion of senescent forest.
  - Considering the long time-spans over which forest development occurs, those general patterns are unlikely to have changed substantially since the data on growth stage were collected.
- The total area of old-growth forest in the Regional Forest Agreement (RFA) regions, which are the regions for which data were collected as part of Comprehensive Regional Assessments, is calculated to have decreased from 5.0 million hectares at the signing of the RFAs to 4.5 million hectares as at 2016.
  - The majority of the decrease in old-growth forest area occurred in Victoria, and was almost entirely due to bushfires in the decade to 2009.

Growth stage

The growth stage of a native forest[37] is one determinant of its biodiversity and ecological values. Growth stage assessment also indicates the balance of different age classes across a forest estate. Both the sustainable production of wood and the maintenance of values (such as species diversity, maximum carbon stocks or uniform water flows) can be improved when an area contains a mix of forest stands in different age classes, forming a mosaic of growth stages in the landscape. In addition, some species depend on more than one growth stage: for example, Leadbeater's possum (*Gymnobelideus leadbeateri*) requires trees at one growth stage for nesting and an understorey or midstorey at different growth stage at the same site or nearby for feeding.

Almost all Australian eucalypt forests are characterised by regular disturbance, predominantly by fire. The disturbance regime that characterises a forest type or site is defined as the pattern of fire extent and intensity over time in that forest type or at that site. Attempting to manage Australian eucalypt forests to achieve a particular balance of growth stages across a given area thus requires working with, and being guided by, the natural disturbance regime. This can be a management goal both in multiple-use forests and in nature conservation reserves.

State and territory governments have developed various methods for describing the different growth stages or age classes of native forest that result from disturbance, especially for wetter eucalypt forests in which individual stands are often even-aged as a result of a severe disturbance event. Commonly, four main growth stages are identified in native forests: regeneration (generally taken as less than 20 years since disturbance), regrowth (generally taken as 20–80 years since disturbance), mature (generally taken as 80 or

[37] Plantation growth stages are reported by ABARES (2016b).

more years since disturbance) and senescent (various ages after 80 years since disturbance, when irregular crowns form, while hollows may take over 100 years to develop) (Figure 1.14); these numerical values can differ substantially between forest types.

These four categories apply reasonably well to even-aged forests. However, substantial areas of forests are mixtures of more than one growth stage, resulting from less severe or less uniform disturbance events that lead to mixed-aged or uneven-aged stands containing trees of different ages. This is especially the case for drier eucalypt forests, or forests dominated by non-eucalypt species such as rainforest or open acacia woodlands.

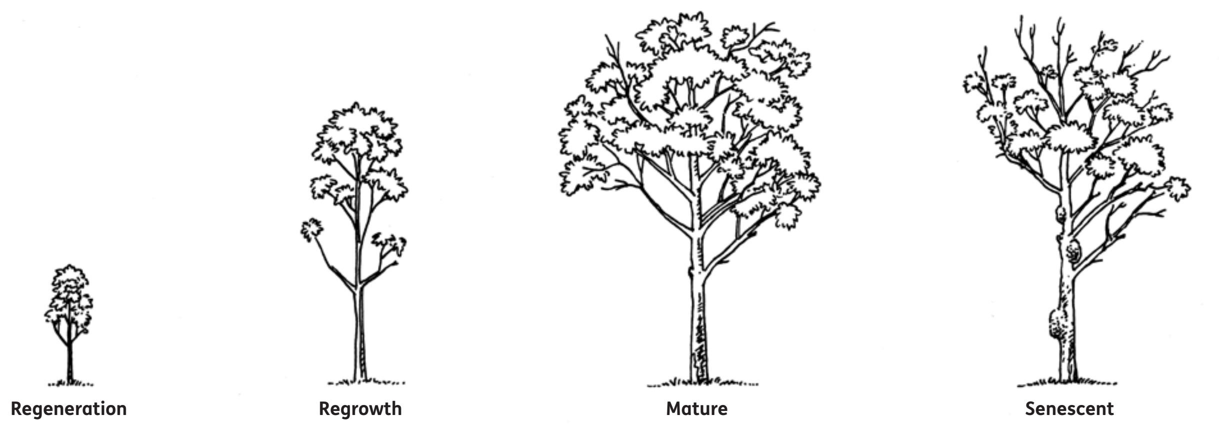
Information on forest growth stage

Growth stage information was collected over the period 1995–2000, as part of the Comprehensive Regional Assessments (CRAs) undertaken in eleven forested regions of five states in preparation for signing of various Regional Forest Agreements (RFAs). This information covered 15.4 million hectares of Australia's native forest, and was presented in previous SOFRs. Growth stages were best characterised for multiple-use public native forests used for wood production, because the mapping of growth stages in such forests is important for ongoing forest resource assessments. Gaps in the data existed on all other tenures. However, this growth-stage information has not been updated, except for forests in Tasmania (see Table 1.16).

In data collected as part of the CRA process for RFAs, all native forest growth stages were found to be present on all tenures. Nearly half of the area of native forest was categorised as mature forest, with large areas of mature forest in nature conservation reserves, multiple-use public forest, and private land. Native forest mapped as senescent was predominantly found in nature conservation reserves, often because forest of this age was placed in reserves due to its particular values. A greater proportion of multiple-use public native forest was at younger growth stages (regeneration and regrowth) than forests in nature conservation reserves, largely because less forest of this age has been placed in reserves, but also because some multiple-use public forests are managed on a cycle of harvesting and regeneration to provide an ongoing forest resource for wood production.

These general patterns of forest growth stages across tenure categories are unlikely to have changed substantially since the RFA data were collected. However, a considerable proportion of forest in the regeneration category will have progressed to the regrowth category, and some of the regrowth forest will have progressed to the mature category. Some mature and senescent forest has been burnt by bushfire (especially in Victoria) and will therefore now be regeneration or regrowth forest (although containing significant quantities of standing dead trees). Some mature forests have also been harvested and regenerated, and will therefore now also be forest in the regeneration growth stage.

Figure 1.14: Classification of growth stages in native forests



Regeneration: includes juvenile and sapling stages, when trees are very small and crowns exhibit apical dominance. (Apical dominance is where the main central stem of the tree is growing more strongly than the side branches.)

Regrowth: trees have well-developed stems with crowns of small branches but are below mature stand height. Apical dominance is apparent in vigorous trees. Includes 'pole' and 'early mature' stages.

Mature: trees are at maximum height and crowns at full lateral development. Branch thickening can occur.

Senescent: crowns are contracting, and crown diameter and crown leaf area are decreasing.

Uneven-aged forests can contain a mixture of two of more of these growth stages.

Source: adapted from Clode and Burgman (1997).

A higher resolution version of this graphic is available via www.doi.org/10.25814/5be3bc4321162

Old-growth forest

Old-growth forest is not a growth stage defined by time since disturbance, but rather is defined in relation to stand structure and features. In Australia, old-growth forest is defined as '*ecologically mature forest where the effects of disturbance are now negligible*' (ANZECC and MCFFA 1997).

The conservation and protection of old-growth forest is a requirement of the *National Forest Policy Statement* (Commonwealth of Australia 1992) and is incorporated in the RFAs. The concept of old-growth forest is captured in Pitman et al. (1996), and in an updated diagram in Davey (2018a), which both show that areas of old-growth forest are a subset of the areas of mature and senescent growth stages.

Old-growth forests typically contain large, old trees, and are also characterised by habitat features such as stem and branch hollows, dead standing trees, and large logs and woody debris on the forest floor. They have low average tree growth rates and rates of carbon sequestration, and relatively low rates of change in composition and structure, but contribute significantly to carbon storage. Old-growth forests also typically transpire less water, have higher soil moisture content, and have higher stream water flow than do younger growth stages of forests of the same type. In summary, old-growth forests have significant habitat, nature conservation and aesthetic values that are not found in forests in earlier stages of development, and contribute significantly to carbon storage and water production.

The regional extent of old-growth forests changes over time due to the effects of forest growth, disturbance (most generally bushfire, but also cyclones in northern Australia), ageing, disease or lack of fire, and occasionally due to limited wood harvesting where that is permitted. Jurisdictions have policies that exclude harvesting from old-growth forest, or management prescriptions to reduce harvesting effects and limit harvest areas.

In the period 1995–2000, one of the projects under the CRAs was to map old-growth forests in eleven forested regions around Australia as part of the RFA process. These assessment results have been updated for some regions from time to time (Case Study 1.1 describes an update to the extent of jarrah (*Eucalyptus marginata*) and karri (*E. diversicolor*) old-growth forests in Western Australia), but there has been no national survey of old-growth forest since that period. The areas of old-growth forest as assessed in the CRAs that led to RFAs, and the areas of old-growth forest in currently available data for each jurisdiction, are summarised by RFA region in Table 1.15.

Table 1.15: Old-growth forest areas in RFA regions ('000 hectares)

	Areas from CRAs (1995–2000)			Areas in most recent data[a]	
RFA region	**Forest**	**Old-growth forest**	**Old-growth forest as proportion of total forest (%)**	**Old-growth forest**	**Old-growth as proportion of total forest at CRA (%)**
Eden	533	98	18	98	18
Upper North East	2,167	655	30	655	30
Lower North East	3,175	1,030	32	1,030	32
Southern NSW	2,446	753	31	753	31
Total RFA regions in NSW	**8,320**	**2,536**	**30**	**2,536**	**30**
Tasmanian	3,205	1,239	39	1,206	38
Total RFA region in Tasmania	**3,205**	**1,239**	**39**	**1,206**	**38**
Central Highlands	692	26	4	9	1
East Gippsland	1,078	225	21	109	10
Gippsland	1,426	209	15	78	5
North East	1,252	259	21	141	11
West Victoria	968	122	13	91	9
Total RFA regions in Victoria	**5,415**	**841**	**16**	**428**	**8**
South-West Forest Region of WA	2,235	347	8	334	15
Total RFA regions in WA	**2,235**	**347**	**8**	**334**	**15**
Total RFA regions in Australia	**19,175**	**4,963**	**26**	**4,504**	**23**

CRA, Comprehensive Regional Assessment.

[a] Dates of most recent data: Victoria, 2009; New South Wales, 2001; Tasmania 2017; Western Australia, 2017. Data include public and private land (including private land protected by conservation covenant).

Sources: National Forest Inventory, data provided by states for Australia's State of the Forests Report 2018, and state forest management planning documentation interpreted by ABARES.

This table, together with other data for Indicator 1.1b, is available in Microsoft Excel via www.doi.org/10.25814/5bda82c8d76d4

Large decaying and hollow logs on the forest floor are a characteristic feature of old-growth forests.

As assessed for the CRAs, there was a total of 5.0 million hectares of old-growth forest in the RFA regions (26% of Australia's forest area in those regions at that time) (Table 1.15). Since that date, areas of old-growth forest have reduced in several regions. The area of old-growth forest in Victoria reduced by 413 thousand hectares (49%), caused almost entirely by bushfires in 2003, 2007 and 2009. The 13 thousand hectare (4%) reduction of old-growth forest area in Western Australia was due to a combination of harvesting prior to 2001 (when harvesting of old-growth forest ceased), improved mapping, bushfire and disease, while the 33 thousand hectare (3%) reduction of old-growth forest area in Tasmania was caused by limited wood harvesting, bushfire, and conversion to plantations and agricultural land uses. Updated data on old-growth forest areas are not available for New South Wales.

Information on forest growth stage and old-growth forest in Tasmania

Data on forest growth stage in Tasmania are based on growth stage mapping on all tenures. This was completed state-wide in 1996, and has since been updated periodically with data from public and private forest practices plans that show areas proposed for wood harvesting or conversion for other purposes. This same approach has been applied to mapping old-growth forest in Tasmania. These data therefore do not generally reflect changes due to natural processes.

The most recent data were published in *State of the forests Tasmania 2017* (FPA 2017a). Table 1.16 presents a combination of data from two tables in that report, in which the area of old-growth eucalypt forest has been extracted from the area of eucalypt forest in the Tasmanian growth stage 'Mature and over-mature', and reported separately. The area of old-growth non-eucalypt forest (such as rainforest) has also been extracted from the area of non-eucalypt forest in the 'Unknown' growth stage, and reported separately.

Across Tasmania, 99 thousand hectares (3%) of native forests are in the regeneration category, 549 thousand hectares (18%) are regrowth, 932 thousand hectares (31%) are mature, and 1.21 million hectares (40%) are old-growth (Table 1.16). A total of 267 thousand hectares of native forest are of unknown growth stage, mostly in the non-eucalypt RFA forest type, which are often multi-aged forests or forests that regenerate without episodic disturbance and for which no growth-stage category is appropriate.

In Tasmania's dry eucalypt forests, the proportion of regeneration and regrowth forests averages 21% across all tenures. However, these forests often grow in multi-aged stands, and forests mapped as regeneration or regrowth usually contain a proportion of older trees.

In Tasmania's wet eucalypt forests, the proportion mapped as regeneration and regrowth across all tenures is higher, at 41%. This is due in part to the ecology of wet eucalypt communities, which tend to grow in single-age stands, so that regrowth stands are readily identifiable. It also reflects the history of disturbance by fire and wood harvesting in wet eucalypt forests. The proportion of wet eucalypt forest mapped as regeneration and regrowth ranges from 20% in nature conservation reserves to 54% on private land and 57% on Permanent Timber Production Zone land.

The transfer of large areas of multiple-use public forests in Tasmania into nature conservation reserves and Future Potential Production Forest (classified nationally as 'Other Crown land', or in Tasmania as 'Other publicly managed land') since the publication of *State of the Forests Tasmania 2012* (FPA 2012) led to substantial changes in the growth-stage distribution of forests by tenure.

Table 1.16: Area of native forest types by tenure and growth stage (including old-growth forest), Tasmania ('000 hectares)

Tenure category[a]	Growth stage (including old-growth forest)[b]					
RFA forest type	Regeneration	Regrowth	Mature	Old-growth	Unknown	Total
Conservation reserves						
Dry eucalypt forest	0	60	144	240	10	455
Wet eucalypt forest	5	53	60	165	3	287
Sub-alpine eucalypt forest	0	11	1	35	4	51
Non-eucalypt forest	0	0	0	423	40	463
Sub-total	**5**	**124**	**205**	**863**	**57**	**1,256**
Permanent Timber Production Zone land						
Dry eucalypt forest	15	67	84	26	7	199
Wet eucalypt forest	49	126	87	36	9	306
Sub-alpine eucalypt forest	0	0	1	1	0	2
Non-eucalypt forest	0	0	0	40	51	91
Sub-total	**64**	**193**	**172**	**103**	**67**	**599**
Other publicly managed land						
Dry eucalypt forest	7	24	80	53	7	171
Wet eucalypt forest	7	29	41	22	3	100
Sub-alpine eucalypt forest	0	0	1	2	1	5
Non-eucalypt forest	0	0	0	56	26	82
Sub-total	**14**	**53**	**122**	**133**	**37**	**358**
Private freehold land						
Dry eucalypt forest	13	122	395	89	59	678
Wet eucalypt forest	3	56	34	6	11	110
Sub-alpine eucalypt forest	0	1	3	2	1	7
Non-eucalypt forest	0	0	0	10	35	45
Sub-total	**16**	**179**	**432**	**107**	**106**	**840**
All tenures						
Dry eucalypt forest	35	273	703	408	83	1,502
Wet eucalypt forest	64	264	222	229	26	805
Sub-alpine eucalypt forest	0	12	6	40	6	64
Non-eucalypt forest	0	0	0	529	152	681
Total	**99**	**549**	**932**	**1,206**	**267**	**3,052**

RFA, Regional Forest Agreement. Tasmania does not use the growth stage category 'senescent'.

[a] Tenure data are as at 30 June 2016, and are reported by Tasmanian tenure categories. The Tasmanian category 'Permanent Timber Production Zone land' is broadly equivalent to the national tenure category 'Multiple-use public forest'. The Tasmanian category 'Other publicly managed land' includes land classified by Tasmania as Future Potential Production Forest, and which is classified nationally as 'Other Crown land'.

[b] Growth stage data are as at 30 June 2016 for publicly managed land, and as at 31 December 2015 for private land.

Notes:

Data are adapted from *State of the forests Tasmania 2017* (FPA 2017a) Table 1.1.b.1 *Area of native forest types by growth stage and tenure* and Table 1.1.e.1 *Old-growth by forest type and tenure*. For each eucalypt RFA forest type in each tenure category, the old-growth forest area from Table 1.1.e.1 was subtracted from the 'Mature and over-mature' growth stage area on Table 1.1.b.1, to give the area of the 'Mature forest' growth stage presented above. For the non-eucalypt RFA forest type in each tenure category, the old-growth forest area from Table 1.1.e.1 was subtracted from the of 'Unknown' growth stage area on Table 1.1.b.1, to give the area of 'Unknown' growth stage presented above. The old-growth forest areas for each eucalypt RFA forest type and the non-eucalypt RFA forest type were then presented separately. The total native forest area above (3.052 million hectares) is the total native forest area reported in *State of the forests Tasmania 2017* (FPA 2017a).

This table, together with other data for Indicator 1.1b, is available in Microsoft Excel via www.doi.org/10.25814/5bda82c8d76d4

Case study 1.1: Updating the extent of jarrah and karri old-growth forests

In the south-west of Western Australia, old-growth forests on lands vested in the Conservation and Parks Commission are protected from disturbances such as timber harvesting, road and track construction, or infrastructure development. However, the extent of old-growth forest can change over time as a consequence of natural events, such as stand-replacing bushfires in karri (*Eucalyptus diversicolor*) forests or the spread of *Phytophthora* dieback disease in jarrah (*E. marginata*) forests. Improved mapping and site-specific information on the extent and intensity of past disturbance events can also change the area of old-growth forests reported.

The planning and approvals process for disturbance activities requires all proponents to check for the presence of unmapped old-growth forest. Maintaining an up-to-date and accurate depiction of the presence of old-growth forest is thus essential, and old-growth forest extent is therefore mapped at a 2-hectare spatial resolution (using information derived from field transects chosen using a 0.5-hectare grid). The planning and approvals process can also involve field inspection and, if necessary, referral of an area to the Department of Biodiversity, Conservation and Attractions[38] (DBCA) for a detailed assessment of the status of the forest.

The assessment combines historical data and aerial photography, recent high-resolution digital imagery, field surveys of *Phytophthora cinnamomi* occurrence, and measurements of stump frequency and stand condition, to determine the presence and boundaries of previously unmapped old-growth forest (Figure 1.15). A process for nomination by the public of areas for assessment is also maintained, and annual updates of the mapped extent of old-growth forest are published[39].

During the period 2011 to 2016, a total of 1,251 hectares of jarrah forest, 69 hectares of karri forest and 83 hectares of wandoo (*E. wandoo*) forest were added to the recorded extent of old-growth forest. The size of the individual patches of previously unmapped old-growth forest ranged from 2 to 256 hectares.

Figure 1.15: A systematic grid of cell size 0.5 hectare used to record the occurrence of stumps, landings, snig tracks and other disturbance features for the assessment of old-growth forest status in karri forest near Pemberton, Western Australia

[38] From July 2017, the Department of Parks and Wildlife.

[39] www.dpaw.wa.gov.au/management/forests/about-our-forests/171-protecting-our-biological-diversity

Indicator 1.1c

Area of forest in protected area categories

Rationale

This indicator uses the area and proportion of forest ecosystems reserved through formal and informal processes as a measure of the emphasis placed by society on the preservation of representative ecosystems as a strategy to conserve biodiversity.

Key points

- This indicator reports on forests reserved in protected areas and on forests otherwise managed for the protection of biological diversity.
- A range of formal and informal processes are used on public and private land in Australia to protect areas of forest for the conservation of biodiversity. Many areas of forest are protected by, and reported under, more than one process.
  - Australia's National Reserve System includes 33.6 million hectares of forest (almost all native forest) that have a primary management intent of nature conservation. This is a total of 25% of Australia's forest area, and 26% of Australia's native forest area.
  - A total of 21.8 million hectares of Australia's forest is in the national land tenure category 'Nature conservation reserve', which is 16% of Australia's total forest area.
  - Australia's Comprehensive, Adequate and Representative (CAR) reserve system comprises public forest in formal reserves, in informal reserves, and in areas in which values are protected by prescription, as well as forest in CAR reserves on private land. In the CAR reserve system, the area of native forest in the Australian Capital Territory is 0.1 million hectares, in New South Wales is 6.4 million hectares, in Tasmania is 2.1 million hectares, and in Victoria is 4.3 million hectares. In addition, the CAR reserve in Western Australia contains 5.8 million hectares of forest.
  - Areas of multiple-use public forest not in the CAR reserve system are managed for multiple objectives, including timber production, water production, recreation, amenity, and biodiversity conservation, with management regulated by codes of forest practice to maintain forest values, and therefore are also reported in this indicator.
  - The Australian Government Department of Defence manages 1.32 million hectares of forest on the national land tenure category 'Other Crown land'. This area comprises forest managed as CAR informal reserves and forest protected by prescription.
  - A total of 3.2 million hectares of forest are on private or leasehold lands with nature conservation covenants.
  - A total of 4.7 million hectares of Australia's native forests are on sites on the World Heritage List established under the World Heritage Convention.
  - A total of 1.8 million hectares of Australia's native forests are on Ramsar wetland sites established under the Convention on Wetlands of International Importance (the Ramsar Convention).
- Across all the above categories, within and outside the National Reserve System, the total area of native forest managed for the protection of biodiversity through formal and informal processes is 46.0 million hectares (35% of Australia's native forest area).
  - SOFR 2013 reported a total of 39.2 million hectares of native forest managed for the protection of biodiversity (32% of Australia's native forest area as reported at that time).
- Aichi Biodiversity Targets are articulated in the Strategic Plan for Biodiversity 2011–2020 under the international Convention on Biological Diversity, and include the target that at least 17% of terrestrial areas are protected. Australia has therefore met the Aichi Biodiversity Target with respect to native forests.

This indicator reports on the area of Australia's forests reserved in protected areas or otherwise managed for the conservation of biological diversity. The area of forest managed specifically for protection of soil and water values is reported in Indicator 4.1a.

Creation of protected areas is the principal global mechanism for the conservation of biodiversity, as was recognised during development of the Convention on Biological Diversity (Worboys 2015). Three definitions for protected areas are used nationally and/or internationally:

- *A geographically defined area which is designated or regulated and managed to achieve specific conservation objectives* (Article 2 of the Convention on Biological Diversity 1992[40]).
- *An area of land and/or sea especially dedicated to the protection and maintenance of biological diversity, and of natural and associated cultural resources, and managed through legal or other effective means* (IUCN[41] 1994; Dudley and Phillips 2006).
- *A clearly defined geographical space, recognised, dedicated and managed, through legal or other effective means, to achieve the long term conservation of nature with associated ecosystem services and cultural values* (revised IUCN definition, Dudley 2008).

Australia's public and private forests are protected through a combination of conservation mechanisms, including formal and informal reserves, management by prescription, conservation covenants, and other management arrangements for the conservation of biodiversity. Some of these areas are recognised in Australia's National Reserve System, but there are also areas outside that system that are managed for protection of biodiversity. This indicator therefore presents data for protected forests in the following categories:

- forests in Australia's National Reserve System[42], as described in the Collaborative Australian Protected Areas Database (CAPAD)[43]. This includes most areas of forest in nature conservation reserves, some forests in the national land tenure category 'Multiple-use public forest', and forests on private land managed under the National Reserve System. Land in the National Reserve System is allocated to one of a number of protection categories set up by the International Union for Conservation of Nature (IUCN)
- forests in the national land tenure category 'Nature conservation reserve'
- forests in the Comprehensive, Adequate and Representative (CAR) reserve system, which comprises public formal reserves, informal reserves, and areas in which values are protected by prescription, as well as private CAR reserves
- native forests on public land in the national land tenure category 'Multiple-use public forest'. These include formal reserves, informal reserves, and areas protected by prescription; the balance of multiple-use public forest is managed for multiple objectives, including timber production, recreation, amenity, water production, and protection of biodiversity, with management regulated by codes of forest practice in order that the values of the forest including biodiversity are maintained (see Indicator 7.1b)
- forests on Australia's Defence estate
- areas of private forest under nature conservation covenants
- areas of forest protected on sites listed on the World Heritage List
- areas of forest protected on Ramsar Wetland sites.

The total area of forest in Australia protected for biodiversity conservation by one or more of the above mechanisms is then calculated and presented.

Forests in Australia's National Reserve System

Australia's National Reserve System is a network of protected areas based on a scientific framework, and comprises Commonwealth, state and territory reserves, Indigenous land and protected areas run by non-profit organisations[44]. Protected areas are terrestrial or marine areas especially dedicated to the protection and maintenance of biological diversity, and are formally protected through "legal or other effective means"[45] and managed in perpetuity. Every two years, the Australian Government collects information on these protected areas, and publishes the information in the Collaborative Australian Protected Areas Database (CAPAD) as a spatial representation of Australia's National Reserve System.

A total of 33.6 million hectares of Australia's forest (almost all of which – 99.9% – is native forest) is protected in the National Reserve System (Table 1.17). This is 25% of Australia's forest area, and 26% of Australia's native forest area. A total of 97% of the area of forest on nature conservation reserve tenure in Australia is in the National Reserve System, as well as 19% of the area of forest on private land tenure. The Australian Capital Territory has the greatest proportion of its forest area formally protected in the National Reserve System (80%), with South Australia having 52%, Tasmania 44% and Victoria 40% formally protected in this way.

Inclusion of an area in Australia's National Reserve System reflects the management intent of that area rather than the underlying land tenure. Forest on nature conservation reserve tenure comprises 21.0 million hectares (62%) of the forest in the National Reserve System, with substantial contributions to the National Reserve System also from forest on private (23%) and leasehold (11%) tenures. For example, some large national parks, including Kakadu National Park in the Northern Territory, are classified as private land tenure but are included in the National Reserve System because they are formally managed for conservation values. Areas of multiple-use public native forest are included in the National

40 www.cbd.int/convention/text/default.shtml
41 IUCN, International Union for Conservation of Nature.
42 www.environment.gov.au/land/nrs
43 www.environment.gov.au/topics/land/nrs/science/capad/2010
44 www.environment.gov.au/land/nrs
45 www.environment.gov.au/land/nrs/about-nrs/requirements

Table 1.17: Area of forest in the National Reserve System, by national forest category, tenure and jurisdiction

	Australia Area ('000 hectares)				Forest in National Reserve System Area ('000 hectares)								
Forest category and tenure[a]	Total forest	Forest in National Reserve System	Proportion of forest that is in the National Reserve System (%)	Proportion of total National Reserve System forest (%)	ACT	NSW	NT	Qld	SA	Tas.	Vic.	WA	Australia
Native forest													
Leasehold forest	47,246	3,763	8	11	0.7	155	1,042	1,952	417	0	0	195	3,763
Multiple-use public forest	9,772	127	1.3	0.4	0	40	0	55	13	0	16	2	127
Nature conservation reserve[b]	21,719	21,009	97	62	112	5,553	14	4,363	1,680	1,540	3,282	4,465	21,009
Other Crown land	11,042	941	9	2.8	0.4	6	196	112	0.4	2	19	605	941
Private forest[c]	41,031	7,762	19	23	0	22	4,594	2,400	502	81	5	157	7,762
Unresolved tenure	805	8	1.0	0	0	0.1	1.1	7	0.1	0	0	0	8
Total native forest	**131,615**	**33,609**	**26**	**99.9**	**114**	**5,776**	**5,847**	**8,889**	**2,613**	**1,622**	**3,322**	**5,426**	**33,609**
Commercial plantation	**1,949**	**2**	**0.1**	**0**	**0**	**0.2**	**0**	**0**	**0.1**	**0.4**	**0.2**	**0.6**	**2**
Other forest	**474**	**30**	**6**	**0.1**	**0.3**	**0.2**	**0**	**0.3**	**0.5**	**0.2**	**8**	**20**	**30**
Total forest	**134,037**	**33,640**	**25**	**100**	**114**	**5,776**	**5,847**	**8,889**	**2,614**	**1,623**	**3,331**	**5,446**	**33,640**
Proportion of forest that is in the National Reserve System (%)					**80**	**28**	**25**	**17**	**52**	**44**	**40**	**26**	**25**

[a] National land tenure category (see Introduction)

[b] These area figures are lower than the area figures for nature conservation reserve tenure on Table 1.6 (Indicator 1.1a) because not all areas of nature conservation reserve tenure are captured in the National Reserve System.

[c] As in SOFR 2013, area figures for native forest on private land in the National Reserve System are in some jurisdictions less than the area figures for native forest on private land protected by conservation covenants (Table 1.28). The reasons for this are unknown, but may include state-based and territory-based private land conservation covenant programs not being captured by the National Reserve System.

Note: Totals may not tally due to rounding.

Source: ABARES, National Forest Inventory for forest area; Collaborative Australian Protected Area Database 2016 (Australian Government Department of the Environment and Energy) for National Reserve System data.

This table, together with other data for Indicator 1.1c, is available in Microsoft Excel via www.doi.org/10.25814/5bda82c8d76d4

Claire Howell

Woodland forest of snowgum (*Eucalyptus pauciflora* ssp. *niphophila*), Kosciuszko National Park, New South Wales.

Reserve System if they are principally managed for the conservation of biodiversity (Dudley and Phillips 2006; see IUCN category VI, Table 1.18).

Under *Australia's Strategy for the National Reserve System 2009–2030* (NRMMC 2009), all the state and territory governments and the Australian Government agreed to adopt international standards for the definition of a protected area and for management categories for protected areas. The seven categories used by the International Union for Conservation of Nature (IUCN) for protected areas are:

- **Ia Strict nature reserve** – protected area managed mainly for science
- **Ib Wilderness area** – protected area managed mainly for wilderness protection
- **II National park** – protected area managed mainly for ecosystem conservation and recreation
- **III Natural monument** – protected area managed for the conservation of specific natural features
- **IV Habitat/species management area** – protected area managed mainly for conservation through management intervention
- **V Protected landscape/seascape** – protected area managed mainly for landscape/seascape conservation and recreation
- **VI Managed resource protected area** – protected area managed mainly for the sustainable use of natural ecosystems.

Table 1.18 classifies the areas of forest in Australia's National Reserve System by these IUCN protected area categories. The spatial distribution of forest in Australia's National Reserve System, by IUCN protected area category, is shown in Figure 1.16.

In 1982, the IUCN recommended that at least 10% of each biome[46] should be in one of these reserve categories[47]. SOFR 2018 reports against this target by forest type. Of Australia's 18 national native forest types and subtypes, 17 have reservation levels exceeding this target (Table 1.19), the same number as reported in SOFR 2013. Only Acacia forests are represented below this target level, with 9.6% of their area protected.

[46] The IUCN defines a 'biome' as "A major portion of the living environment of a particular region (such as a fir forest or grassland), characterized by its distinctive vegetation and maintained largely by local climatic conditions."

[47] The target of 10% was proposed at the Third World Congress on National Parks in Bali, Indonesia, in 1982 and endorsed as a target "that protected areas cover at least 10 percent of each biome by the year 2000" in the Caracas Action Plan at the IVth IUCN World Parks Congress held in Caracas, Venezuela in 1992

Table 1.18: Area of forest in the National Reserve System by IUCN protected area category, forest category and jurisdiction

	Area ('000 hectares)											
	Forest by IUCN protection category											Proportion of forest in all IUCN categories[c] (%)
Forest category Jurisdiction	Ia	Ib	II	III	IV[a]	V	VI	ND[b]	I–IV	I–VI, ND[b]	Total forest	
Native forest												
ACT	0	28	77	0	8	0	0	0	114	114	**130**	87
NSW	781	1,732	3,083	6	142	21	3	9	5,744	5,776	**19,925**	29
NT	9	0	1,785	1.4	49	1,331	2,433	239	1,844	5,847	**23,686**	25
Qld	49	41	5,806	212	59	337	2,302	83	6,167	8,889	**51,580**	17
SA	235	477	96	511	314	115	855	9	1,634	2,613	**4,856**	54
Tas.	8	8	821	48	265	118	343	12	1,149	1,622	**3,342**	49
Vic.	258	142	2,627	171	30	25	69	0	3,229	3,322	**7,645**	43
WA	1,764	0.8	2,262	14	70	317	877	122	4,110	5,426	**20,450**	27
Total native forest	**3,103**	**2,429**	**16,557**	**964**	**937**	**2,264**	**6,881**	**474**	**23,990**	**33,609**	**131,615**	**26**
Commercial plantation	**0.2**	**0**	**0.5**	**0.1**	**0.3**	**0**	**0.5**	**0**	**1.1**	**2**	**1,949**	**0.1**
Other forest	**5**	**0**	**7**	**0.9**	**1.5**	**0.9**	**13**	**0.2**	**15**	**30**	**474**	**6**
Total forest	**3,109**	**2,429**	**16,565**	**965**	**939**	**2,265**	**6,895**	**474**	**24,006**	**33,640**	**134,037**	**25**
Proportion of total forest area in National Reserve System (%)	**9**	**7**	**49**	**3**	**3**	**7**	**20**	**1**	**71**	**100**		

IUCN, International Union for Conservation of Nature; NRS, National Reserve System.

[a] Multiple-use public forest could arguably be classified under IUCN category VI; however, multiple-use public forest is only classified in CAPAD if it is principally managed for the conservation of biodiversity (see Dudley and Phillips 2006).

[b] 'ND' areas are protected in the National Reserve System but are not yet classified into an IUCN category.

[c] Includes protected forest areas with an IUCN listing of ND.

Note: Totals may not tally due to rounding.

Source: ABARES, National Forest Inventory for forest area; Collaborative Australian Protected Area Database 2016 (Australian Government Department of the Environment and Energy) for IUCN data.

This table, together with other data for Indicator 1.1c, is available in Microsoft Excel via www.doi.org/10.25814/5bda82c8d76d4

Table 1.19: Area of forest in IUCN protected-area categories, by forest type

Forest category	Area ('000 hectares)											Proportion of forest in all IUCN categories[c] (%)
	Forest by IUCN protection category										Total forest	
Forest type	Ia	Ib	II	III	IV	V	VI[a]	ND[b]	I–IV	I–VI, ND[b]		
Native forest												
Acacia	68	9	633	25	9	30	242	16	745	1,034	**10,813**	9.6
Callitris	89	1.4	127	2	15	0.1	17	1.4	235	253	**2,011**	13
Casuarina	57	70	165	4	13	19	82	0.1	309	411	**1,236**	33
Eucalypt	2,785	2,132	12,666	848	807	1,886	5,871	441	19,237	27,435	**101,058**	27
Eucalypt closed	6	2	88	1.5	0.8	16	16	0.8	99	132	**534**	25
Eucalypt open	456	1,164	5,106	153	176	395	1,388	35	7,055	8,873	**27,695**	32
Eucalypt woodland	2,323	966	7,472	693	630	1,475	4,467	405	12,084	18,430	**72,829**	25
Mangrove	15	0.1	101	17	4	34	49	3	137	224	**854**	26
Melaleuca	10	6	623	15	8	203	169	4	663	1,038	**6,382**	16
Rainforest	25	164	1,582	12	72	74	311	5	1,855	2,246	**3,581**	63
Other native forest	53	47	659	40	9	18	140	2	807	968	**5,679**	17
Total native forest	**3,103**	**2,429**	**16,557**	**964**	**937**	**2,264**	**6,881**	**474**	**23,990**	**33,609**	**131,615**	**26**
Commercial plantation	**0.2**	**0**	**0.5**	**0.1**	**0.3**	**0**	**0.5**	**0**	**1.1**	**2**	**1,949**	**0**
Other forest	**5**	**0**	**7**	**0.9**	**1.5**	**0.9**	**13**	**0.2**	**15**	**30**	**474**	**0**
Total	**3,109**	**2,429**	**16,565**	**965**	**939**	**2,265**	**6,895**	**474**	**24,006**	**33,640**	**134,037**	**25**

IUCN, International Union for Conservation of Nature.

[a] Multiple-use public forest could arguably be classified under IUCN category VI; however, multiple-use public forest is only classified in CAPAD this way if it is principally managed for biodiversity conservation (Dudley and Phillips 2006).

[b] 'ND' areas are protected in the National Reserve System but are not yet classified into an IUCN category.

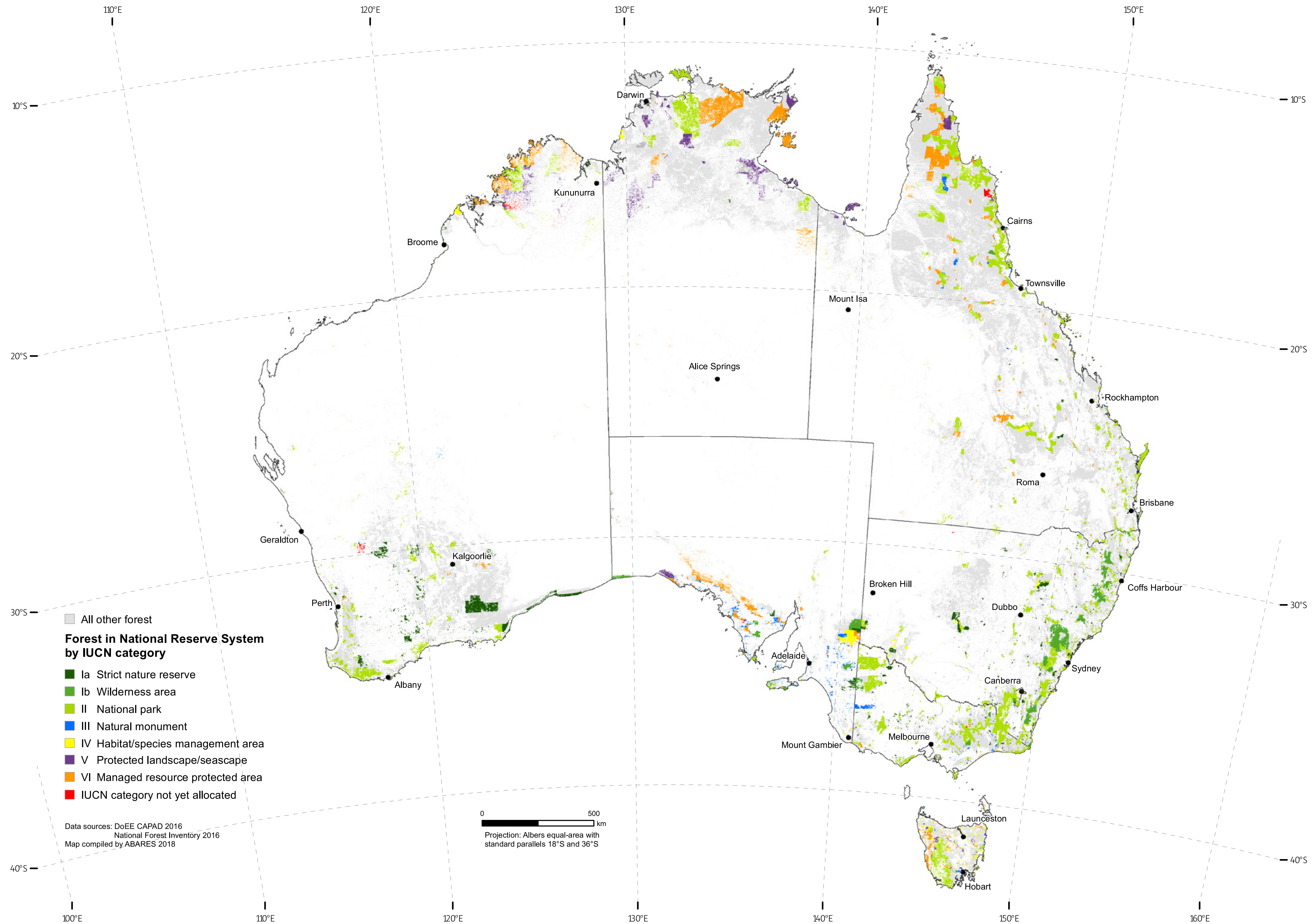
[c] Includes protected forest areas with an IUCN listing of ND.

Note: Totals may not tally due to rounding.

Source: ABARES, National Forest Inventory for forest area; Australian Government Department of the Environment and Energy (Collaborative Australian Protected Area Database 2016) for IUCN data.

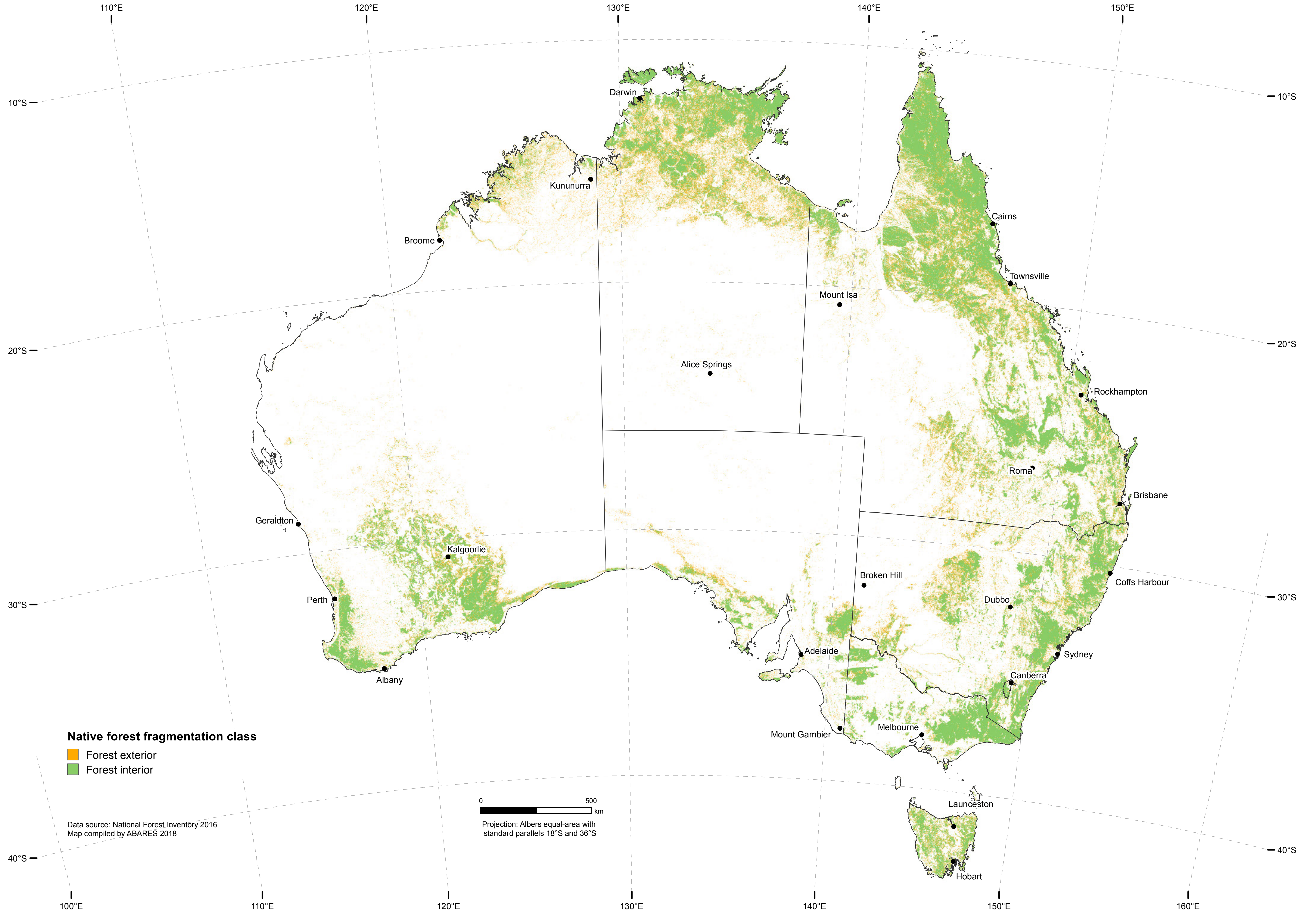
This table, together with other data for Indicator 1.1c, is available in Microsoft Excel via www.doi.org/10.25814/5bda82c8d76d4

Figure 1.16: Australia's forests in the National Reserve System, by IUCN protected area category



A higher resolution version of this map is available via www.doi.org/10.25814/5be3bc4321162

Figure 1.18: Native forest fragmentation class distribution across Australia



A higher resolution version of this map is available via www.doi.org/10.25814/5be3bc4321162

Nature conservation reserve tenure

The national land tenure category of nature conservation reserve comprises publicly owned lands formally reserved for environmental, conservation and recreational purposes that are managed by state and territory governments (see Introduction).

There are 21.8 million hectares of forest on nature conservation reserve tenure (16% of Australia's total forest area), almost all of which (99.8%) is native forest. This is 0.3 million hectares larger than the figure reported in SOFR 2013 (Table 1.20).

Increases in the area of forest reported in nature conservation reserves occurred in Western Australia (0.4 million hectares), Tasmania (0.3 million hectares) and South Australia (0.2 million hectares), while there was no substantial change in the area reported for the Australian Capital Territory, New South Wales, the Northern Territory or Victoria. In Queensland, a change in land tenure designation resulted in approximately 0.7 million hectares of forest identified in SOFR 2013 as the national land tenure category 'Nature conservation reserve' (mostly national parks on Cape York Peninsula Aboriginal lands) being reclassified as the national land tenure category 'Private forest' in SOFR 2018 (see Indicator 1.1a); this area continues to be managed for conservation purposes.

Australia's total area of forest reported in SOFR 2018 (134 million hectares) is larger than the area reported in SOFR 2013 (125 million hectares), due to the use of improved data and methods (see Indicator 1.1a). Most of the newly reported forest area is in the Northern Territory, and is not in the NFI national land tenure category of nature conservation reserve. This increase in the reported area of forest in SOFR 2018 results in 16.2% of Australia's total forest area being classified in the land tenure category nature conservation reserve, compared with 17.2% in SOFR 2013 (Table 1.20).

Australia's Comprehensive, Adequate and Representative (CAR) reserve system

The *National Forest Policy Statement* (Commonwealth of Australia 1992) describes Australia's approach to forest conservation:

> *The nature conservation objectives are being pursued in three ways. First, parts of the public native forest estate will continue to be set aside in dedicated nature conservation reserve systems to protect native forest communities, based on the principles of comprehensiveness, adequacy and representativeness (CAR reserves). The reserve system will safeguard endangered and vulnerable species and communities. The terms 'reserves' and the 'reservation system' mean National Parks and all other areas that have been specifically dedicated by government for the protection of conservation values. Other areas of forest will also be protected to safeguard special areas and to provide links where possible between reserves or other protected areas. Second, there will be complementary management outside reserves, in public native forests that are available for wood production and other commercial uses and in forests on unallocated or leased Crown land. Third, the management of private forests in sympathy with nature conservation goals will be promoted.*

The goal of a CAR reserve system for Australia was endorsed by all Australian governments as signatories to the *National Forest Policy Statement* (1992) and the *National Strategy for Conservation of Australia's Biological Diversity* (2010). The CAR reserve system is built on nationally agreed criteria (Commonwealth of Australia 1997), forms the scientific framework for the National Reserve System[48], and applies throughout Australia for both terrestrial and marine areas at Commonwealth, state and territory levels.

The development of Regional Forest Agreements (RFAs) (see Introduction) implemented the CAR (comprehensive, adequate and representative) principles in the allocation

Table 1.20: Forest in nature conservation reserve tenure

Forest area	Unit	SOFR 2013	SOFR 2018
Total forest[a]	**million hectares**	**124.7**	**134.0**
Forest in nature conservation reserve[b]	million hectares	21.5	21.8
Proportion of forest in nature conservation reserves	%	17.2	16.2
Native forest[c]	**million hectares**	**122.6**	**131.6**
Native forest in nature conservation reserve[b]	million hectares	21.5	21.7
Proportion of native forest in nature conservation reserve	%	17.5	16.5

[a] 'Total forest' includes all categories of forest. For SOFR 2018, total forest is reported under the three categories: native forest, commercial plantation, and other forest. Reasons underpinning changes in how Australia's forest area is reported over time are discussed in Indicator 1.1a.

[b] Nature conservation reserve tenure, as described in Indicator 1.1a. Does not include formal or informal reserves on other tenures.

[c] Reasons underpinning changes in how Australia's native forest area is reported over time are discussed in Indicator 1.1a

Note: Figures may differ from those reported in state, territory or regional reports, such as Regional Forest Agreement reports, due to different input datasets.

Source: ABARES, National Forest Inventory (NFI), for forest area and national land tenure (see Indicator 1.1a).

This table, together with other data for Indicator 1.1c, is available in Microsoft Excel via www.doi.org/10.25814/5bda82c8d76d4

[48] www.environment.gov.au/land/nrs/science/scientific-framework

Kosciuszko National Park, New South Wales.

of forest areas to the nature conservation reserve system or to multiple-use public forests (including land where wood production can be a management objective). All states that undertook comprehensive regional assessments as part of the RFA process (New South Wales, Queensland, Tasmania, Victoria and Western Australia) have developed approaches to forest protection and conservation that include the four components of the CAR reserve system:

- **Formal reserves** are publicly managed land tenures that cannot be revoked without parliamentary approval. "Dedicated" formal reserves exclude mining. Publicly owned reserves are an integral part of the total area protected for biodiversity conservation, and include the areas reported above under the land tenure category nature conservation reserve.
- **Informal reserves** on public land are protected through administrative instruments by public agencies. Informal reserves are an integral part of the CAR reserve system, and many are part of the National Reserve System.
- **Values protected by prescription**: some states and territories, where the nature of a forest value on public land makes inclusion in either formal or informal reserves impractical, provide protection for these values as prescribed in codes of practice, forest management plans or systems, or other regulatory instruments. Examples of such values include very rare values, values with fragmented distributions, values occurring in linear form such as riparian vegetation, or values that are not otherwise mappable. Examples of areas managed by prescription include Harvest Exclusion and Special Prescription Zones in multiple-use public forest in New South Wales, and fauna habitat zones in multiple-use public forest in Western Australia[49]. (Special Protection Zones in Victorian state forests are informal and formal reserves.) Areas managed by prescription are also an integral part of the CAR reserve system.
- **Private CAR reserves** are areas of private land that are managed in the long term for the protection of CAR values under secure arrangements, including proclamation under legislation and contractual agreements such as management agreements and conservation covenants. They also include reserves set aside under independently certified forest management systems. Private CAR reserves are also an integral part of the CAR reserve system.

CAR reserves are present on a variety of tenures within and outside RFA regions. CAR reserves are also present across a range of other categories of protected forest (such as the National Reserve System, formal nature conservation reserves, and forest under privately managed covenants). Management arrangements and approaches differ between the four different components of the CAR reserve system and between different tenure categories.

The area of forest in formal and informal CAR reserves on public land in the Australian Capital Territory, New South Wales, Tasmania, Victoria and Western Australia, and on private land in New South Wales and Tasmania, is shown in Tables 1.21–1.25. Areas of forest on public land not in formal or informal reserves, but included in the CAR reserve system as they are managed by prescription, are also presented for the Australian Capital Territory, New South Wales, Victoria and Western Australia. As with SOFR 2013, data for CAR reserves in Queensland were incomplete and are not reported here. All multiple-use public native forest in South Australia is protected under jurisdictional legislation that excludes harvesting of any native forest, but is not reported here as part of the CAR reserve system.

The total area of public native forest in the Australian Capital Territory that is protected in formal and informal CAR reserves, and in areas protected by prescription, is 120 thousand hectares. This is 92% of the total native forest area in the Australian Capital Territory (Table 1.21).

In New South Wales, the total area of public and private native forest protected in CAR reserves (formal and informal reserves, areas protected by prescription, and private reserves) is 6.39 million hectares. This includes 51% of the area of native forest on public land (Table 1.22), as well as 3% of the area of native forest on private land. Together, 32% of the total area of native forest in New South Wales is protected in the CAR reserve system (Table 1.22).

[49] Fauna habitat zones in Western Australia are described at www.dpaw.wa.gov.au/management/forests/about-our-forests/171-protecting-our-biological-diversity.

The total area of public and private native forest protected in formal, informal and private CAR reserves in Tasmania is 2.10 million hectares, which is 63% of the total native forest area in that state (Table 1.23). This is an increase of almost 0.60 million hectares of forest in reserves over the area reported in SOFR 2013. Table 1.23 includes the area of forest on other formal reserves on public land, such as those established under the 2005 Tasmanian Community Forest Agreement, which have the official land tenure of multiple-use public forest rather than nature conservation reserve. A total of 17% of Tasmania's native forest is in either informal public CAR reserves or privately owned CAR reserves; the area of forest in private CAR reserves has increased by 10,000 hectares over that reported in SOFR 2013.

Table 1.21: Area of native forest in the CAR reserve system on public land in the Australian Capital Territory, by CAR reserve type

Forest area	Unit	Components of public CAR reserve system			Total native forest in CAR reserve system
		Formal reserves	Informal CAR reserves	Values protected by prescription	
Native forest	'000 hectares	113[a]	6[b]	1.3[c]	120
Proportion of total native forest[d,e]	%	86	5	1	92

CAR, Comprehensive, Adequate and Representative.

[a] Native forest with tenure type 'Nature conservation reserve' (Indicator 1.1a).

[b] Includes areas of 'multiple-use public forest', and areas of forest on 'other Crown land'.

[c] Native forest in areas managed by the Australian Government Department of Defence.

[d] Calculated based on ACT native forest area of 130 thousand hectares (Indicator 1.1a).

[e] The national land tenure category 'private' does not apply in the ACT.

Source: ABARES, National Forest Inventory (NFI) for forest area; ACT Environment, Planning and Sustainable Development Directorate.

This table, together with other data for Indicator 1.1c, is available in Microsoft Excel via www.doi.org/10.25814/5bda82c8d76d4

Table 1.22: Area of native forest in the CAR reserve system on public and private land in New South Wales, by CAR reserve type

Forest area	Unit	Components of public CAR reserve system			Private CAR reserves	Total native forest in CAR reserve system
		Formal reserves	Informal reserves	Values protected by prescription		
Native forest	'000 hectares	5,602[a]	188[b]	355[b]	244	6,389
Proportion of native forest on public land[c]	%	45	2	3	n.a.	51
Proportion of total native forest[d]	%	28	1	2	1	32

CAR, Comprehensive, Adequate and Representative; n.a., not applicable.

[a] Native forest in tenure type 'nature conservation reserve' (Indicator 1.1a), plus native forest in Special Protection Zones in tenure type 'multiple-use public forest'.

[b] Includes some native forest on 'other Crown land' managed by the Australian Government Department of Defence. Reported area figures for informal reserves are lower than reported for SOFR 2013, and reported area figures for values protected by prescription are higher than for SOFR 2013, as a result of the correction of a data coding error for data reported in SOFR 2013.

[c] Calculated based on NSW native forest area on public land (leasehold, multiple-use public forest, nature conservation reserve, other Crown land) of 12.43 million hectares (Indicator 1.1a).

[d] Calculated based on NSW total native forest area of 19.93 million hectares (Indicator 1.1a).

Source: ABARES, National Forest Inventory (NFI) for forest area, Forestry Corporation of NSW, Australian Government Department of Defence.

This table, together with other data for Indicator 1.1c, is available in Microsoft Excel via www.doi.org/10.25814/5bda82c8d76d4

Table 1.23: Area of native forest in the CAR reserve system on public and private land in Tasmania, by CAR reserve type

Forest area	Unit	Components of public CAR reserve system			Private CAR reserves	Total native forest in CAR reserve system
		Dedicated formal reserves	Other formal reserves	Informal reserves		
Native forest	'000 hectares	881	661[a]	459[b]	93	2,093[c]
Proportion of native forest on public land[d]	%	35	26	18	n.a.	79
Proportion of total native forest[e]	%	26	20	14	3	63

CAR, Comprehensive, Adequate and Representative; n.a., not applicable.

[a] Areas subject to the *Mineral Resources Development Act 1995* (Tas.).

[b] Includes areas of native forest on other Crown land that are managed by the Australian Government Department of Defence.

[c] Total does not include 'values protected by prescription', because these are not reported by the state in this format.

[d] Calculated based on Tasmania native forest area on public land (multiple-use public forest, nature conservation reserve, other Crown land) of 2.54 million hectares (Indicator 1.1a).

[e] Calculated based on reported native forest area in Tasmania of 3.34 million hectares (Indicator 1.1a).

Note: Totals may not tally due to rounding.

Source: ABARES, National Forest Inventory (NFI) for forest area; Forest Practices Authority Tasmania.

This table, together with other data for Indicator 1.1c, is available in Microsoft Excel via www.doi.org/10.25814/5bda82c8d76d4

In Victoria, the total area of public native forest in formal reserves, informal CAR reserves and areas protected by prescription is 4.32 million hectares, which is 65% of the area of native forest on public land and 56% of the total native forest area in that state (Table 1.24). Since SOFR 2013, there was an overall increase in native forest protected on public land in both formal and informal CAR reserves of 67 thousand hectares, but a net decrease of 70 thousand hectares in the reported area protected by prescription mainly due to a revision of outdated fire management zones in the East Gippsland Forest Management Area.

Data on forests on private CAR reserves in Victoria are incomplete. However, the available data indicate that the area of such reserves has increased. For example, the organisation Trust for Nature[50] has established more than 1,300 conservation covenants across Victoria that offer legally binding protection to 61 thousand hectares of native vegetation on private land, which includes forested land (Trust for Nature 2016). This is an increase of 16 thousand hectares over the figure reported in SOFR 2013.

In Western Australia, the total area of public forest in formal reserves, informal CAR reserves and areas protected by prescription is 5.8 million hectares, which is 33% of the area of forest on public land and 28% of the total forest area in that state (Table 1.25). Most of this protected area is in the south-west of the state.

A key tenet of the RFA process was the development and implementation of the CAR reserve system. A total of 70% of native forest on public land (48% of the area of native forests on all tenures) is protected by these mechanisms in the 11 RFA regions (Table 1.26). Tasmania and East Gippsland RFA regions are the RFA regions with the greatest proportion of native forest in the CAR reserve system (both 56%), with 53% of the native forest in the South-West Forest Region of Western Australia and 51% of the native forest in the Southern RFA region (New South Wales) in the CAR reserve system. Data on forests located on private CAR reserves in Western Australia are incomplete. However, the data provided indicate that the area of such reserves has increased.

Table 1.24: Area of native forest in the CAR reserve system on public land in Victoria, by CAR reserve type

		Components of public CAR reserve system			
Forest area	**Unit**	**Dedicated formal reserves**	**Informal CAR reserves**	**Values protected by prescription**	**Total native forest in CAR reserve system**
Native forest	'000 hectares	3,366[a]	764[b]	186[b]	4,316
Proportion of native forest on public land[c]	%	51	11	3	65
Proportion of total native forest[d]	%	44	10	2	56

CAR, Comprehensive, Adequate and Representative.

[a] Native forest in tenure type 'Nature conservation reserve' (Indicator 1.1a).

[b] Includes areas of native forest on other Crown land managed by the Australian Government Department of Defence.

[c] Calculated based on reported native forest on public land (multiple-use public forest, nature conservation reserve, other Crown land) in Victoria of 6.66 million hectares (Indicator 1.1a).

[d] Calculated based on reported native forest area in Victoria of 7.64 million hectares (Indicator 1.1a).

Note: Totals may not tally due to rounding.

Source: ABARES, National Forest Inventory (NFI) for forest area; Victorian Department of Environment, Land, Water and Planning; Australian Government Department of Defence.

This table, together with other data for Indicator 1.1c, is available in Microsoft Excel via www.doi.org/10.25814/5bda82c8d76d4

Table 1.25: Area of forest in the CAR reserve system on public land in Western Australia, by CAR reserve type

		Components of public CAR reserve system			
Forest area	**Unit**	**Dedicated formal reserves**	**Informal CAR reserves**	**Values protected by prescription**	**Total forest in CAR reserve system**
Forest	'000 hectares	5,418[a]	99[b]	328[c]	5,845
Proportion of forest on public land[d]	%	n.d.	n.d.	n.d.	33
Proportion of total forest[e]	%	26	0	1	28

CAR, Comprehensive, Adequate and Representative; n.d., data not available.

[a] Calculated from the total forest area figures supplied by WA for CAR reserve areas inside the WA RFA region plus the native forest area in tenure type 'Nature conservation reserve' (Indicator 1.1a) outside the WA RFA region.

[b] Forest in the 'CAR informal reserves' category in tenure type 'Multiple-use public forest', plus the area of 'CAR informal reserves' on other Crown land that are managed by the Australian Government Department of Defence.

[c] Forest in the 'Other informal reserves and fauna habitat zones' category in tenure type 'Multiple-use public forest', plus the area of native forest with values protected by prescription on 'other Crown land' that are managed by the Australian Government Department of Defence.

[d] Calculated from the reported total forest area on public land (leasehold, multiple-use public forest, nature conservation reserve, other Crown land) in Western Australia of 17.98 million hectares (Indicator 1.1a)

[e] Calculated from the reported total forest area in Western Australia of 20.98 million hectares (Indicator 1.1a).

Source: ABARES, National Forest Inventory (NFI) for forest area; Western Australian Department of Parks, Attractions and Wildlife; Australian Government Department of Defence.

This table, together with other data for Indicator 1.1c, is available in Microsoft Excel via www.doi.org/10.25814/5bda82c8d76d4

[50] www.trustfornature.org.au

Table 1.26: Area of native forest in the CAR reserve system in RFA regions, on public and private land tenure

RFA region	Area of native forest ('000 hectares)										
	Public CAR reserve system										
	Dedicated formal reserve	Informal CAR reserve	Values protected by prescription	Other formal reserve	Total public CAR reserve system	Private CAR reserve system	Total CAR reserve system	Total RFA region	Proportion that is in CAR reserve system (%)	Total public land in RFA region[c]	Proportion that is in CAR reserve system[c] (%)
Eden	270	4	18	n.a.	292	3	295	550	54	425	69
Upper North East	636	57	90	n.a.	783	15	798	2,297	35	1,100	71
Lower North East	1,324	79	80	n.a.	1,483	14	1,497	3,404	44	1,886	79
Southern NSW	1,272	26	48	n.a.	1,346	11	1,357	2,510	54	1,672	81
Total RFA regions in NSW	**3,503**	**166**	**235**	**n.a.**	**3,904**	**42**	**3,947**	**8,761**	**45**	**5,083**	**77**
Tasmanian[a]	871	450	n.a.	658	1,979	92	2,071	3,319	62	2,521	78
Total RFA region in Tasmania	**871**	**450**	**n.a.**	**658**	**1,979**	**92**	**2,071**	**3,319**	**62**	**2,521**	**78**
Central Highlands	178	92	20	n.a.	290	n.d.	290	699	41	589	49
East Gippsland	455	106	60	n.a.	621	n.d.	621	1,104	56	1,039	60
Gippsland	479	250	13	n.a.	742	n.d.	742	1,480	50	1,329	56
North East	411	173	24	n.a.	608	n.d.	608	1,281	47	1,133	54
West Victoria	471	137	37	n.a.	645	n.d.	645	1,074	60	810	80
Total RFA regions in Victoria	**1,994**	**758**	**154**	**n.a.**	**2,906**	**n.d.**	**2,906**	**5,638**	**52**	**4,900**	**59**
South-West Forest Region of WA[b]	1,311	83	162	n.a.	1,556	n.d.	1,557	2,698	58	2,235	70
Total RFA regions in WA	**1,311**	**83**	**162**	**n.a.**	**1,556**	**n.d.**	**1,557**	**2,698**	**58**	**2,235**	**70**
Total RFA regions	**7,679**	**1,457**	**552**	**658**	**10,346**	**134**	**10,480**	**20,416**	**51**	**14,740**	**70**

RFA, Regional Forest Agreement. In NSW, the Upper North East and Lower North East regions are covered by a single RFA.
n.a., not applicable to this jurisdiction; n.d., data not available.

[a] Areas for Tasmania are derived from the spatial boundary of the Tasmanian RFA region held by ABARES, and differ slightly from the areas derived from the spatial boundary of the state of Tasmania used in other tables.

[b] For Western Australia, area figures in the CAR reserve system are for total forest.

[c] Public land includes national land tenure categories of 'Leasehold forest', 'Nature conservation reserve', 'Multiple-use public forest' and 'Other Crown land'.

This table, together with other data for Indicator 1.1c, is available in Microsoft Excel via www.doi.org/10.25814/5bda82c8d76d4

Protected native forests in Australia's Defence estate

The Australian Government Department of Defence manages 1.32 million hectares of land with native forest. This is classified under the national land tenure category 'Other Crown land' (see Indicator 1.1a). A total of 40% of the native forest in the Defence estate is in the Northern Territory, 37% is in Queensland and 14% is in Western Australia.

A total of 58 thousand hectares of native forest in Tasmania, New South Wales and Western Australia in the Defence estate was identified as 'Informal CAR reserve' through the RFA process (Table 1.27). The Buckland Military Training Area in Tasmania is an example of land in his category. The remaining 1.26 million hectares of native forest in the Defence estate are outside RFA regions, for example the Shoalwater Bay Training Area in Queensland, and are classified in the CAR system as 'Values protected by prescription'; the largest of these areas are in the Northern Territory, Queensland and Western Australia (Table 1.27).

Together, all native forest on the Defence estate is classified as protected. In 2016 a twenty-year Defence Environmental Strategy[51] was released that describes the process the Department is implementing to deliver sustainable environmental management on the land that it manages.

Conservation covenants on private forests

Private reserves established under a conservation covenant are important because they are often selected to protect rare or endangered species or other important values, and can complement protected areas on publicly managed land. A conservation covenant is a voluntary, permanent, legally binding agreement made between a landholder and a Covenant Scheme Provider that aims to protect and enhance the natural, cultural and/or scientific values of an area of land[52]. The owner can continue to own, use and live on the land while the natural values of an area are conserved by the landholder in partnership with the Covenant Scheme Provider. Providers can include not-for-profit organisations, government agencies or local Councils. Conservation covenant programs can apply to privately managed forest on private freehold or leasehold tenure.

A number of national and state and territory organisations undertake conservation covenanting programs. For SOFR 2018, data describing conservation covenants on private forests were supplied by a number of state- and territory-based conservation covenant organisations, including Trust for Nature (Victoria), the Nature Conservation Trust (New South Wales) and the National Trust of Australia (Western Australia), and were assembled into the National Forest Inventory. Data on the national programs managed by the Australian Wildlife Conservancy[53], Bush Heritage Australia[54] and the Nature Conservancy[55] have not been included; however, the areas managed by the Australian Wildlife

Table 1.27: Area of native forest in Australia's Defence estate, by jurisdiction and CAR reserve type

	Area ('000 hectares)			
		Native forest in Defence estate in CAR reserve system		
Jurisdiction	Total native forest in Defence estate	Informal CAR reserve[a]	Values protected by prescription[b]	Total CAR reserve system
ACT	1.3	0	1.3	1.3
NSW	39	18	21	39
NT	531	0	531	531
Qld	487	0	487	487
SA	35	0	35	35
Tas.	24	24	0	24
Vic.	22	0	22	22
WA	181	16	165	181
Australia	**1,321**	**58**	**1,263**	**1,321**

[a] Informal CAR reserves are in RFA regions.
[b] Values are protected by prescription outside RFA regions.
Note: Totals may not tally due to rounding.
Source: ABARES, National Forest Inventory (NFI); Australian Government Department of Defence.

This table, together with other data for Indicator 1.1c, is available in Microsoft Excel via www.doi.org/10.25814/5bda82c8d76d4

[52] www.defence.gov.au/estatemanagement/Governance/Policy/Environment/Policy/EnvironmentStrategy2016.PDF
[52] www.environment.gov.au/biodiversity/conservation/covenants
[53] www.australianwildlife.org/
[54] www.bushheritage.org.au/
[55] www.nature.org/ourinitiatives/regions/australia/index.htm?redirect=https-301

Conservancy and Bush Heritage Australia are captured in the National Reserve System (see above). The National Conservation Lands Database, which was used as a data source for SOFR 2013, has not been maintained.

The area of forest in Australia over which a legally binding private conservation covenant is in place is identified in the National Forest Inventory as 3.2 million hectares (Table 1.28). SOFR 2013 reported that 1.8 million hectares of forest were protected through private conservation covenant programs.

The largest areas of forest under private conservation covenant are in Queensland and South Australia (Table 1.28)[56]. Nationally, 69% of the total area of forest identified in the National Forest Inventory as protected under private conservation covenant is on leasehold land tenure, 30% is on private tenure and 1% on other Crown land. The most common forest types on conservation covenanted land are Eucalypt woodland forests (2.5 million hectares), Eucalypt open forests (0.3 million hectares) and Acacia forests (0.2 million hectares) (Table 1.28).

Many covenanting schemes are recognised under the National Reserve System. Of the 3.2 million hectares of forested land under private conservation covenant, 3.1 million hectares are listed in CAPAD as protected areas in the National Reserve System (compare Tables 1.28 and 1.31). However, the private covenanted forest dataset and CAPAD are assembled using different criteria, and data are collected using different methods.

Except for Tasmania and New South Wales, data describing conservation covenants on privately managed forests are not included in the figures on CAR reserve areas above, because they are derived from different datasets with an undetermined degree of overlap.

UNESCO[57] World Heritage List

The World Heritage Convention[58] establishes a list of places that have natural and/or cultural values of outstanding global significance. Inclusion of a place on the World Heritage List does not affect ownership rights, and a country's jurisdictional and local government laws still apply. However, as a signatory to the convention, Australia has an obligation to identify places for, and protect and conserve places on, the World Heritage List. Australia's forested World Heritage List areas include Kakadu National Park (Northern Territory), the Wet Tropics of Queensland, Shark Bay (Western Australia), Fraser Island (Queensland), Gondwana Rainforests (New South Wales), the Greater Blue Mountains Area (New South Wales), and the Tasmanian Wilderness World Heritage Area.

Table 1.28: Area and type of forest on land protected by private conservation covenants

	Area ('000 hectares)								
Forest type	**ACT**	**NSW[a]**	**NT**	**Qld**	**SA**	**Tas.**	**Vic.**	**WA**	**Australia**
Native forest									
Acacia	0	1	0	196	1.3	2	0	2	202
Callitris	0	19	0	15	2	0	0	0	36
Casuarina	0	15	0	2	3	1.3	0.5	0.1	22
Eucalypt	0.7	201	0	1,512	768	80	34	142	2,738
Eucalypt closed	0	0	0	0	0	0	0.2	1	1
Eucalypt open	1.6	94	0	101	52	17	15	5	284
Eucalypt woodland	0.1	106	0.1	1,411	716	64	19	137	2,454
Mangrove	0	0	0	3	0	0	0	0	3
Melaleuca	0	0	0	59	3	0.5	0.2	0.1	64
Rainforest	0	3	0	62	0	8	0	0	72
Other native forest	0	4	0	50	9	0.7	2	2	68
Total native forest	**0.8**	**243**	**0.1**	**1,899**	**787**	**93**	**37**	**145**	**3,205**
Commercial plantation	**0**	**0**	**0**	**0**	**0**	**1.3**	**0**	**0**	**2**
Other forest	**0**	**0**	**0**	**0**	**0**	**2**	**0.7**	**0.2**	**3**
Total forest	**0.8**	**243**	**0.1**	**1,899**	**787**	**96**	**38**	**145**	**3,209**

[a] The difference between the area reported for land protected by private conservation covenants in SOFR 2018 and that reported in SOFR 2013 is due to inconsistent input datasets, as well as differences in the forest extent (see Indicator 1.1a). In the five years since SOFR 2013, there has been no removal of protection status from areas of private land in New South Wales that were legally protected in perpetuity, nor any revocations in private conservation mechanisms.

Note: Totals may not tally due to rounding.

Source: ABARES, National Forest Inventory.

This table, together with other data for Indicator 1.1c, is available in Microsoft Excel via www.doi.org/10.25814/5bda82c8d76d4

[56] All native vegetation on privately managed land in South Australia (except in parts of metropolitan Adelaide) is protected under the *Native Vegetation Act 1991* (South Australia): see www.environment.sa.gov.au/topics/native-vegetation/clearing

[57] United Nations Educational, Scientific and Cultural Organization.

[58] whc.unesco.org/en/conventiontext

Table 1.29: Area of native forest in World Heritage Areas, by forest type and jurisdiction

	Area ('000 hectares)										
	Native forest in World Heritage Areas										Proportion of native forest in World Heritage Areas (%)
Native forest type	ACT	NSW	NT	Qld	SA	Tas.	Vic.	WA	Australia	Total	
Acacia	0	0.2	0.2	15	0	5	0	0.4	21	10,813	0.2
Callitris	0	0.7	0	0	0	0	0	0	1	2,011	0.03
Casuarina	0	58	0	26	0	0	0	0	84	1,236	6.8
Eucalypt	0	1,138	1,054	396	0.2	517	0	18	3,124	101,058	3.1
Eucalypt closed	0	0	3	10	0	4	0	0	17	534	3.2
Eucalypt open	0	767	363	271	0	315	0	0	1,716	27,695	6.2
Eucalypt woodland	0	370	689	115	0.2	198	0	18	1,391	72,829	1.9
Mangrove	0	0	11	62	0	0	0	0.4	73	854	8.6
Melaleuca	0	0	102	16	0	9	0	0.9	129	6,382	2.0
Rainforest	0	132	46	678	0	301	0	0	1,157	3,581	32
Other native forest	0	16	5	79	0	32	0	5	136	5,679	2.4
Total native forest	**0**	**1,345**	**1,218**	**1,272**	**0.2**	**865**	**0**	**24**	**4,724**	**131,615**	**3.6**
Native forest in World Heritage Area as proportion of total native forest in World Heritage Areas (%)	0	28	26	27	0	18	0	0.5	100		
Native forest in World Heritage Area as proportion of total native forest in jurisdiction (%)	0.0	6.7	5.1	2.5	0.0	26	0.0	0.1	3.6		
Total native forest in jurisdiction	**130**	**19,925**	**23,686**	**51,580**	**4,856**	**3,342**	**7,645**	**20,450**	**131,615**		

Notes: Totals may not tally due to rounding.

Source: ABARES, National Forest Inventory (NFI); Australian Government Department of the Environment and Energy.

This table, together with other data for Indicator 1.1c, is available in Microsoft Excel via www.doi.org/10.25814/5bda82c8d76d4

Upper reaches of Jim Jim Creek, Kakadu National Park, Northern Territory.

In 2016, Australia had 19 areas on the World Heritage List. Excluding those offshore or in urban areas, the 12 World Heritage Areas on mainland Australia covered a total of 7.7 million hectares, of which 4.7 million hectares carries native forest (Table 1.29). A total of 3.6% of Australia's native forest area is in World Heritage Areas. The most recent additions of Australian sites on the list were the extensions to the Tasmanian Wilderness World Heritage Area.

New South Wales has the largest area of native forest listed as World Heritage Areas (1.35 million hectares), followed by Queensland (1.27 million hectares), and the Northern Territory (1.22 million hectares). Tasmania has the highest proportion of its total native forest area (26%) listed in World Heritage Areas.

The area of forest in World Heritage Areas as at 2016 (4.7 million hectares) is 0.44 million hectares more than was reported in SOFR 2013. This is due to increases in the reported area of forest in the Northern Territory (mostly in Kakadu National Park), and consequently the area of forest in World Heritage Areas in that jurisdiction; and to extensions to the Tasmanian Wilderness World Heritage Area.

Australia's World Heritage Areas contain a high representation of rainforest: 32% of the area of the Rainforest forest type is in World Heritage Areas (Table 1.29).

Most (4.5 million hectares, 95%) of the native forest in World Heritage Areas is also protected through the National Reserve System. The 0.2 million hectares of native forest in World Heritage Areas outside the National Reserve System are predominantly on private land, other Crown land and leasehold tenures.

Ramsar List of Wetlands of International Importance

The Convention on Wetlands of International Importance (the Ramsar Convention)[59], signed in Ramsar, Iran, in 1971, aims to prevent worldwide loss of wetlands, and to achieve conservation and wise use of wetlands through international cooperation and responsible national land management. The Ramsar definition of wetlands include waterbodies such as lakes, reservoirs, rivers, estuaries, swamps and marshes, bogs, salt pans, mud flats, mangroves and coral reefs.

As a Contracting Party to the Convention, Australia has a commitment to list wetlands that meet the Ramsar criteria for inclusion in the List of Wetlands of International Importance. Australia is committed to the protection, conservation, and promotion of wise use of Ramsar wetland sites, and designated the world's first Ramsar site, the Cobourg Peninsula in the Northern Territory[60], in 1974.

Australia has 65 Ramsar sites which cover about 5.7 million hectares of the Australian mainland. A total of 1.8 million

59 www.ramsar.org/about/the-ramsar-convention-and-its-mission

60 www.environment.gov.au/water/wetlands/publications/cobourg-peninsula-ramsar-site-ecological-character-description

hectares of Ramsar sites carry native forest (Table 1.30), which is 1.3% of Australia's native forest. The Northern Territory contains most (1.4 million hectares, 79%) of Australia's native forest on Ramsar sites, of which 1.2 million hectares are in Kakadu National Park. Most of Australia's forest in Ramsar sites is Eucalypt medium woodland, Eucalypt medium open and Melaleuca forest types. Over 10% of Australia's mangrove forests are within Ramsar sites (Table 1.30).

Most (1.6 million hectares, 92%) of the native forest on Ramsar sites is also protected through the National Reserve System. The 0.14 million hectares of native forest on Ramsar sites outside the National Reserve System are predominantly on other Crown land, multiple-use public forest and unresolved tenure.

Forest in areas managed for protection of biodiversity

A range of formal and informal processes, detailed above, are used on public and private land in Australia to protect areas of forest for the conservation of biodiversity. Table 1.31 presents the total area of native forest on land reserved or managed for protection of biodiversity, by jurisdiction. These areas are derived from a spatial analysis of data assembled in the National Forest Inventory, comprising native forest in the National Reserve System, in formal nature conservation reserves, in the CAR reserve system, in multiple-use public forests, in the Defence estate, under privately managed covenants, in World Heritage Areas, and on Ramsar wetland sites.

Together there is a total of 46.0 million hectares of native forest on land protected for biodiversity conservation, or where biodiversity conservation is a specified management intent (Table 1.31). This represents 35% of Australia's native forest estate. The Australian Capital Territory, Victoria and Tasmania have the highest proportion of forest area managed for protection of biodiversity.

SOFR 2013 reported a total of 39.2 million hectares of native forest managed for the protection of biodiversity (32% of Australia's native forests as reported at that time).

International targets for the proportion of forest protected for biodiversity

There are international targets for the proportion of land protected for biodiversity conservation, whether inside or outside the national reserve system. In 2010, Parties to the Convention on Biological Diversity, including Australia, agreed a Strategic Plan for Biodiversity 2011–2020 including Aichi Biodiversity Targets[61]. Under the Plan's strategic goal "to improve the status of biodiversity by safeguarding ecosystems, species and genetic diversity", Aichi Biodiversity Target 11[62] specifies:

> *By 2020, at least 17 per cent of terrestrial and inland water areas and 10 per cent of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well-connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscape and seascape.*

The 35% of Australia's native forest estate on land managed for protection of biodiversity (Table 1.31), which includes Australia's forest area in IUCN protected area categories I–VI in the National Reserve System (Table 1.19) as well as other forest land managed for protection of biodiversity, therefore represents achievement of Aichi Biodiversity Target 11 with respect to Australia's native forests.

View from the walk to the top of Barrk Marlam (Jim Jim Falls), Kakadu National Park, Northern Territory. Kakadu National Park is included on the World Heritage List for both cultural and natural outstanding universal values.

61 Conference of Parties to the Convention on Biological Diversity (Tenth Meeting, Nagoya, Japan, 18–29 October 2010) Decision X/2 – The Strategic Plan for Biodiversity 2011–2020 and the Aichi Biodiversity Targets.

62 www.cbd.int/sp/targets/rationale/target-11/

Table 1.30: Area of native forest on Ramsar wetland sites, by forest type and jurisdiction

	Area ('000 hectares)										
	Native forest on Ramsar wetland sites										
Native forest type	**ACT**	**NSW**	**NT**	**Qld**	**SA**	**Tas.**	**Vic.**	**WA**	**Australia**	**Total**	**Proportion of native forest on Ramsar wetland sites (%)**
Acacia	0	1	0	27	0	0	1	0	29	10,813	0.3
Callitris	0	0	0	0	0	0	0	0	0	2,011	0
Casuarina	0	1	0	5	0	0	0	0	6	1,236	0.5
Eucalypt	0.3	108	1,217	50	12	0.6	55	15	1,459	101,058	1.4
Eucalypt closed	0	0	5	7	0	0	0	0	12	534	2.3
Eucalypt open	0	32	510	18	3	0	30	2	595	27,695	2.1
Eucalypt woodland	0.2	77	702	25	10	0	25	13	852	72,829	1.2
Mangrove	0	0	29	51	0	0	1	12	93	854	11
Melaleuca	0	3	106	11	0	0	1	1	123	6,382	1.9
Rainforest	0	1	54	3	0	0	0	0	58	3,581	1.6
Other native forest	0	2	6	5	2	0	3	3	20	5,679	0.4
Total native forest	**0.3**	**116**	**1,411**	**152**	**15**	**1**	**61**	**32**	**1,788**	**131,615**	**1.4**
Total native forest in jurisdiction	**130**	**19,925**	**23,686**	**51,580**	**4,856**	**3,342**	**7,645**	**20,450**	**131,615**		
Native forest on Ramsar sites as a proportion of total native forest (%)	**0.2**	**0.6**	**6.0**	**0.3**	**0.3**	**0**	**0.8**	**0.2**	**1.4**		
Native forest on Ramsar sites as a proportion of total native forest on Ramsar sites (%)	**0.02**	**7**	**79**	**9**	**1**	**0.08**	**3**	**2**	**100**		

Notes: Totals may not tally due to rounding.

Source: ABARES, National Forest Inventory (NFI); Australian Government Department of the Environment and Energy.

This table, together with other data for Indicator 1.1c, is available in Microsoft Excel via www.doi.org/10.25814/5bda82c8d76d4

Table 1.31: Area of native forest on land managed for protection of biodiversity, by jurisdiction

	Area ('000 hectares)								Proportion of native forest managed for protection of biodiversity (%)
		Native forest not in the National Reserve System but managed for protection of biodiversity[a]							
Jurisdiction	Native forest in the National Reserve System	Nature conservation reserve tenure[b]	Areas under private covenant[c]	Multiple-use public forests[d]	Protected areas in Defence estate[e]	Protected areas not otherwise reported[f]	Total native forest managed for protection of biodiversity	Total native forest	
ACT	114	0	0	5	1	2	122	130	93
NSW	5,776	17	86	1,816	34	33	7,762	19,925	39
NT	5,847	1.1	0	0	526	0	6,374	23,686	27
Qld	8,889	16	3	2,826	448	189	12,371	51,580	24
SA	2,613	17	0.1	8	35	4	2,678	4,856	55
Tas.	1,622	4	17	612	24	324	2,603	3,342	78
Vic.	3,322	86	35	3,036	22	26	6,527	7,645	85
WA	5,426	569	8	1,342	181	3	7,528	20,450	37
Australia	**33,609**	**710**	**148**	**9,645**	**1,272**	**581**	**45,965**	**131,615**	**35**

[a] Native forest areas in the CAR reserve system are either in the National Reserve System or in one of the other categories listed in this table.
[b] Comprises native forest on nature conservation reserve tenure not included in the National Reserve System.
[c] Comprises areas of native forest under private conservation covenant not in the National Reserve System. These areas are on predominantly leasehold and private land tenures.
[d] Multiple-use public native forests are included where biodiversity conservation is a specified management intent, either through jurisdictional legislation designating protection of the forest area and conservation of biodiversity being specified in legislation, or through conservation of biodiversity being regulated or managed through a management planning instrument.
[e] Comprises forest on the Defence estate (on other Crown land tenure) not included in other categories.
[f] Comprises forest in the CAR reserve system, World Heritage Areas and Ramsar wetland sites not included in other categories; includes CAR reserves on Future Potential Production Forest land in Tasmania.

Note: Totals may not tally due to rounding.

Source: ABARES, National Forest Inventory (NFI) for forest area; Australian Government Department of the Environment and Energy (CAPAD); Australian Government Department of Defence.

This table, together with other data for Indicator 1.1c, is available in Microsoft Excel via www.doi.org/10.25814/5bda82c8d76d4

Indicator 1.1d

Fragmentation of forest cover

Rationale

This indicator describes the loss of forest cover and the spatial configuration of that loss. Fragmentation can impact on forest-dwelling species and gene pools through changes in the connectivity of populations and the loss of species genetic variability.

Key points

- Simple metrics of forest fragmentation were calculated for Australia's current forest coverage. These metrics were based on whether each hectare of forest has an edge to an area of non-forest, and on forest patch size.
  - Fragmentation is expected in some unmodified landscapes, while additional fragmentation results from human modification of the landscape.
  - It is not possible with available data to determine the rate of change of forest fragmentation over time, or its impact on species. Information on loss and gain of forest cover is presented in Indicator 1.1a.
- A total of 72% of Australia's native forest area is comprised of one hectare cells that are completely bounded by forest. These are named 'forest-interior' cells.
  - The jurisdictions in which the highest area proportion of native forest is in forest-interior cells are the Australian Capital Territory (89%) and Victoria (88%).
  - The areas of forest with the lowest proportion of forest-interior cells, and thus the highest proportions of fragmentation, are found in ecoregions where woodland forest intergrades into woody non-forest vegetation, and in areas with the highest impacts of historical land clearing for agriculture and for urban development.
- A total of 68% of Australia's native forest is in patches of over 100,000 hectares
  - All jurisdictions have 44% or more of their native forest in patches of over 100,000 hectares.
  - The jurisdictions with the largest proportion of their native forest in patches of less than 10,000 hectares (South Australia and Western Australia) are also the jurisdictions with the highest area proportions of native forest that is woodland forest, and that borders areas carrying woody non-forest vegetation.
- The majority of Australia's forest cover is therefore continuous, not fragmented.
  - Native forest that is not fragmented is found in forested areas of higher rainfall, as well as in regions that have experienced the least clearing for agricultural land use, and in nature conservation reserves and in multiple-use public forests.
  - The main component of fragmented forest cover occurs in woodland forest, likely from the interspersion of woodland forest with areas of non-forest vegetation, as occurs in drier ecoregions of Australia. Fragmentation is also associated with stands of remnant forest in mostly cleared agricultural landscapes.
- Fragmentation statistics are also reported by Tasmania and Victoria in their respective 'State of the Forests' reports.

Otherwise continuous tracts of native forest can be naturally fragmented because of the presence of non-forest vegetation where soils or local climate are not suitable for forest, or because of features such as rock outcrops, cliffs, wetlands, lakes, streams and rivers. Fragmentation also occurs naturally around the boundary between woodland forest (which has 20–50% crown cover) and woody non-forest vegetation (with less than 20% crown cover, often called sparse woodland). Successional change can occur in both directions between forest and non-forest vegetation types, for example as forest invades grassland, or as forest dieback results in larger areas of grass-dominated ecosystems.

In addition, areas of individual forest types can be fragmented within a continuous area of forest, due to differences in soil type or rainfall. Even within a forest type, fragmentation of the spatial arrangement of age-classes, associated with successional changes and driven by response to disturbance, has also always been a feature of Australian native forests. These types of fragmentation are not considered in this indicator.

The main cause of increasing forest fragmentation over the past 200 years has been forest clearing associated with land-use change, mainly for agriculture, mining and urban development, but also for infrastructure such as roads, railways, pipelines and electricity transmission lines. As much as one-third of Australia's native vegetation in intensively used areas (mainly the agricultural and urban zones) has been cleared or substantially modified over that time. As a result, some ecological communities now occupy less than 1% of their original extent, and others have become highly fragmented (DoEE 2016a)[63].

An increase in forest fragmentation in previously continuous forest can increase edge effects, reducing habitat quality for species adapted to forest interiors. Fragmentation involving permanent clearing of forested land can thus reduce the habitat available for those plant, mammal, reptile, bird and amphibian species that require large areas of continuous forest; the impact varies considerably by species and community. On the other hand, an increase in forest fragmentation could improve habitat quality for species that live at forest edges or in open country. Threats from non-native species, including weeds and predators, also generally increase when forests are divided into smaller patches. Consequently, historical fragmentation is a key threat to some forest-dwelling species (see Indicators 1.2c and 1.3a).

References on forest fragmentation studies in Australia are given in Bradshaw (2012), and a global meta-analysis of the effect of fragmentation on biodiversity and ecosystem function is presented by Haddad et al. (2015). However, impacts due to habitat fragmentation may be confounded by impacts due to changes in the total area of habitat (Fahrig 2013).

The general cessation of broadscale clearing of native forest in much of Australia (Indicator 1.1a, Indicator 5.1a) and increased protection of forests (Indicator 1.1c) have been critical in reducing the rate of forest fragmentation. Native trees and shrubs planted in corridors can re-establish connectivity between patches of forest in agricultural landscapes.

Analysis of fragmentation involves measuring one or more of a number of parameters derived from spatial analysis of the configuration of forest cover (Tickle et al. 1998; Lindenmayer et al. 1999). Fragmentation parameters can include the relative amounts of edge and interior forest, and the size and shape of forest patches. Connectivity is generally taken to be the converse of fragmentation, with a high level of connectivity being associated with large, contiguous patches of forest.

This indicator reports a circumscribed set of spatial variables that can form the basis of tracking forest fragmentation nationally and regionally over time. However, no simple fragmentation metric can be used as a surrogate for habitat quality for forest-dwelling species, as species respond to more complex habitat features and landscape patterns (Lindenmayer et al. 2003).

National forest fragmentation statistics

Australia's forests are mapped at a one-hectare scale in the National Forest Inventory (NFI), with each one-hectare cell or 'pixel' across Australia being scored as forest or non-forest (Indicator 1.1a). This dataset is suitable for analysis of native forest fragmentation. Two sets of metrics were calculated, one set derived from the number of forest cells that each native forest cell has as (edge-to-edge) neighbours, and the other set derived from the size of patches of native forest in which every cell is a neighbour (edge-to-edge) to another forest cell (Figure 1.17).

Forest fragmentation analysed as the extent to which forest is adjacent to forest or non-forest

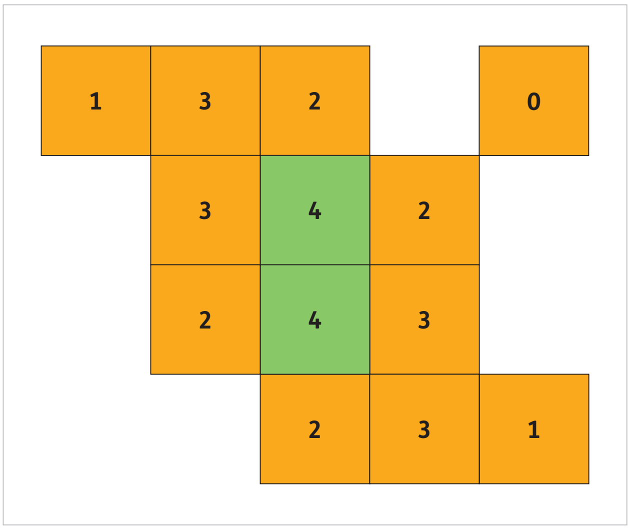
This metric distinguishes two fragmentation classes of cells (Figure 1.17):

- 'Forest-interior' cells are native forest cells that has have all their four neighbouring (edge-adjacent) cells as forest, whether native forest, commercial plantation or other forest. A higher proportion of forest-interior cells implies a forest that is relatively unfragmented, and not affected by any nearby non-forest area.
- 'Forest-exterior' cells are native forest cells that have one or more non-forest neighbouring cells, and are therefore at a boundary between forest and non-forest. They could also be named 'forest-edge' cells. A more fragmented forest has a higher proportion of forest-exterior cells and a lower proportion of forest-interior cells.

  The non-forest adjacent to forest-exterior cells may be land cleared for agricultural land use, urban development or infrastructure, with potential to affect the forest ecosystem; may be woody non-forest vegetation such as sparse woodland with under 20% crown cover, and representing a natural vegetation transition with a lesser impact on the native forest area; or may be other non-forest vegetation.

63 soe.environment.gov.au/theme/biodiversity/topic/2016/terrestrial-ecosystems-and-communities#figure-bio11a-total-loss-of-extent-of-vegetation-communities-in-australia-from-pre-1750-extents-b-a-fragmentation-measure-reflecting-the-change-in-proportion-of-vegetation-patches-made-up-of-less-than-5000hectares--119566

Figure 1.17: Schematic diagram illustrating fragmentation metrics



Notes: Diagrammatic representation of a small area of forest. White, non-forest; orange, forest-exterior cells; green, forest-interior cells (same colour scheme as Figures 1.18–20). The figures in each forest cell are the number of neighbouring (edge) cells that are forested. Each cell is one hectare (100 metres x 100 metres).

The area comprises two patches of forest. The top-right cell is a patch containing just one hectare of forest, not being edge-connected to any other forest cell, while the remaining forest cells are all edge-connected and make up a 12-hectare patch of forest.

The 13 cells in this area of forest comprise 11 forest exterior cells (coloured orange) and 2 forest interior cells (coloured green and containing the number '4'): the latter are the cells that have all four of their neighbouring (edge) cells as forest. In this area of forest, the mean number of neighbouring cells forested is 2.3, and the proportion of forest interior cells is 2/13 = 15%.

A higher resolution version of this graphic is available via www.doi.org/10.25814/5be3bc4321162

Table 1.32 shows the area proportions of each of these types of forest-interior and forest-exterior cells in the native forest of each jurisdiction. A total of 72% of Australia's native forest area is comprised of one-hectare cells completely bounded by forest. Equally, 28% of Australia's native forest area adjoins (has an edge with) an area of non-forest. The jurisdictions in which the highest area proportion of native forest that is forest-interior are the Australian Capital Territory (89%) and Victoria (88%), whereas South Australia (64%), Northern Territory (64%) and Western Australia (66%) have the lowest area proportions of native forest that is forest-interior.

The distribution of native forest by fragmentation class is shown in Figures 1.18–20, at increasing scales. Nationally (Figure 1.18, see page 88), native forest that is not fragmented is found in the forested regions of higher rainfall, as well as in regions that have experienced least clearing for agriculture, and in nature conservation reserves and in multiple-use public forests. Regionally, such as in south-west Western Australia (Figure 1.19), native forest that is not fragmented is present through forest regions of higher rainfall, while fragmented native forest is present at the drier inland margins and scattered through the agricultural zone. Locally, such as in south-western Sydney, a similar pattern is seen (Figure 1.20), where the native forest in cleared agricultural and urban areas and at the margins of more continuous forest comprises almost completely forest-exterior cells.

Table 1.33 compares these fragmentation metrics to the area proportion of woodland forest in each jurisdiction. Woodland forest, with a crown cover 20–50%, typically occurs in the drier regions of Australia (see Indicator 1.1a). The Australian Capital Territory and Victoria, which have the highest proportion of native forest area that is forest interior, have the lowest area proportions of native forest that is woodland forest. Equally, South Australia and Western Australia, which are two of the jurisdictions with the lowest proportions of native forest that is forest interior, have the highest area proportions of native forest that is woodland forest. This indicates that, as would be expected, the highest proportions of forest edge and therefore fragmented forest are found in regions where woodland forest intergrades into the non-forest category of sparse woodland (that is, woody vegetation with a crown cover below 20%).

Other drivers of forest configuration occur in the sub-tropical forests of the Northern Territory, which has a relatively high area proportion of open and closed forest adjacent to non-forest areas (Table 1.33).

Table 1.33 also compares these fragmentation metrics between the 2011 forest coverage published in SOFR 2013, and the 2016 forest coverage published in SOFR 2018. There is a slight decrease in the extent of native forest fragmentation over time. However, as only two time-points are compared, and as improved (more accurate) datasets were used to compile the 2016 coverage (see Indicator 1.1a), this difference does not necessarily represent meaningful on-ground

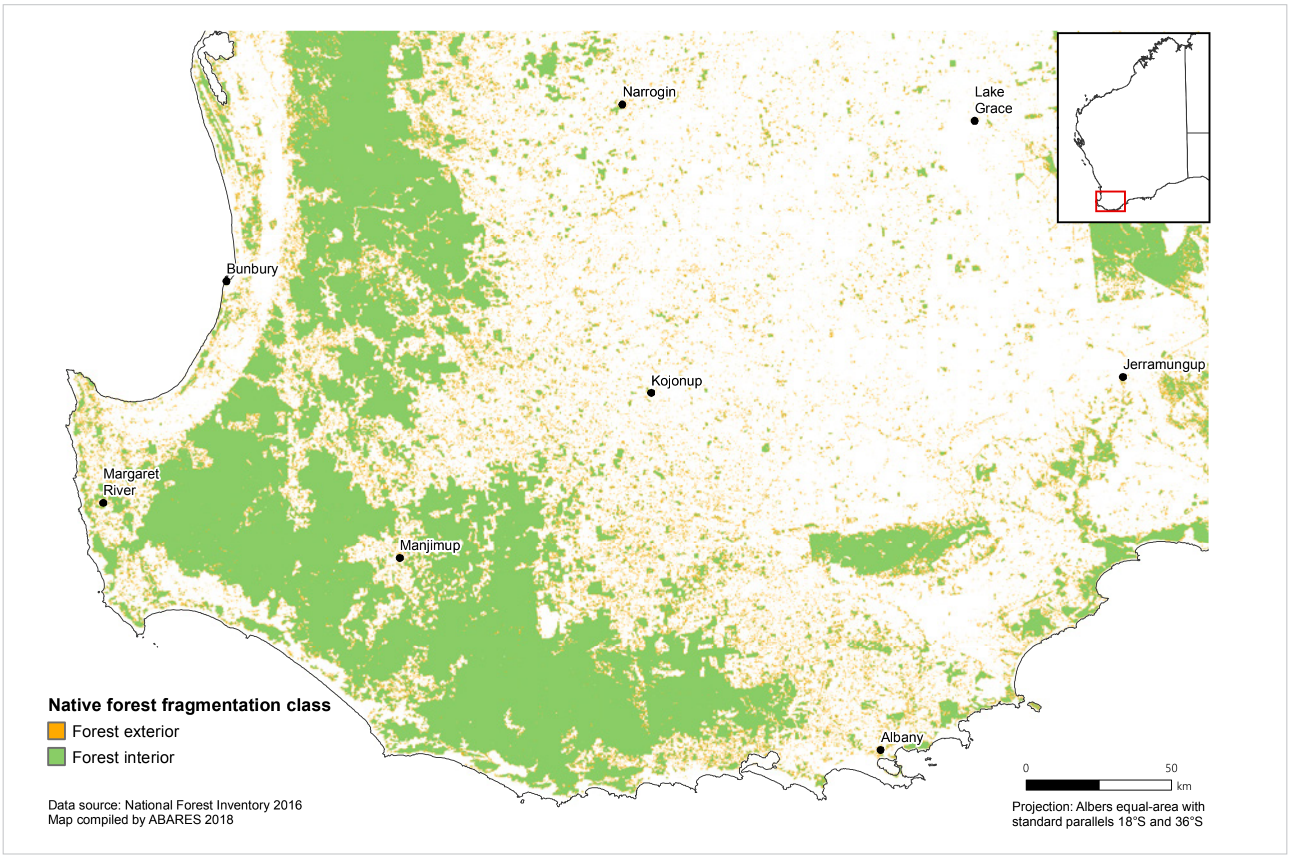
Table 1.32: Native forest area by fragmentation class, by jurisdiction

Number of neighbouring cells forested	Fragmentation class	ACT	NSW	NT	Qld	SA	Tas.	Vic.	WA	Australia
		Area as proportion of total native forest area (%)								
4	Forest interior	89	73	64	74	64	75	88	66	72
3	Forest exterior	6	12	17	13	15	14	6	15	14
2	Forest exterior	3	8	11	8	11	7	3	10	8
1	Forest exterior	1.0	4	6	3	7	3	1.5	5	4
0	Forest exterior	0.3	2	3	1.3	4	0.7	0.6	3	2
Mean number of neighbouring cells forested[a]		**3.83**	**3.49**	**3.34**	**3.57**	**3.27**	**3.61**	**3.80**	**3.37**	3.49

[a] The 'Mean number of neighbouring cells forested' is the average number of neighbouring forested cells for each forested cell in that jurisdiction.
Notes: The cells for this analysis are the 100 m x 100 m grid cells used by the National Forest Inventory. Forest coverage as at 2016 is from SOFR 2018, Indicator 1.1a. Totals may not tally due to rounding.

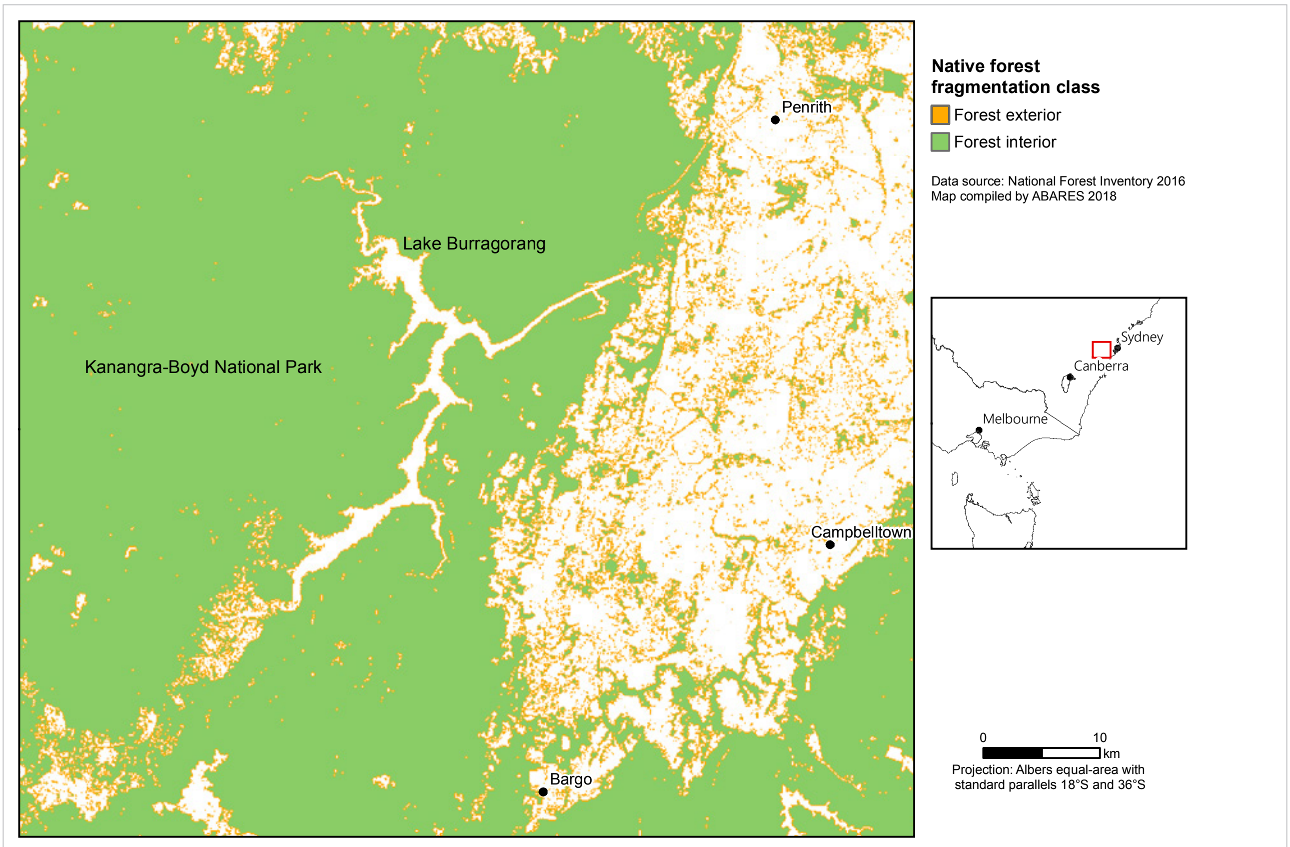
This table, together with other data for Indicator 1.1d, is available in Microsoft Excel via www.doi.org/10.25814/5bda82c8d76d4

Figure 1.19: Native forest fragmentation class distribution across south-west Western Australia



A higher resolution version of this map is available via www.doi.org/10.25814/5be3bc4321162

Figure 1.20: Native forest fragmentation class distribution across an area near Lake Burragorang (Warragamba Dam), south-west of Sydney, New South Wales



A higher resolution version of this map is available via www.doi.org/10.25814/5be3bc4321162

Table 1.33: Native forest fragmentation, by jurisdiction

	ACT	NSW	NT	Qld	SA	Tas.	Vic.	WA	Australia
Forest coverage as at 2016									
Native forest area ('000 ha)	130	19,925	23,686	51,580	4,856	3,342	7,645	20,450	131,615
Area proportion woodland forest	29%	47%	65%	77%	93%	41%	37%	89%	69%
Mean number of neighbouring cells forested[a]	3.83	3.49	3.34	3.57	3.27	3.61	3.80	3.37	3.49
Proportion forest interior[b]	89%	73%	64%	74%	64%	75%	88%	66%	72%
Forest coverage as at 2011									
Native forest area ('000 ha)	128	22,270	15,173	50,782	4,377	3,361	7,729	18,752	122,574
Area proportion woodland forest	29%	47%	51%	76%	94%	40%	36%	88%	67%
Mean number of neighbouring cells forested[a]	3.80	3.36	3.32	3.57	3.22	3.57	3.71	3.38	3.47
Proportion forest interior[b]	89%	68%	64%	75%	62%	74%	84%	66%	71%

[a] 'Mean number of neighbouring cells forested' is the average number of neighbouring forested cells for each forested cell in that jurisdiction.

[b] 'Proportion forest interior' is the proportion of forest cells that are interior. A forest interior cell is a native forest cell that has all of its four neighbouring (edge-adjacent) cells forested (with native forest, other forest or commercial plantation).

Note: the cells for this analysis are the 100 m x 100 m grid cells used by the National Forest Inventory. Forest coverage as at 2016 is from SOFR 2018, Indicator 1.1a. Forest coverage as at 2011 is from SOFR 2013, Indicator 1.1a.

This table, together with other data for Indicator 1.1d, is available in Microsoft Excel via www.doi.org/10.25814/5bda82c8d76d4

Table 1.34: Native forest fragmentation, by IBRA ecoregion

					Fragmentation metrics	
IBRA ecoregion[a]	Land area[b] ('000 ha)	Native forest area ('000 ha)	Native forest as proportion of land area	Woodland forest as proportion of native forest area	Mean number of neighbouring cells forested[c]	Proportion forest interior[d]
Deserts, xeric shrublands	356,971	5,019	1.4%	98%	2.89	49%
Temperate grasslands, savanna, shrublands	52,978	7,835	15%	75%	3.05	51%
Tropical/subtropical grasslands, savannas, shrublands	220,744	70,750	32%	78%	3.49	71%
Mediterranean. forests, woodlands, scrub	78,278	20,388	26%	84%	3.55	74%
Temperate broadleaf, mixed forest	55,255	24,034	43%	31%	3.65	80%
Tropical/subtropical moist broadleaf forests	3,456	2,489	72%	26%	3.82	89%
Montane grasslands, shrublands	1,233	1,100	89%	47%	3.91	94%
Australia	**768,915**	**131,615**	**17%**	**69%**	**3.49**	**72%**

[a] IBRA ('Interim Biogeographic Regionalisation of Australia') ecoregions are from www.environment.gov.au/land/nrs/science/ibra/australias-ecoregions. The ecoregion 'Montane grasslands, shrublands' contains areas of alpine and subalpine forest.

[b] The total land area differs slightly from that in Table 1.1, Indicator 1.1a, because of differences in coastlines used

[c] 'Mean number of neighbouring cells forested' is the average number of neighbouring forested cells for each forested cell in that jurisdiction.

[d] 'Proportion forest interior' is the proportion of forest cells that are interior. A forest interior cell is a native forest cell that has all of its four neighbouring (edge-adjacent) cells forested (with native forest, other forest or commercial plantation).

Note: The cells for this analysis are the 100 m x 100 m grid cells used by the National Forest Inventory. Forest coverage is from SOFR 2018, Indicator 1.1a.

This table, together with other data for Indicator 1.1d, is available in Microsoft Excel via www.doi.org/10.25814/5bda82c8d76d4

change. Analysis of a different dataset, such as the National Greenhouse Gas Inventory dataset used to assess the extent of forest cover change over time (see Indicator 1.1a), would be needed to assess any change in fragmentation over time.

Ecoregions are regions that contain geographically distinct groups of animals and plants, and are another approach to distinguishing different broad vegetation types across Australia[64]. Table 1.34 presents fragmentation metrics for native forest in the seven ecoregions present on mainland Australia. The most fragmented native forest is found in those ecoregions ('Deserts, xeric shrublands'; and 'Temperate grasslands, savanna, shrublands') that contain the lowest proportion of forest, which also are the ecoregions with the highest proportions of native forest as woodland forest. This is to be expected, as forests in environments that are drier, or where other vegetation types such as grassland are dominant, attain a lower canopy cover. The least fragmented native forest is found in the wettest ecoregion ('Tropical/subtropical moist broadleaf forests'), and in the 'Montane grasslands, shrublands' ecoregion that contains Australia's subalpine and mountain forests; large areas of both these ecoregions are in nature conservation reserves or in multiple-use public forests.

Analysis by ecoregion thus confirms that variation in the extent and configuration of native forest across the wider Australian landscape, driven by large-scale ecological considerations, is a major determinant of the extent to which forest and non-forest areas are interspersed, and thus of the extent of forest fragmentation. At smaller scales, the impacts of land clearing

[64] A full list, descriptions and maps of Australia ecoregions under the Interim Biogeographic Regionalisation for Australia (IBRA) is available at www.environment.gov.au/land/nrs/science/ibra/australias-ecoregions

for agricultural land use, infrastructure and urban development are also determinants of the extent of forest fragmentation. Quantitative analysis of human-induced fragmentation at a national or regional scale is difficult in the absence of historical spatial forest coverages to act as baselines for comparison.

Forest fragmentation analysed as the size of forest patches

Fragmented forests generally occur in smaller patches of isolated forest, whereas forests that are less fragmented occur in larger patches of continuous forest. The proportion of native forest in patches of different size is therefore another measure of forest fragmentation and its converse, forest connectivity.

Table 1.35 presents the area proportion of native forest in patches of different size, by jurisdiction, and Figure 1.21 shows the distribution of native forest by patch size across Australia. Forest in patch sizes of over 100,000 hectares has a similar geographic distribution to that of forest in the forest-interior fragmentation class (compare Figure 1.18 and Figure 1.21). This indicate that the two fragmentation metrics (proportion of forest that is forest-interior, and forest patch size) are correlated, and likely influenced by similar landscape variables.

Nationally, 68% of native forest is in patches of over 100,000 hectares. All jurisdictions have 44% or more of their forest in patches of over 100,000 hectares. The Australian Capital Territory has 90% of its native forest in one patch of over 100,000 hectares, which includes Namadgi National Park. South Australia and Western Australia are the jurisdictions with the lowest proportion of their native forest in patches of over 100,000 hectares (44% and 56%, respectively), and are also the jurisdictions with the largest proportion of their native forest in patches of less than 10,000 hectares (38% and 32%, respectively). South Australia and Western Australia are also the jurisdictions with the highest area proportions of native forest that is woodland forest (Table 1.33). This again indicates that the highest proportions of fragmented forest are found in regions where woodland forest intergrades into the non-forest vegetation category of sparse woodland (other woody vegetation with a crown cover below 20%).

Forest fragmentation statistics in Victoria

Victoria reported forest fragmentation in Indicator 1.1d of *Victoria's State of the Forests Report 2013* (DEPI 2014d). These data have since been updated in preparation for in *Victoria's State of the Forests Report 2018* (DELWP, unpublished).

The method involved allocating each 30 m x 30 m pixel (cell) in a forest coverage modelled from a composite Landsat image from 2009 to 2013 to one of five categories of increasing fragmentation, and is based on the method of Riitters et al. (2000) that has been applied to forests globally. The categories are named 'interior', 'patch', 'transitional', 'perforated' and 'edge' (Table 1.36), and are defined probabilistically considering the forest status of the eight cells (edge cells plus corner cells) surrounding a central cell, and the proportion of forest in a broader window.

Descriptions of the fragmentation categories and the results of application of this method to Victoria are shown in Table 1.36, and the distribution of the categories across Victoria is shown in Figure 1.22.

Victoria's State of the Forests Report 2013 (DEPI 2014d) also presented these results by region, IBRA bioregion, and tenure, as well as presenting patch-size data for each bioregion. Bioregions in the north-west of the state contain the lowest proportion of forest cover, and also have the smallest average forest patch sizes, a high degree of fragmentation, and the smallest average core forest areas. Eastern Victoria contains the largest areas of continuous forest in the state that is not fragmented.

Forest fragmentation statistics in Tasmania

Forest fragmentation statistics for Tasmania are presented in Indicator 1.1d of *State of the forests Tasmania 2017* (FPA 2017a), and report the proportion of total native forest area that occurs in patches of different size. A total of 45% of Tasmania's forests is in patches larger than 50,000 hectares, and 72% is in patches larger than 10,000 hectares. There was minimal change to these statistics over the period 2005 to 2015.

As for the national analysis, forests in Tasmania are often naturally fragmented where they occur in a matrix of non-forest communities, including in the Tasmanian Wilderness World Heritage Area.

Table 1.35: Native forest patch size distribution, by jurisdiction

Jurisdiction	Total native forest area ('000 ha)	Area proportion of native forest in patches[a] of different size				
		1–1000 ha	>1000–10,000 ha	>10,000–100,000 ha	>100,000–1,000,000 ha	>1,000,000 ha
ACT	130	5%	5%	0%	90%	0%
NSW	19,925	18%	8%	10%	21%	43%
NT	23,686	19%	5%	5%	16%	55%
Qld	51,580	13%	6%	8%	14%	59%
SA	4,856	30%	9%	18%	23%	21%
Tas.	3,342	12%	6%	6%	23%	53%
Vic.	7,645	8%	6%	11%	22%	53%
WA	20,450	24%	8%	12%	14%	42%
Australia	**131,615**	**17%**	**7%**	**9%**	**15%**	**53%**

[a] A patch is defined as an area of native forest in which every cell adjoins (is edge-adjacent to) another forest cell. For each state and territory, patches are confined within the boundary of that state and territory, whereas for Australia patches can cross state and territory boundaries; the number of native forest patches in Australia is therefore less than the sum of the number of native forest patches in the states and territories.

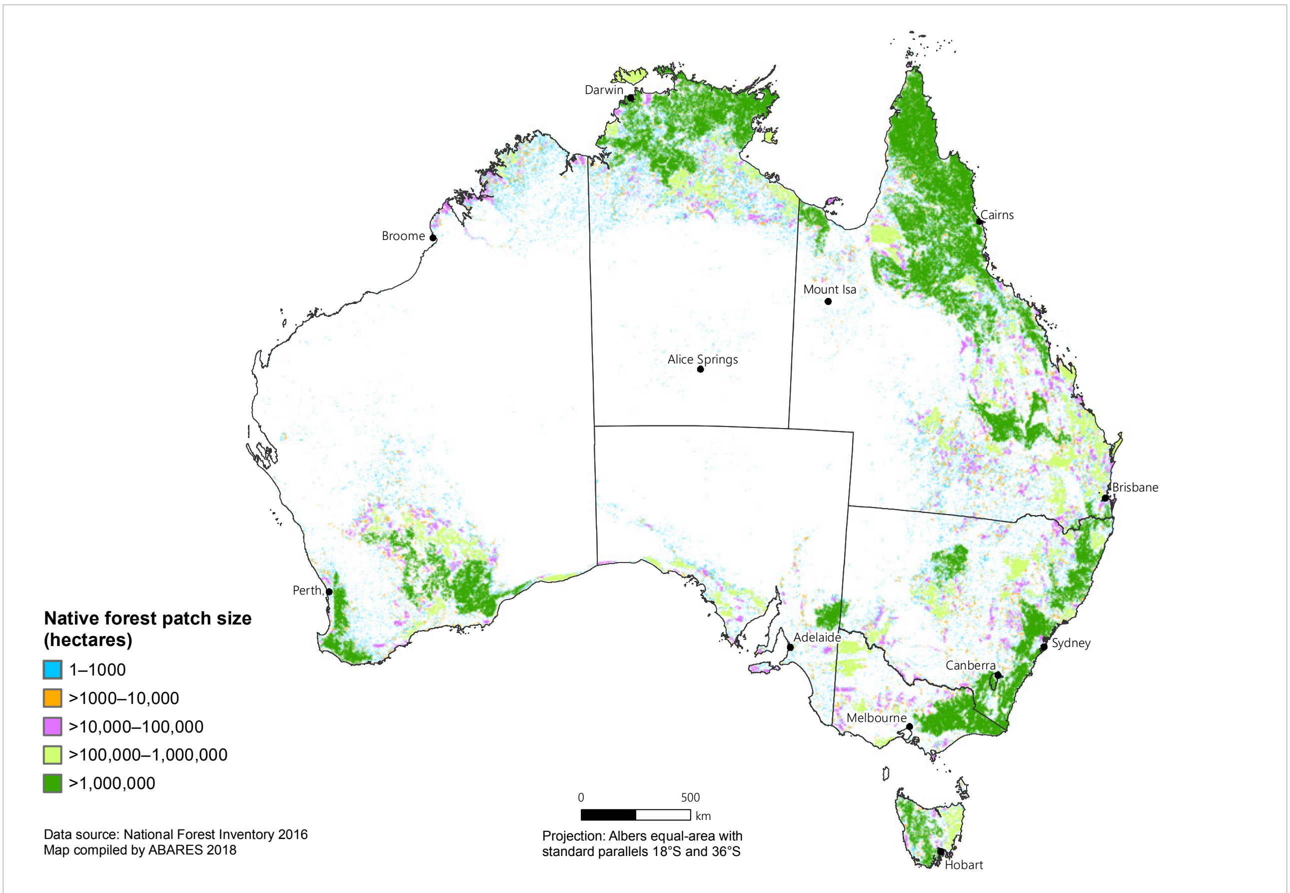
Notes:

The cells for this analysis are the 100 m x 100 m grid cells used by the National Forest Inventory. Forest coverage is from SOFR 2018, Indicator 1.1a.

Totals may not tally due to rounding.

This table, together with other data for Indicator 1.1d, is available in Microsoft Excel via www.doi.org/10.25814/5bda82c8d76d4

Figure 1.21: Native forest patch size distribution across Australia



A higher resolution version of this map is available via www.doi.org/10.25814/5be3bc4321162

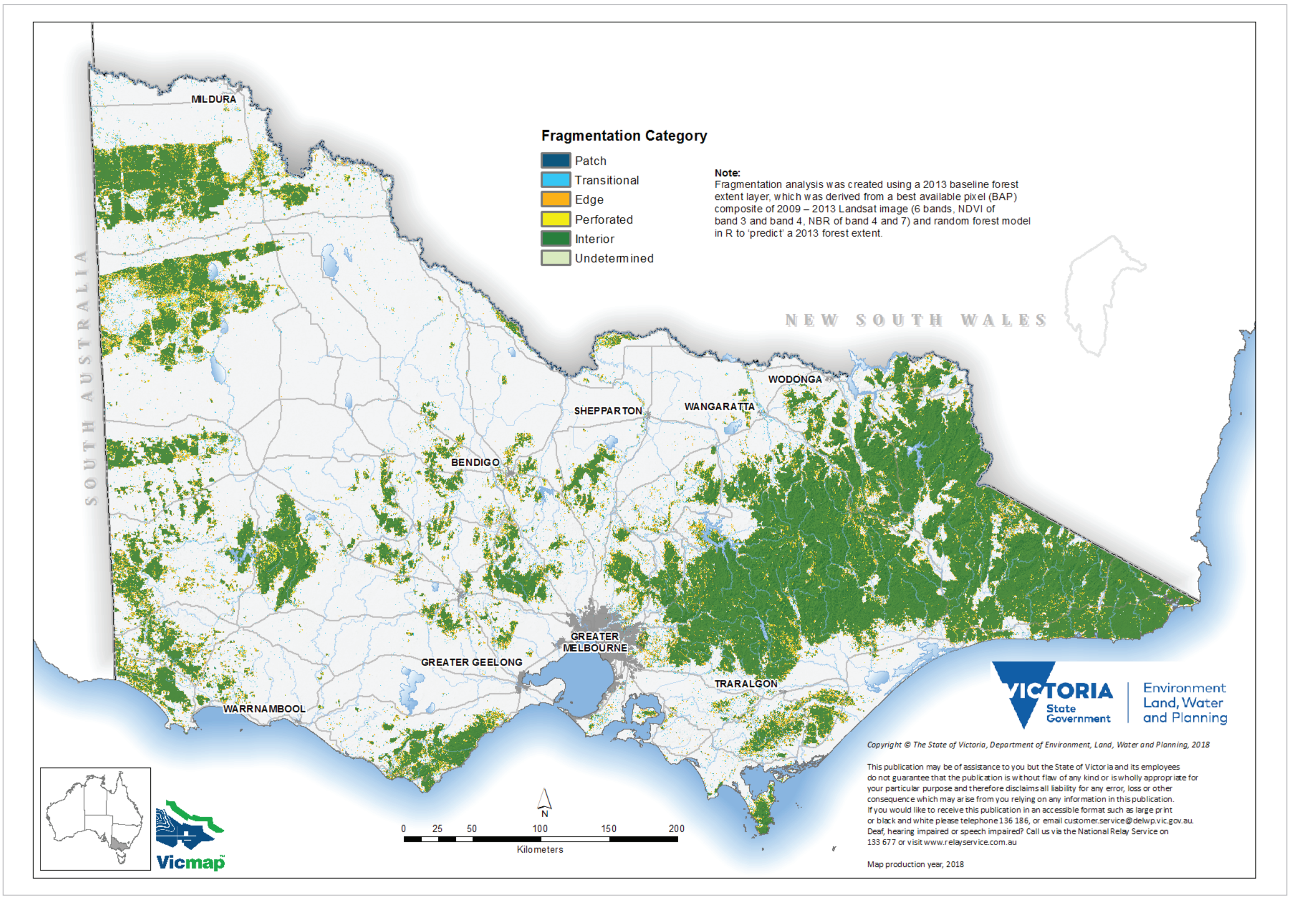
Table 1.36: Fragmentation statistics for Victoria's forests, 2009–13

Fragmentation category	Description	Area proportion
Interior	Forest pixels that are relatively far from the forest-non-forest boundary. Essentially these are forested areas surrounded by more forested areas	75%
Patch	Forest pixels that comprise a small forested area surrounded by non-forested land cover	2.9%
Transitional	Transition areas between connected forest and fragmented forest	3.6%
Perforated	Forest pixels that define the boundary between core forest and relatively small clearings (perforations) within the forested landscape	5.7%
Edge	Forest pixels that define the boundary between core (interior) forest and large non-forested land cover features	13%

Source: DELWP. Data based on a composite Landsat image from 2009 to 2013.

This table, together with other data for Indicator 1.1d, is available in Microsoft Excel via www.doi.org/10.25814/5bda82c8d76d4

Figure 1.22: Forest fragmentation in Victoria, 2013



Note: this is an update of the map that was published in *Victoria's State of the Forests Report 2013* (DEPI 2014d) and that is available at www.forestsandreserves.vic.gov.au/__data/assets/pdf_file/0013/29002/ForestFragmentation_map_SFR2013.pdf

Source: DELWP.

Indicator 1.2a

Forest dwelling species for which ecological information is available

Rationale

This indicator reports the level of information available to manage forest dwelling species and tracks changes in this knowledge over time. The amount of habitat, disturbance and life history information available to make management decisions indicates the capacity to assess risk to species and to implement conservation strategies.

Key points

- All states and territories have developed lists of forest-dwelling vertebrate fauna (animal) and vascular flora (plant) species, allowing compilation into national lists.
  - These national lists show that the number of known forest-dwelling species has generally increased in each jurisdiction since the number was first reported in SOFR 1998, reflecting improved information from a variety of survey mechanisms.
- As of July 2016, the national list contained 2,486 forest-dwelling native vertebrate fauna species, with 1,119 of these species being identified as forest-dependent species.
- As of July 2016, the national list also contained 16,836 identified forest-dwelling native vascular flora species. Approximately half of these species occur in Queensland.
- Partial ecological information is available for around 60% of Australia's forest-dwelling vertebrate fauna and vascular flora species. Comprehensive ecological information is available on at least 10% of vertebrate fauna species, mainly mammals, birds and amphibians.
  - Significantly improved information is available for species in regions that have been subject to formal assessment processes, such as those associated with Regional Forest Agreements; and other assessments such as the Kimberley Islands Biological Survey; and for reptiles, frogs, bats and fish.
  - Information on forest-dwelling invertebrates, fungi, algae and lichens for areas other than south-west Western Australia and Tasmania remains very limited.

Knowledge of the species present in a forest, and increases or decreases in their populations, can provide an indication of the extent and condition of forest habitat, and an indication of ecosystem health. This is particularly important in Australia, where knowledge of species diversity is a precondition for the effective management of forest ecosystems. However, the changes in numbers of forest-dwelling and forest-dependent species over time often reflect improvements in the knowledge base from which species lists are compiled, and not actual changes in forest ecosystem diversity.

Davey (2018b) reviews the historical development of Indicators 1.2a–c and 1.3a, the development of databases used to inform indicators, and the reporting of species-level indicators in SOFR 2013.

Forest-dwelling species are species that may use forest habitat for all or part of their lifecycles. This is a broader set of species than forest-dependent species, which are species that must inhabit a forest habitat for all or part of their lifecycles.

The last *Numbers of Living Species in Australia and the World* report (Chapman 2009) reported that, at that date, Australia was home to an estimated 566,398 species, of which 147,579 species had been described. Of the described species in Australia at that date, 92% of flora species, 87% of mammal species, 45% of bird species, 93% of reptile species and 94% of frog species were endemic, that is, were found only in Australia. This high level of endemism increases the importance of conserving the suite of species found in Australia.

Forest-dwelling and forest-dependent vertebrate fauna species

All states and territories have developed lists of extant[65] and extinct forest-dwelling vertebrate fauna (animal) species. These lists have been used as inputs into the development of National Forest Inventory databases for forest-dwelling vertebrate fauna species.

Nationally, in 2016, there were 2,486 native forest-dwelling vertebrate fauna species (Table 1.37). This number of species has increased from that reported in SOFR 2013 as a result of improved information and targeted surveys, even though data accuracy is limited by the absence of data from some states and territories for some reporting periods.

The greatest number of forest-dwelling vertebrate fauna species in each taxonomic group, and in total, is found in Queensland. An improved understanding of fish habitat and fish species distribution has contributed to a doubling of the number of reported forest-dwelling fish species nationally, from 220 species reported in SOFR 2013 to 449 species reported in SOFR 2018. Many of the fish species that were added occupy forested estuarine and mangrove habitats.

Of these vertebrate fauna species, a total of 1,119 are assessed as forest-dependent (Table 1.38). This is an increase from the 1,101 such species reported in SOFR 2013. Approximately half the forest-dwelling vertebrate fauna species are therefore forest-dependent. The greatest number of forest-dependent vertebrate fauna species in each taxonomic group, and in total, is found in Queensland.

These forest-dwelling and forest-dependent vertebrate species are found across a range of habitat types (Table 1.39). Across all forest-dwelling vertebrate species, 30% of habitat usage is of woodland or open eucalypt forest; non-forest habitats represent 37% of habitat types used. There are no substantial differences between taxon groups of forest-dwelling species in the extent to which they use forest versus non-forest habitats. Forest habitats are naturally more highly represented for forest-dependent vertebrate species, comprising 86% of habitats used (Table 1.39). Again, woodland and open eucalypt forest are the most common habitat types used. Fish are the taxon group of forest-dependent species with greatest use of other habitat types.

Table 1.37: Number of native forest-dwelling vertebrate fauna species, by jurisdiction, 2016, and across the five SOFR reporting periods[a]

Taxonomic group[b]	ACT	NSW	NT	Qld	SA	Tas.	Vic.	WA	Australia[c]
Fish	11	134	196	331	38	35	74	144	449
Amphibians	17	82	55	137	25	11	35	66	229
Reptiles	52	212	273	435	179	18	109	343	786
Birds	207	344	343	491	182	79	247	167	668
Mammals	47	124	119	207	98	40	99	144	354
Total 2016	**334**	**896**	**986**	**1,601**	**522**	**183**	**564**	**864**	**2,486**
Total 1998[d]	–	504	449	582	–	125	485	239	1,227
Total 2001[e]	8	780	439	1,214	462	131	415	646	1,817
Total 2006[e]	–	760	440	–	574[f]	137	513	226	–
Total 2011[e]	334	827	788	1,423	481	165	508	711	2,212
Total 2016	334	896	986	1,601	522	183	564	864	2,486

–, not available

a Forest-dwelling species are species that may use forest habitat for all or part of their lifecycles.

b As far as possible, subspecies are included separately where they are managed or reported separately, either nationally or by jurisdictions. Non-native species are not included.

c Numbers for Australia are less than the sum of numbers for each jurisdiction (i) because many species occur in more than one jurisdiction, and (ii) because numbers for Australia include data from offshore forested islands (such as Torres Strait, Christmas, Lord Howe and Norfolk Islands) not necessarily included in state or territory figures.

d As reported in SOFR 1998, and described as a national *minimum* estimate with data from New South Wales, the Northern Territory, Tasmania and parts of Queensland being incomplete.

e Data from SOFR 2003, SOFR 2008 and SOFR 2011 respectively.

f Potentially incorrectly reported in SOFR 2008.

Note: For this table, lists of fish, amphibian and mammal species were extensively updated using Atlas of Living Australia records, and lists of bird and reptile species lists were partly updated.

Source: National Forest Inventory, ABARES datasets of extant and extinct native vertebrate forest fauna, SOFR 1998, SOFR 2003, SOFR 2008, state and territory agencies and analyses of Atlas of Living Australia records (data download in January–February 2017).

This table, together with other data for Indicator 1.2a, is available in Microsoft Excel via www.doi.org/10.25814/5bda82c8d76d4

65 'Extant' means still living, not extinct.

Table 1.38: Number of native forest-dependent vertebrate fauna species, by jurisdiction, 2016[a]

Taxonomic group[b]	ACT	NSW	NT	Qld	SA	Tas.	Vic.	WA	Australia[c]
Fish	5	41	23	94	7	7	22	17	116
Amphibians	3	32	3	71	0	0	10	11	96
Reptiles	24	92	90	242	32	9	37	77	350
Birds	122	199	147	280	91	55	147	76	371
Mammals	33	70	49	135	38	27	55	49	186
Total 2016	**187**	**434**	**312**	**822**	**168**	**98**	**271**	**230**	**1,119**

[a] Forest-dependent species are species that must inhabit a forest habitat for all or part of their lifecycles.

[b] Subspecies are included separately where they are managed by jurisdictions or nationally. Non-native species are not included.

[c] Numbers for Australia are less than the sum of numbers for each jurisdiction (i) because many species occur in more than one jurisdiction, and (ii) because numbers for Australia include data from offshore forested islands (such as Torres Strait, Christmas, Lord Howe and Norfolk Islands) not necessarily included in state or territory figures.

Note: For this table, lists of fish, amphibian and mammal species were extensively updated using Atlas of Living Australia records, and lists of bird and reptile species lists were partly updated.

Source: National Forest Inventory, ABARES dataset of extant and extinct native vertebrate forest fauna, state and territory agencies and analyses of Atlas of Living Australia records (data download in January–February 2017).

This table, together with other data for Indicator 1.2a, is available in Microsoft Excel via www.doi.org/10.25814/5bda82c8d76d4

Table 1.39: Habitat use of forest-dwelling and forest-dependent vertebrate species, 2016

	Habitat use as a proportion of total habitat use (%)											
	Forest-dwelling species						Forest-dependent species					
Habitat types	Fish	Amphibians	Reptiles	Birds	Mammals	All species	Fish	Amphibians	Reptiles	Birds	Mammals	All species
Forest habitats												
Rainforest	5	9	6	6	9	6	12	23	17	11	17	15
Closed eucalypt forest	2	8	3	7	5	4	4	20	9	13	10	10
Open eucalypt forest	13	13	11	15	14	13	16	17	21	23	21	21
Woodland eucalypt forest	13	13	21	16	18	17	14	7	24	17	21	18
Forested waterways	19	18	5	10	5	11	19	23	7	9	6	11
Mangrove	8	0	1	5	2	4	4	0	1	7	3	4
Other forest	6	4	12	6	7	8	10	4	6	4	3	6
Plantation	0	0	0	1	1	1	0	0	1	2	2	1
Total forest habitats	**66**	**66**	**60**	**66**	**62**	**63**	**80**	**95**	**87**	**87**	**84**	**86**
Non-forest habitats												
Arid and semi-arid	1	2	8	2	5	4	0	0	1	0	0	0
Marine and coastal	9	1	1	4	1	4	2	1	1	2	1	2
Alpine	0	1	0	0	1	0	0	0	0	0	1	0
Scrubland	4	5	15	11	13	10	3	1	4	5	7	5
Grassland	3	10	10	8	9	7	3	0	2	1	3	2
Other non-forest	16	14	6	10	8	11	13	3	5	5	5	6
Total non-forest habitats	**34**	**34**	**40**	**34**	**38**	**37**	**20**	**5**	**13**	**13**	**16**	**14**

Notes:

Each species was allocated up to six habitat types based on habitat records (see Davey 2018b). For each taxon group, the number of species allocated to each habitat type was then expressed as a percentage of the total number of species habitat-type allocations for that taxon group.

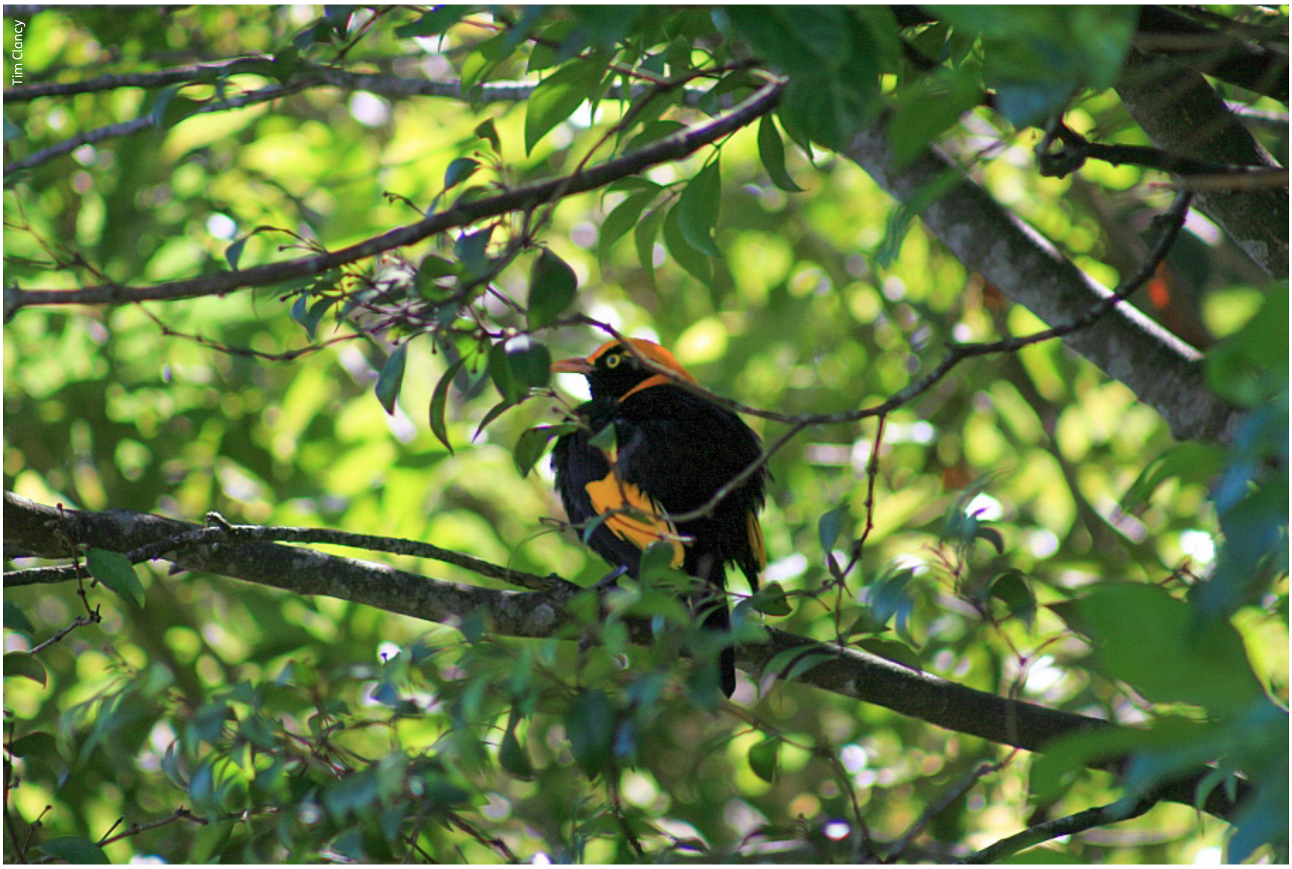
Forest habitats are grouped into rainforest, closed eucalypt forest, open eucalypt forest, woodland eucalypt forest, forested waterways, mangrove, other forest dominated by *Acacia*, *Casuarina*, *Callitris* or other non-eucalypt species, and plantation (see Indicator 1.1a for descriptions and distribution). 'Forested waterways' includes riparian forests and woodlands, swamp forests, fringing forests around water features, and aquatic habitats found within rainforest, forest and woodland ecosystems; examples are creeks, rivers, seepage areas, swamps, wetlands, soaks, small lakes and dams. Non-forest habitats are grouped into arid and semi-arid, marine and coastal (includes marine and wetland environments), alpine, scrubland (other woody vegetation, including heathland, shrubland and open woodland), grassland, and other non-forest (includes non-forest waterways and wetlands, rock outcrops, mudflats, farmland).

For this table, lists of fish, amphibian and mammal species were extensively updated using Atlas of Living Australia records, and lists of bird and reptile species lists were partly updated.

Totals may not tally due to rounding.

Source: National Forest Inventory, ABARES dataset of native vertebrate forest fauna, state and territory agencies and analyses of Atlas of Living Australia records.

This table, together with other data for Indicator 1.2a, is available in Microsoft Excel via www.doi.org/10.25814/5bda82c8d76d4



The Regent Bowerbird (*Sericulus chrysocephalus*) lives in rainforests in Queensland and New South Wales.

Forest-dwelling and forest-dependent vascular flora species

Lists of forest-dwelling vascular flora have been compiled by all states and territories, and combined to produce a national list of 16,836 species (Table 1.40). The number of such species and their distribution changes over time, as more surveys are performed and new species are described. As with vertebrate fauna, the changing number of species reported reflects an improved information base rather than changes in the actual numbers of forest-dwelling species. The list of forest-dwelling vascular flora was not updated for SOFR 2018, other than through reporting a more accurate figure for the Australian Capital Territory and an updated figure for Western Australia. Regional surveys in Western Australia, in particular in the Kimberley region, and improved knowledge in the south-west of the state have contributed to the increase in the number of reported Western Australian forest-dwelling vascular flora species.

The number of forest-dependent vascular flora species has not been calculated either by state and territory jurisdictions or nationally.

Table 1.40: Number of forest-dwelling vascular flora species, by jurisdiction, 2016

Reporting date	ACT	NSW	NT	Qld	SA	Tas.	Vic.	WA	Australia[d]
2016[a]	1,043	7,472	3,854	8,470	2,453	1,034	2,913	3,820[b]	16,836
2011	1,551	7,472	3,854	8,470	2,453	1,034	2,913	3,313[c]	16,836
2006	n.r.	7,461	3,970	n.r.	2,306	1,017	2,853	3,000[c]	n.r.
2001	4	7,448	4,042	8,443	2,346	908	2,872	3,178[c]	16,532
1998	–	–	1,691	7,830	–	1,043	2,959	2,639[c]	13,622

–, not available; n.r., not reported.

[a] Not updated from that reported in SOFR 2013, except for WA and the ACT.

[b] South-west Western Australia and Kimberley region only.

[c] South-west Western Australia only.

[d] Numbers for Australia are less than the sum of numbers for each jurisdiction because many species occur in more than one jurisdiction. The figure for Australia has not been updated with the additional species reported here in south-west Western Australia and the Kimberley region, or with the amended figure for the ACT.

Source: National Forest Inventory, ABARES dataset of forest flora, SOFR 1998, SOFR 2003, SOFR 2008, state and territory agencies.

This table, together with other data for Indicator 1.2a, is available in Microsoft Excel via www.doi.org/10.25814/5bda82c8d76d4

Level of ecological knowledge

Conservation management processes carried out as part of the development of Regional Forest Agreements (see Indicator 7.1a and Davey 2018a), as well as subsequent specific surveys of rare, threatened or endangered species, have been important in increasing knowledge of forest-dwelling species. Increased knowledge of populations and distributions of some threatened species has resulted in them no longer being classified as threatened and hence being removed from threatened species lists (see Indicator 1.2b). The number of species for which ecological knowledge is considered to be adequate is also increasing as a result of scientific surveys and studies, and of regional planning exercises, especially for species that are considered under threat. As more surveys are undertaken, it is likely that species will be found in areas where they were previously unknown; occasionally, species previously unknown to science will also be discovered. A comprehensive survey of fauna and flora has recently occurred in the Kimberley region of Western Australia (Gibson et al. 2017).

There are no comprehensive lists of the invertebrate fauna, non-vascular flora (including algae, liverworts and mosses, as well as fungi and lichens) or microorganisms that occur in forests, even though these species play key roles in ecological processes. The overall level of knowledge about these species is low, and priority is given to species listed in regulations, schedules or management plans. There are probably well over 100,000 terrestrial invertebrate species in Australia's forests, of which only a small fraction have been described (SOFR 2008).

To date, south-west Western Australia and the Huon region of southern Tasmania are the only forest regions within Australia with comprehensive lists of forest-dwelling invertebrate species and non-vascular flora. Western Australia is collecting comprehensive information on lesser-studied fauna and flora groups in the south-west through Forestcheck (see Case Study 7.7). This should result in the development of a more comprehensive list of forest-dwelling invertebrates and non-vascular flora in the south-west of the state; SOFR 2003 reported an incomplete list of 1,992 forest-dwelling invertebrates occurring in south-west Western Australia alone. In southern Tasmania, the Tasmanian Forest Insect Collection contains more than 216,000 beetle specimens of more than 2,200 species from Tasmanian forests; more than 60% of these species remain to be formally identified, and many are undescribed. The collection specialises in saproxylic (log-dwelling) and ground beetles. Species lists for many other taxa, including lichens, fungi and other non-vascular flora, are also maintained for the Warra Long-term Ecological Research site[66] (see Case study 7.8 in Indicator 7.1e).

Table 1.41 illustrates the level of ecological knowledge about forest-dwelling fauna and flora species. Partial ecological information is available for around 60% of Australia's forest-dwelling vertebrate fauna and vascular flora species. Comprehensive ecological information is available on at least 10% of vertebrate fauna species, mainly mammals, birds and amphibians.

Knowledge varies markedly across taxa. The level of knowledge has generally increased across all vertebrate groups and vascular plants nationally compared with that reported in SOFR 2013. State and territory agencies reported that confidence is greatest in the level of information for species occurring in areas where comprehensive regional assessments have been undertaken. Other than Western Australia, all states and territories reported that confidence was low in the level of knowledge for invertebrates and non-vascular flora. Victoria reported a decline in level of ecological knowledge about forest-dwelling birds, reptiles and mammals since their reporting for SOFR 2008.

For all taxa for which ecological information is minimal or inadequate, risk assessments are necessarily based on information about better studied, closely related taxa in similar ecological niches. Management strategies can also rely on general conservation measures, such as additions to the national reserve system (see Indicator 1.1c), additional environmental protection measures, and measures that provide for the maintenance of ecosystem processes.

[66] www.warra.com

Table 1.41: Assessed level of ecological knowledge on forest-dwelling species, by taxonomic group, 2016

Taxonomic group	Number of forest-dwelling species assessed	Assessed level of knowledge: Minimal or inadequate information available to inform management decisions[a]	Partial information available, but some crucial information may be absent or limited[b]	Comprehensive or adequate information available to inform management decisions[c]
		Proportion of species to which knowledge level applies (%)		
Invertebrates				
Insects	– [d]	85	11	4
Other arthropods	– [d]	90	8	3
Non-arthropods	– [d]	90	8	3
Vertebrates				
Fish	459	59	33	8
Amphibians	229	35	46	13
Reptiles	789	33	47	8
Birds	668	26	44	19
Mammals	356	22	61	14
Plants				
Vascular flora	16,836	40	48	8
Non-vascular flora[e]	– [d]	82	15	3

[a] Minimal or inadequate information available to inform management decisions: information limited to species taxonomic identification, with no or very limited knowledge of past and present distribution and population trends.

[b] Partial information available, but some crucial information may be absent or limited: knowledge of at least broad habitat requirements and population trends.

[c] Comprehensive or adequate information available to inform management decisions: knowledge of life history parameters, habitat requirements and distribution, and population status and trends.

[d] The level of knowledge for forest-dwelling species in these taxonomic groups was assessed by jurisdictional agencies for species or taxa listed as threatened either by state and territory legislation or under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*.

[e] Non-vascular flora are plants without a water-conducting system, including algae, liverworts and mosses; fungi and lichens are also reported under this category.

Notes: Each state and territory was asked to assess the level of knowledge available for species by taxonomic group according to the above descriptions. Figures are the mean of all responses; incomplete, unknown or uncertain responses are included under 'minimal or inadequate information' (except for arthropods, non-arthropods and non-vascular flora where incomplete, unknown or uncertain responses were excluded). Figures are indicative and reflect subjective national understanding of ecological knowledge of taxonomic groups.

Source: Based on state and territory responses to SOFR 2008, SOFR 2013 and SOFR 2018.

This table, together with other data for Indicator 1.2a, is available in Microsoft Excel via www.doi.org/10.25814/5bda82c8d76d4

Indicator 1.2b

The status of forest dwelling species at risk of not maintaining viable breeding populations, as determined by legislation or scientific assessment

Rationale

This indicator measures the conservation status of nationally listed threatened forest dwelling species. Documentation of this information over time allows analysis of changes to species' conservation status, indicating the extent to which forest species biodiversity is being maintained.

Key points

- A total of 1,420 forest-dwelling species are on a national list of threatened species under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).
  - Of these, 842 species were assessed as forest-dependent.
- The listed threatened forest-dwelling species comprise 307 vertebrate fauna species, 38 invertebrate fauna species, 1,074 vascular flora species and one non-vascular flora species.
  - Of these, 149 vertebrate fauna species are forest-dependent, 28 invertebrate fauna species are forest-dependent, 664 vascular flora species are forest-dependent, and the one non-vascular flora species is forest-dependent.
- A total of 41 forest communities are listed as threatened under the EPBC Act.
- Of the 21 key threatening processes listed under the EPBC Act, 18 apply to forest ecosystems.
- The modelled distribution of listed threatened forest-dwelling and forest-dependent fauna and flora species across Australia's forest area is presented, together with the modelled distribution of listed threatened forest ecological communities.
- During the reporting period 2011–16, 68 forest-dwelling species were added to the national list of threatened species, and 77 were removed from the list.
  - Most additions were based on inherently small population sizes and/or ongoing impacts on habitat extent and quality, including impacts of introduced species and unsuitable fire regimes.
  - Most removals were a result of improved information that indicated that species were no longer considered valid species, or were not threatened.
- Listing statements give information on the nature of the threats to each species.
  - For forest-dwelling fauna species, the most common threat categories are historical land-use change and forest loss caused by clearing for agriculture, grazing, and urban and industrial development, followed by predation from introduced predators (e.g. fox, cat, rat and trout).
  - For threatened forest-dwelling flora, the most common threat categories are small population size and localised distribution, followed by mortality agents (including illegal collection, recreational pressure, pressures from peri-urban development, and genetic or breeding issues) and unsuitable fire regimes.
  - For threatened forest ecological communities, the most common threat categories are weeds, and forest loss due to clearing for agriculture.
  - Forestry operations pose a less significant threat to forest-dwelling fauna and flora species compared with other identified threat categories.
- States and territories have formal threat abatement plans in place to reduce the impacts of key threats and threatening processes on threatened species. A significant amount of research is occurring on key threatened species.

Protecting listed threatened species and ecological communities

The *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) is the Australian Government's principal piece of environmental legislation. Among other things, it is designed to protect Australia's native species and ecological communities by providing for:

- identification and listing of threatened[67] species and ecological communities
- development of conservation advice and, where appropriate, recovery plans for listed species and ecological communities
- development of a register of critical habitat
- identification and listing of key threatening processes[68]
- development of threat abatement plans to reduce the impacts of threatening processes where appropriate.

The EPBC Act requires the establishment of national lists of threatened species, threatened ecological communities, and key threatening processes. Listing of species, ecological communities or processes is administered through a scientific assessment process overseen by the Threatened Species Scientific Committee[69]. Once a species or ecological community is listed under the EPBC Act, its recovery is promoted using a published Conservation Advice, or (if developed) a Recovery Plan, under the assessment and approval provisions outlined in the EPBC Act. Recovery plans set out the research and management actions that are necessary to stop the decline of, and support the recovery of, listed threatened species or ecological communities, including the identification of critical habitat. The aim of a recovery plan is to maximise the long-term survival in its natural environment of the species or ecological community. Threat abatement plans are used to ameliorate key threatening processes.

Regional Forest Agreements (RFAs) are alternative (substitute) mechanisms for providing for protection of environmental values and matters of national environmental significance in RFA regions. The four RFA states provide for the protection of listed threatened species and communities in RFA regions through their forest management systems, as recognised in the RFAs.

Key threatening processes

As at end of June 2016, the EPBC Act listed 21 key threatening processes, 18 of which (86%) are direct threats to forest ecosystems (Table 1.42). These listed key threatening processes are separate from the threats identified in individual species listing statements. However, one or more of the forest-related key threatening processes feature in the listing advice for each threatened forest-dwelling fauna and flora[70] species and for each threatened ecological community.

Two new key threatening processes were added to the list during the SOFR 2018 reporting period (Table 1.42), both directly relating to forest ecosystems:

- 'Aggressive exclusion of birds from potential woodland and forest habitat by over-abundant noisy miner (*Manorina melanocephala*)' was listed because of the potential impact of Noisy Miner, a native bird species, on other bird species
- 'Novel biota and their impact on biodiversity' groups together the impacts of competition, predation or herbivory, and habitat degradation by vertebrate and invertebrate pests; competition, habitat loss and degradation by terrestrial and aquatic weeds; and mortality, habitat loss and degradation caused by pathogens.

  'Novel biota' refers to non-native or non-indigenous invasive species that have been introduced and naturalised in a new habitat and have a significant detrimental impact on the environment. It does not include species in domestic, agricultural and commercial forestry situations where these species remain appropriately managed: these species are only included if they escape or are released from managed situations and become invasive, threatening biodiversity. Case study 1.2 discusses an example of 'novel biota' in the form of the sugar glider (*Petaurus breviceps*) that was introduced from Victoria into Tasmania, and its consequent impact on the Swift Parrot (*Lathamus discolor*).

All states and territories maintain legislation to protect native species of flora and fauna, including forest-dwelling and forest-dependent species. Recent changes in forest-related legislation, including those related to the protection of threatened species, are reported in Indicator 7.1a.

Australia's Biodiversity Conservation Strategy 2010–2030 (NRMMC 2010) provides national direction for protection of Australia's biodiversity, including threatened species. A review of the first five years of the strategy has been published (Biodiversity Working Group 2016), with key findings in the areas of improving engagement and communication, considering biodiversity across all landscapes (not just natural terrestrial landscapes), influencing conservation activities, and alignment with international obligations. Australia's first Threatened Species Commissioner[71] was appointed in June 2014.

Australia's Native Vegetation Framework (COAG Standing Council on Environment and Water 2012) guides the ecologically sustainable management of Australia's native vegetation, and provides national goals and targets to improve the extent, connectivity, condition and function of native vegetation.

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67 'Threatened' is a general term covering the formal categories of Extinct, Critically Endangered, Endangered and Vulnerable. Additional formal categories are Conservation-dependent (for forest-dwelling species, currently applies only to seven threatened marine fish) and 'Extinct in the wild' (for forest-dwelling species, currently applies only to the Pedder galaxid, a fish species).

68 Threatening processes to species are natural, human-induced or human-exacerbated factors or processes that increase the risk of population reduction or extinction.

69 www.environment.gov.au/biodiversity/threatened/tssc

70 In this indicator, 'flora' and 'plant' are generally used interchangeably, as are 'fauna' and 'animal'.

71 www.environment.gov.au/biodiversity/threatened/commissioner

Table 1.42: Listed key threatening processes affecting forest-dwelling threatened species

Key threatening process	Effective date[a]
Competition and land degradation by rabbits	16 July 2000
Competition and land degradation by unmanaged goats	16 July 2000
Dieback caused by the root-rot fungus (*Phytophthora cinnamomi*)	16 July 2000
Predation by European red fox	16 July 2000
Predation by feral cats	16 July 2000
Land clearance	4 April 2001
Loss of climatic habitat caused by anthropogenic emissions of greenhouse gases	4 April 2001
Psittacine circoviral (beak-and-feather) disease affecting endangered psittacine species	4 April 2001
Predation, habitat degradation, competition and disease transmission by feral pigs	6 August 2001
Infection of amphibians with chytrid fungus, resulting in chytridiomycosis	23 July 2002
The reduction in the biodiversity of Australian native fauna and flora due to the red imported fire ant, *Solenopsis invicta*	2 April 2003
Loss of biodiversity and ecosystem integrity following invasion by the yellow crazy ant (*Anoplolepis gracilipes*) on Christmas Island, Indian Ocean	12 April 2005
Biological effects, including lethal toxic ingestion, caused by cane toads (*Bufo marinus*[b])	12 April 2005
Predation by exotic rats on Australian offshore islands of less than 1000 km^2 (100,000 hectares)	29 March 2006
Invasion of northern Australia by gamba grass and other introduced grasses	16 September 2009
Loss and degradation of native plant and animal habitat by invasion of escaped garden plants, including aquatic plants	8 January 2010
Novel biota and their impact on biodiversity	26 Feb 2013
Aggressive exclusion of birds from potential woodland and forest habitat by over-abundant noisy miners (*Manorina melanocephala*)	9 May 2014

a Date from which the threatening process was listed.
b Now known as *Rhinella marina*.
Note: Key threatening processes are as listed in the EPBC database.
Source: www.environment.gov.au/cgi-bin/sprat/public/publicgetkeythreats.pl.

This table, together with other data for Indicator 1.2b, is available in Microsoft Excel via www.doi.org/10.25814/5bda82c8d76d4

Number and distribution of threatened forest-dwelling and forest-dependent species

Forest-dwelling species are species that occur in forest vegetation types, although they may also occur outside forests. As at August 2016, a total of 1,420 forest-dwelling species were listed as threatened under the EPBC Act, comprising 1,347 extant (i.e. living, not extinct) species listed as Critically Endangered, Endangered or Vulnerable, and 73 species (including subspecies) listed as Extinct (Table 1.43).

Of the 1,420 threatened forest-dwelling species listed in the various categories, 307 are vertebrate fauna species, 38 are invertebrate fauna species, 1,074 are vascular flora species and one is a non-vascular flora species.

Based on listings against the EPBC Act in the Species Profile and Threats Database (SPRAT), no forest-dwelling species are known to have become extinct during the last or any SOFR reporting period. Three vascular flora species reported in SOFR 2013 as Extinct, an orchid (*Oberonia attenuata*), a herb (*Ptilotus pyramidatus*) and a shrub (*Prostanthera albohirta*), have been rediscovered. Woinarski et al. (2017) report that a bat (the Christmas Island pipistrelle, *Pipistrellus murrayi*) and a reptile (the Christmas Island forest skink, *Emoia nativitatis*), both forest-dependent species, became extinct between 2009 and 2014, but these species have not yet been formally noted as extinct in SPRAT so are not included as extinct in these tables. A total of 43 forest-dwelling vertebrate fauna species and 30 forest-dwelling flora species are known to have become extinct since European settlement.

Forests comprise 17% of Australia's land base (Table 1.1). The 1,420 listed threatened forest-dwelling taxa (Table 1.43) comprise 79% of Australia's total listed threatened taxa, with the proportion of taxa that are forest-dwelling varying from 72% for Critically Endangered taxa to 83% for Vulnerable taxa (Table 1.44). All threatened amphibians and Critically Endangered mammals are forest-dwelling, as is the one non-vascular plant and the fish species listed as 'Extinct in the wild'. A total of 71% of threatened vertebrate fauna species are forest-dwelling, as are 68% of threatened invertebrate fauna species. Forest-dwelling threatened vascular flora species represent 83% of threatened vascular flora species.

Forest-dependent species are species that require a forest habitat for at least part of their lifecycles. As at August 2016, 149 forest-dependent vertebrate fauna species, 28 forest-dependent invertebrate fauna species, 664 forest-dependent vascular flora species and the one non-vascular flora species, were listed as threatened under the EPBC Act. This totals 842 forest-dependent species.

Figure 1.23A–D shows the modelled number per hectare of listed threatened forest-dwelling and forest-dependent fauna and flora species across Australia (see Davey 2018c for

Table 1.43: Number of listed threatened forest-dwelling species and subspecies, by taxonomic group, 2016

	Threatened							
Taxonomic group	Extinct	Critically Endangered	Endangered	Vulnerable	Total	Non-threatened	Total taxa[a]	Proportion of taxa that are threatened (%)
Fish	1[b]	5	13	11	30	419	449	7
Amphibians	4	5	14	10	33	196	229	14
Reptiles	0	7	11	22	40	749	789	5
Birds	18	8	35	34	95	584	679	14
Mammals	20	6	33	50	109	264	373	29
Total vertebrates	**43**	**31**	**106**	**127**	**307**	**2,212**	**2,519**	**12**
Invertebrates	**0**	**22**	**9**	**7**	**38**	–[d]	–	–
Vascular plants[c]	**30**	**104**	**411**	**529**	**1,074**	–[d]	–	–
Non-vascular plants	**0**	**0**	**1**	**0**	**1**	–[d]	–	–
Total taxa	**73**	**157**	**527**	**663**	**1,420**	–	–	–
Proportion of total threatened forest-dwelling taxa	**5%**	**11%**	**37%**	**47%**	**100%**			

–, not available; n.a., not applicable.

[a] Taxa include species and subspecies. Under the EPBC Act, species are frequently listed at the subspecies level, and the total number of taxa presented here is thus slightly larger than that in Table 1.37, Indicator 1.2a.

[b] Pedder galaxid (*Galaxias pedderensis*) is listed as 'Extinct in the wild' to recognise captive populations and translocated populations outside of its natural range, and is grouped here under 'Extinct'. It was known to occur in the forested waterways of the edges of Lake Pedder and its tributaries before flooding from impoundments occurred in 1972.

[c] Threatened vascular plants include clubmosses, spikemosses, horsetails, ferns, gymnosperms (including conifers) and angiosperms (flowering plants).

[d] The total number of forest-dwelling invertebrate and plant species is unknown.

Notes:

Species are listed as threatened under the EPBC Act.

Species were determined to be 'forest-dwelling' (see Indicator 1.2a) if they were known to occur, were likely to occur or might possibly occur in vegetation types designated as being forest communities in the National Vegetation Information System, or were identified as forest-dwelling in National Forest Inventory datasets.

The application of the 'forest-dwelling' definition has changed slightly from previous SOFRs. Species that occasionally visit forests, or are transient in their visits to forests, are not included as forest-dwelling. For example, migratory listed waders that utilise mudflats fringing mangrove forest are not included. In addition, Lewin's Rail (western) (*Lewinia pectoralis clelandi*), an extinct bird, has continued to be excluded because of uncertainty over whether the wetlands where it was found in Western Australia were in forest.

Listed subspecies or races are reported as separate taxa. Orchidaceae taxonomy is being revised; where the Species Profile and Threats Database (SPRAT, www.environment.gov.au/cgi-bin/sprat/public/sprat.pl) has grouped subspecies/races of orchids, the classification used by the national authority (the Australian Plant Census, www.anbg.gov.au/chah/apc/) has been preferred and these subspecies/races are reported here as separate taxa.

Figures include species found on forested islands (Norfolk and Phillip, Lord Howe, Christmas, Cocos (Keeling), Tiwi and Bathurst (Northern Territory), Kangaroo (South Australia), King and Flinders (Tasmania) and the Torres Strait Island Group (Queensland)).

Source: Environmental Resources Information Network (ERIN) Species of National Environmental Significance database[72] and Species Profile and Threats Database (SPRAT), Australian Government Department of Environment and Energy; National Forest Inventory (NFI), ABARES datasets of extant and extinct native vertebrate forest fauna, vascular and non-vascular forest flora and invertebrate forest fauna.

This table, together with other data for Indicator 1.2b, is available in Microsoft Excel via www.doi.org/10.25814/5bda82c8d76d4

Table 1.44: Proportion of listed threatened species that are forest-dwelling, by taxonomic group (%), 2016

	Threatened category				
Taxonomic group	Extinct	Critically Endangered	Endangered	Vulnerable	Total
Fish	0	63	81	46	61
Amphibians	100	100	100	100	100
Reptiles	0	78	61	67	67
Birds	82	50	71	50	61
Mammals	74	100	87	78	81
Total vertebrates	**81**	**70**	**79**	**64**	**71**
Invertebrates	**0**	**88**	**47**	**64**	**68**
Vascular plants	**83**	**70**	**78**	**90**	**83**
Non-vascular plants	**0**	**0**	**100**	**0**	**100**
Total threatened taxa	**80**	**72**	**77**	**83**	**79**

Species are listed as threatened under the EPBC Act.

Notes: See notes for Table 1.43. Proportions are based on listed threatened taxa in the SPRAT database accessed at 01 August 2016 (495 fauna species, 1,299 flora species, totalling 1,794 threatened taxa). The database included seven threatened marine fish species classed as 'Conservation-dependent', and these were included in the total taxa numbers for fish, total vertebrates and total threatened taxa.

This table, together with other data for Indicator 1.2b, is available in Microsoft Excel via www.doi.org/10.25814/5bda82c8d76d4

[72] www.environment.gov.au/science/erin/databases-maps/snes

methodology). The modelled number of listed forest-dwelling fauna species per unit area of forest is highest in the eastern coastal regions of Australia, the Great Dividing Range, and the Kakadu region of Northern Territory, while the modelled number of listed forest-dependent fauna species per unit area of forest is highest in coastal and hinterland areas in north Queensland. The modelled number of listed forest-dependent and forest-dwelling flora species per unit area of forest is highest in wetter coastal and hinterland areas in northern New South Wales and Queensland. These are all areas where species diversity is also high.

Threats and threat categories relating to forest fauna and flora

The individual threats specified in the listing statement for each threatened species were documented (up to six separate threats for each species), then ranked as primary, secondary or tertiary threats based on the emphasis given in the listing advice in regard to their impacts. Threats were then grouped into threat categories based on the methodology of Davey (2018c). The significance of a threat category was assessed on the basis of the number of species for which a threat in that category was specified, and whether that those specified threats were ranked as primary, secondary or tertiary threats.

Table 1.45 provides an assessment of primary, secondary and tertiary threats for all forest-dwelling listed threatened species, based on current listing advice. The proportions of total specified threats in each threat category was similar for both flora and fauna in 2011 (as reported in SOFR 2013) and in 2016 (as reported here).

Land-use change and forest loss caused by clearing for agriculture, grazing, urban and industrial development has been the most significant threat category for forest-dwelling fauna species, followed by predation from introduced predators (e.g. fox, cat, rat and trout). Other significant threat categories are mortality agents, population size and localised distribution, unsuitable fire regimes, and competition from introduced fauna (e.g. rabbits, house mouse, foxes, cats, rats, trout, pigs and goats, and domestic livestock). Disease and pathogens, indirect impacts of invasive species, hydrological changes, forestry operations and identified climatic effects are progressively less significant threat categories for forest-dwelling fauna.

Small population size and localised distribution is the most significant threat category for threatened forest-dwelling flora, followed by mortality agents and unsuitable fire regimes. Land-use change and forest loss, competition from introduced flora (primarily invasive and non-invasive weeds, and escaped pasture grasses), impacts of invasive species (e.g. rabbits, goats, pigs, buffalo and invasive weeds such as lantana and blackberry), and predation and grazing (primarily grazing by domestic livestock, rabbits and macropods) are also significant threat categories. Hydrological changes, disease and pathogens, climatic effects, and forestry operations are progressively less significant threat categories for forest-dwelling flora.

The threat category 'unsuitable fire regimes' includes infrequent fire, too frequent fire, wildfire, lack of management of fire and, for flora, inappropriate intensity of fire. Fire regimes are an intrinsic part of forest management activities and are applied widely across Australia's forests. Where fire is used in forestry operations and is an identified threat to a species, the species has been included under both the 'unsuitable fire regime' and the 'forestry operations' threat categories. However, forestry operations are not a significant threat category for threatened forest flora, compared with other identified threat categories.

Notes to Figures 1.23A–D (on the following pages):

Fauna include both vertebrate and invertebrate taxa. Flora include both vascular and non-vascular plants.

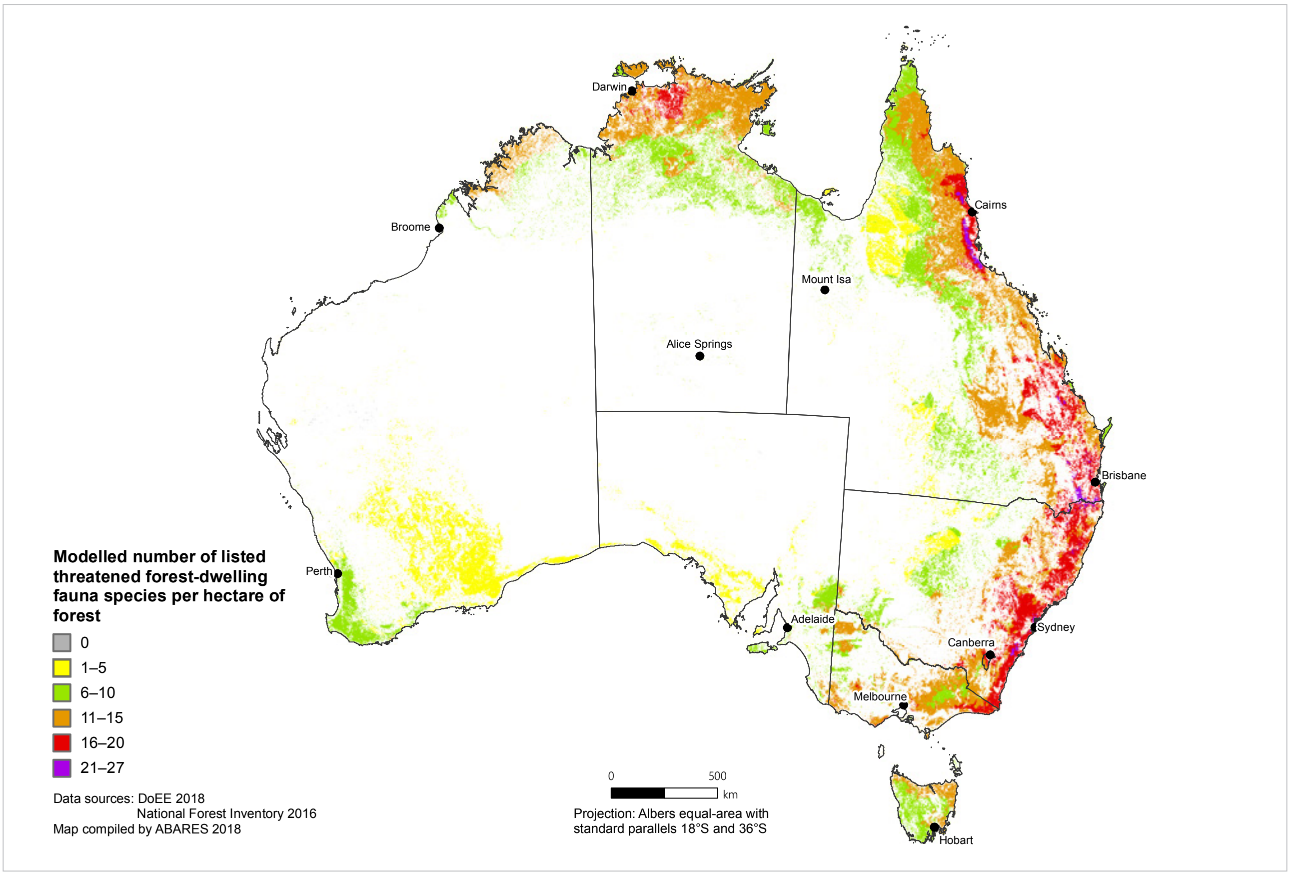
Species were determined to be forest-dependent if they are known to require, are likely to require, vegetation types designated as being forest communities in the National Vegetation Information System, or were reported as forest-dependent by national, state or territory agencies (see Indicator 1.2a).

The maps result from the intersection between the modelled potential extent of extant threatened species listed under the EPBC Act, and the 2016 forest extent (see Indicator 1.1a). The modelling of potential species extent was undertaken by the Environmental Resources Information Network (ERIN) within the Department of the Environment and Energy, and included areas where the species are known to occur, areas where they are likely to occur, and areas where they may occur. The number of species per hectare was calculated by summing the number of listed threatened species (flora or fauna, forest-dwelling or forest-dependent) in each hectare of forest (Davey 2018c). Extinct species were excluded.

Source: ERIN Species of National Environmental Significance Database[73] and National Forest Inventory (NFI).

[73] www.environment.gov.au/science/erin/databases-maps/snes

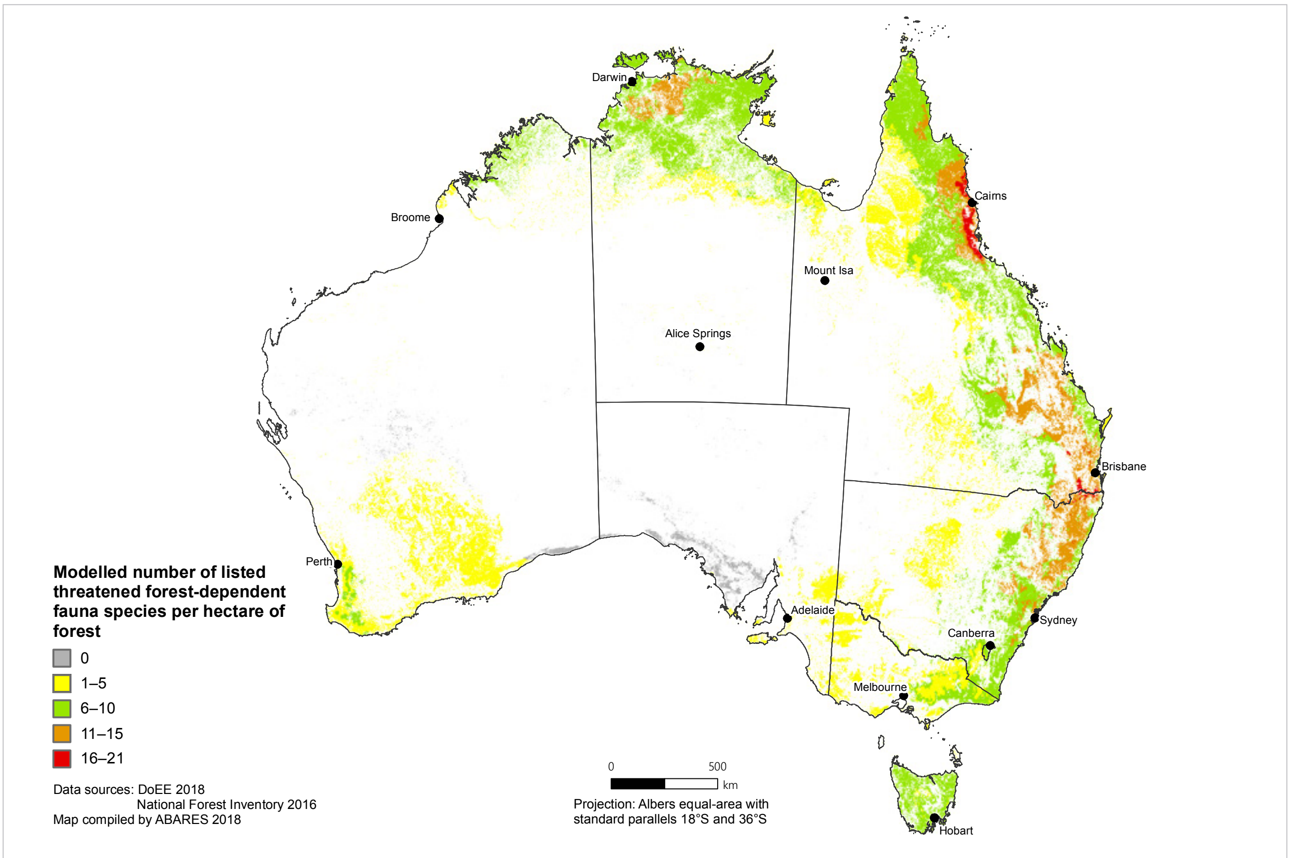
Figure 1.23: Modelled distribution of listed threatened species. A forest-dwelling fauna.



A higher resolution version of this map is available via www.doi.org/10.25814/5be3bc4321162

See notes on page 119.

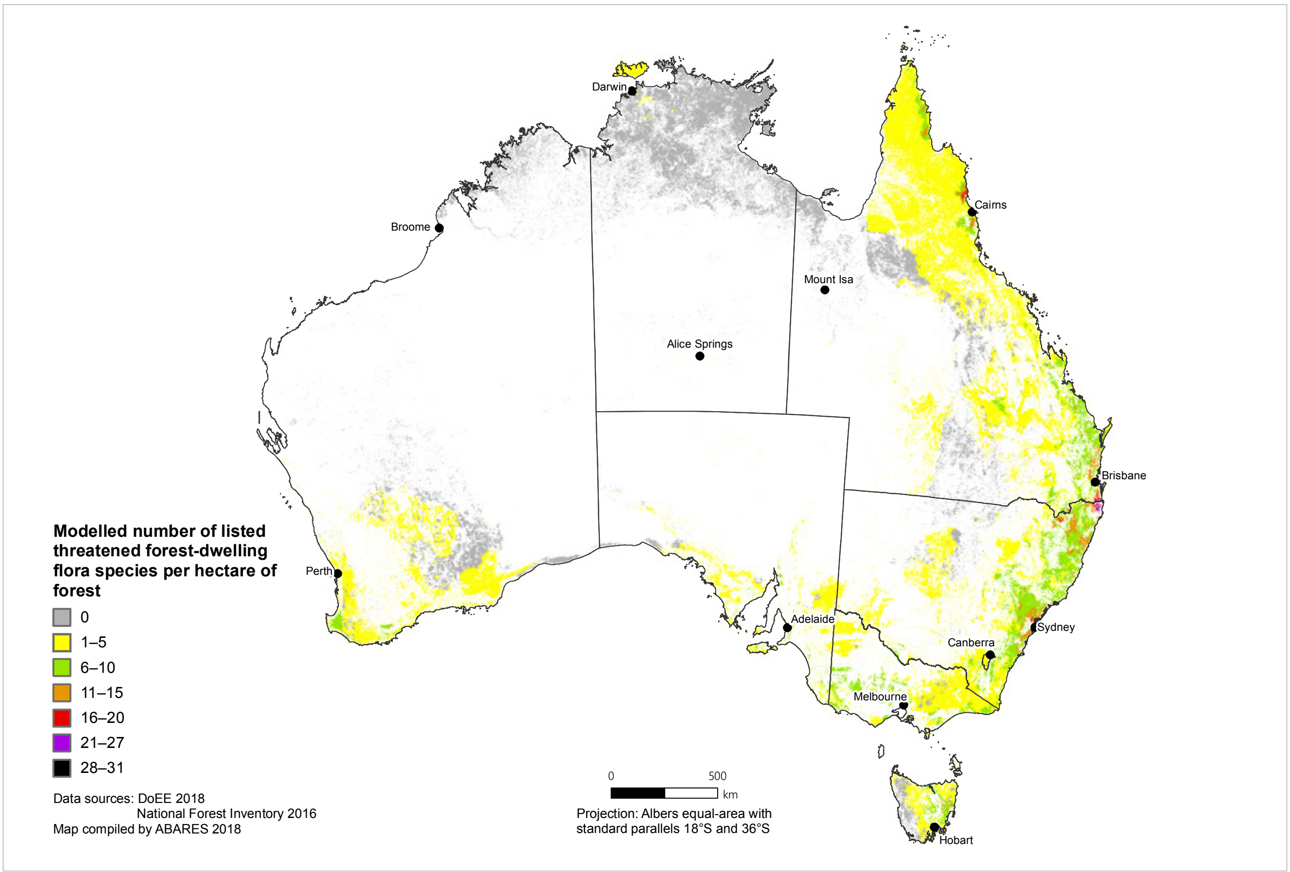
Figure 1.23: Modelled distribution of listed threatened species. B forest-dependent fauna.



A higher resolution version of this map is available via www.doi.org/10.25814/5be3bc4321162

See notes on page 119.

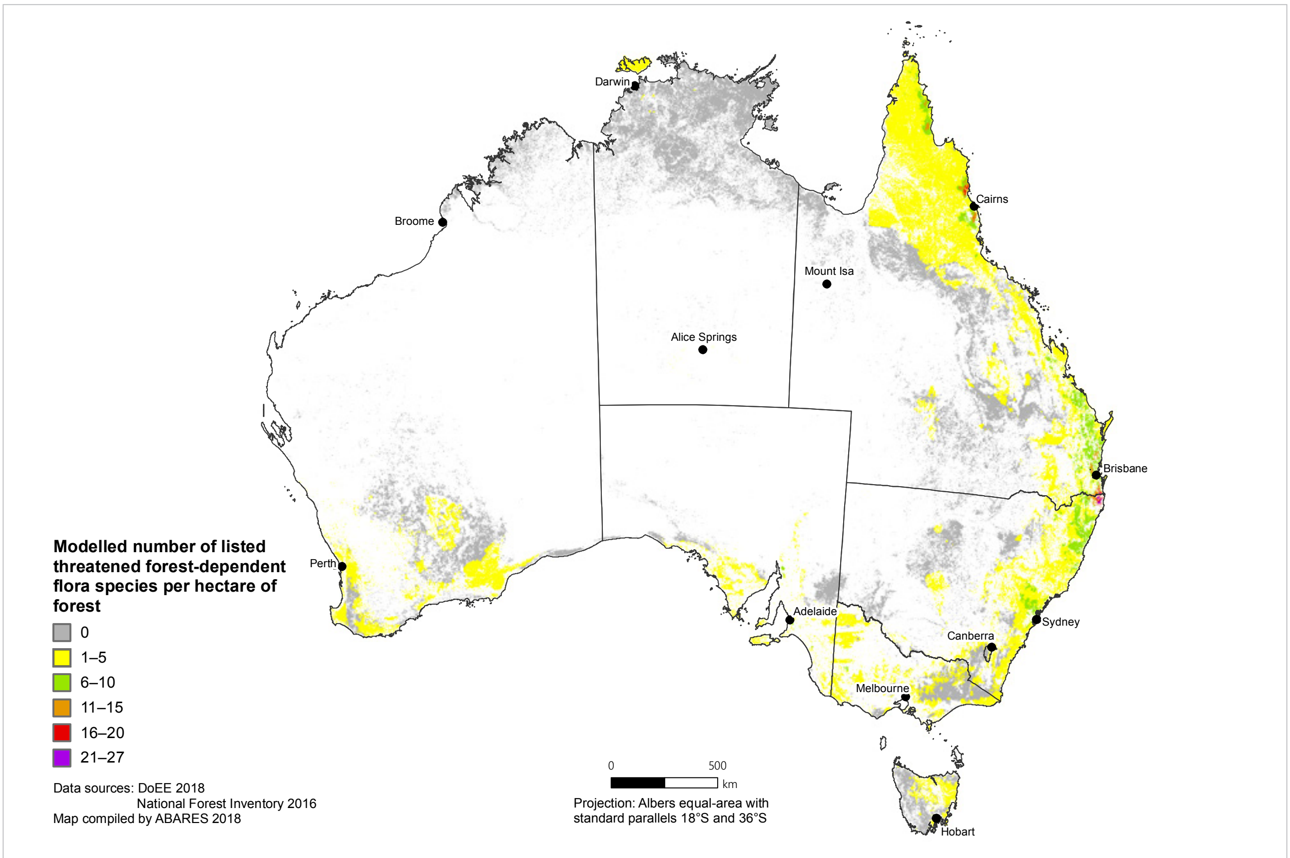
Figure 1.23: Modelled distribution of listed threatened species. **C** forest-dwelling flora.



A higher resolution version of this map is available via www.doi.org/10.25814/5be3bc4321162

See notes on page 119.

Figure 1.23: Modelled distribution of listed threatened species. **D** forest-dependent flora.



A higher resolution version of this map is available via www.doi.org/10.25814/5be3bc4321162

See notes on page 119.

Table 1.45: Threat rating and threat categories for forest-dwelling threatened species, as at 2016

Threat category	Number of species for which a threat in that category was specified				Proportion of total specified threats (%)
	Primary threat	Secondary threat	Tertiary threat	Total	
Fauna (invertebrate and vertebrate)					
Land-use change and/or forest loss[a]	187	45	6	238	17
Predation by introduced fauna	107	58	40	205	15
Mortality agents[b]	71	60	30	161	12
Small or localised population	127	20	10	157	11
Unsuitable fire regime[c]	64	56	20	140	10
Competition from introduced fauna[d]	41	63	15	119	9
Indirect invasive species impacts[e]	32	46	13	91	7
Disease and/or pathogens	31	18	27	76	6
Hydrological change	38	22	10	70	5
Forestry operations[f]	29	24	11	64	5
Climatic effects[g]	13	32	15	60	4
Flora					
Small or localised population	628	193	17	838	15
Mortality agents[h]	493	226	8	727	13
Unsuitable fire regime[c]	410	277	17	704	13
Land-use change and/or forest loss[a]	481	144	1	626	12
Competition from introduced flora[i]	432	173	6	611	11
Invasive species impacts[e]	411	173	3	587	11
Predation and grazing[j]	418	137	5	560	10
Hydrological change	133	125	1	259	5
Disease and/or pathogens	72	142	13	227	4
Climatic effects[g]	60	117	1	178	3
Forestry operations[f]	64	73	11	148	3

[a] 'Land-use change and/or forest loss' includes forest conversion and forest clearing resulting from agriculture, mining operations, and urban and industrial development, but excludes plantation development.

[b] For fauna, 'mortality agents' include hunting, illegal collection, agricultural chemical poisoning, competition and predation from native fauna, road-kill, and genetic or breeding issues.

[c] An 'unsuitable fire regime' can include infrequent fire, too frequent fire, wildfire, lack of management of fire, and (for flora) inappropriate intensity of fire.

[d] 'Competition from introduced fauna' can include competition from Australian fauna introduced to a locality or where their range has extended to new habitats, or where their abundance has increased to a point where they are in unnatural competition (e.g. Noisy Miner).

[e] 'Invasive species impacts' (flora and fauna) include pest fauna and weeds where their invasive nature is emphasised in the listing and the invasive species is listed as a threatening process separately from 'novel biota'. The threat rating is based on the emphasis given to their impact as invasive species in the listing.

[f] 'Forestry operations' are operational forest management activities related to wood production, such as silviculture, harvesting, maintenance of forest roads and fire-trails, fire management relating to wood production, plantation operations and development, and indirect or off-site effects, including impacts of escaped plantation species.

[g] 'Climatic effects' include climate change, climate variability, drought, winds and cyclone impacts.

[h] For flora, 'mortality agents' include illegal collection, agricultural chemical poisoning, road pressures (e.g. mowing, maintenance of forest roads and fire-trails not associated with production forestry, such as reserve management and public roads), human pressures (e.g. dumping, recreational pressure, pressures from development at urban edges), competition from native flora, and genetic or breeding issues.

[i] 'Competition from introduced flora' includes competition from weeds, pasture plants and Australian flora introduced to a locality, but excludes impacts of escaped plantation species.

[j] 'Predation and grazing' includes grazing by introduced and native herbivores, and vertebrate predation of seeds or plants.

Notes:

Classification of threats into primary, secondary and tertiary threats is based on the emphasis given in the listing advice in regard to past and current threat impacts. Up to six separate threats were included for each species; the total number of threats is thus larger than the total number of threatened species.

Flora taxa include vascular plants and one non-vascular plant. Data presented for fauna and flora exclude species removed from the list previously reported in SOFR 2013. Where species listings have been updated during the reporting period, earlier listings of threats are excluded. Data current at 01 August 2016; 1,420 taxa records used grouped into 1,075 flora records and 344 fauna records (307 vertebrate and 38 invertebrate records).

Totals may not tally due to rounding.

Source: ERIN Species of National Environmental Significance Database and SPRAT database; National Forest Inventory (NFI), ABARES datasets of extant and extinct native vertebrate forest fauna, vascular forest plants and invertebrate forest fauna.

This table, together with other data for Indicator 1.2b, is available in Microsoft Excel via www.doi.org/10.25814/5bda82c8d76d4

Changes in conservation status in reporting period

Since SOFR 2013, a number of changes have occurred in the national listing of threatened forest-dwelling species.

The conservation status of 106 listed threatened forest-dwelling species reported in SOFR 2013 (89 vascular flora species, 16 vertebrate fauna species, and one invertebrate fauna species) was amended during the SOFR 2018 reporting period (Table 1.46). Of these species, 17 were moved into a category corresponding to a higher level of threat, six were moved into a category corresponding to a lower level of threat, six were updated but remained in the same category, and 77 were removed from the list (Table 1.46).

All six forest-dwelling species that were moved into a category with a lower level of threat were vascular plants, three of which had previously been classified as Extinct and because of their rediscovery were relisted as Critically Endangered. Eight forest-dwelling vascular plant species were moved up in threat level due to progressive declines in already small populations attributed to mortality agents, pests and weed impacts, and further habitat loss or decline, with five species re-listed as Critically Endangered. Nine forest-dwelling vertebrate species (five birds, two frogs, a mammal and a reptile) were moved up in threat level, with seven of these re-listed as Critically Endangered. Increases in threat level for these nine vertebrates were attributed to continuing land-use change and forest loss, fire impacts, predation by introduced fauna, disease and mortality agents.

Impacts from forest operations were identified as primary threats in the re-listing as Critically Endangered of the Swift Parrot (*Lathamus discolor*), Regent Honeyeater (*Anthochaera phrygia*) and Leadbeater's possum (*Gymnobelideus leadbeateri*). In the case of the Regent Honeyeater, however, it is unclear how 'silviculture practice' (as specified in the listing statement) has resulted in a threat relating to fragmentation of its woodland landscape habitat. Case studies are included below for Swift Parrot (Case study 1.2) and Leadbeater's possum (Case study 1.3).

Of the 77 forest-dwelling species removed from the list, 70 were vascular plant species, six were vertebrate fauna species and one was an invertebrate fauna species (Table 1.47). Two plant and one vertebrate fauna species previously listed as Extinct were removed because of uncertainty about their taxonomic status. Most (59 species, 77% of the total) of the species removed were removed because of better information about their populations, distributions, ecology or threats, because their populations were considered no longer to be in decline, or because they no longer met the eligibility criteria for listing. The remaining 18 species (23% of the total) were removed because they were no longer scientifically recognised as a species as a result of taxonomic revisions (Table 1.48). Of the 77 species removed from the list, forestry operations had been listed as a threatening process for one vertebrate fauna species and seven flora species.

Over the SOFR 2018 reporting period, 68 forest-dwelling species were added to the national list of threatened species, comprising 33 vertebrate fauna species, 28 vascular flora species and seven invertebrate fauna species (Table 1.49). Species classed as Critically Endangered represented 41% (28 species) of the new listings. Other new listings were classed as Endangered (31%) or Vulnerable (28%) (Table 1.49). Newly listed invertebrate fauna and vascular flora species were predominately listed in the Critically Endangered and Endangered categories, including 14 orchids (52% of the new listings of vascular flora). The addition of a species to the national list of threatened species, or movement of a species to a higher risk category (e.g. from Vulnerable to Endangered), may result from a change in the actual threats to a species. However, changes in species ranking should be interpreted with caution, because many listings and de-listings reflect changes in information rather than changes in threat level. Addition of species to the national list of threatened species does give the opportunity to take additional steps to ensure the survival of the species, such as improvements in the management regime, or protection of additional habitat.

Most newly listed forest-dwelling fauna and flora species were added to the list of threatened species because of their small population size and/or restricted range, and threat categories

Table 1.46: Forest-dwelling species on the national list of threatened species with changed rating during the SOFR 2018 reporting period

Change in rating	Invertebrate	Vascular plants[a]	Vertebrate	Total
Transferred up in category	0	8	9	17
Transferred down in category	0	6	0	6
Updated but remained in category	0	5	1	6
Removed from list	1	70	6	77
Total	**1**	**89**	**16**	**106**

[a] Threatened vascular plants include clubmosses, spikemosses, horsetails, ferns, gymnosperms (including conifers) and angiosperms (flowering plants).

Notes:

Refer to notes in Table 1.43 for an explanation of the determination of forest-dwelling species, and for inclusion of data for species found on forested islands. Species added to the national list of threatened forest-dwelling species are given on Tables 1.49 and 1.50.

For these data, the reporting period for SOFR 2018 is January 2013 (when data collection for the corresponding table in SOFR 2013 ceased) to August 2016 (when data collection for this table ceased). The reporting period for SOFR 2013 was December 2007 to December 2012, and the reporting period for SOFR 2008 was January 2001 to December 2007.

Source: ERIN Species of National Environmental Significance Database and SPRAT database; National Forest Inventory (NFI), ABARES datasets of extant and extinct vertebrate forest fauna, vascular forest plants and invertebrate forest fauna.

This table, together with other data for Indicator 1.2b, is available in Microsoft Excel via www.doi.org/10.25814/5bda82c8d76d4

Table 1.47: Forest-dwelling species removed from the national list of threatened species during the SOFR 2018 reporting period

Taxa	Extinct	Critically Endangered	Endangered	Vulnerable	Total
Vertebrate fauna	1	0	0	5	6
Invertebrate fauna	0	0	1	0	1
Vascular plants[a]	2	2	11	55	70
Total	**3**	**2**	**12**	**60**	**77**

[a] Threatened vascular plants include clubmosses, spikemosses, horsetails, ferns, gymnosperms (including conifers) and angiosperms (flowering plants).

Notes:

Refer to notes in Table 1.43 for an explanation of the determination of forest-dwelling species, and for inclusion of data for species found on forested islands.

For these data, the reporting period for SOFR 2018 is January 2013 (when data collection for the corresponding table in SOFR 2013 ceased) to August 2016 (when data collection for this table ceased).

Source: ERIN Species of National Environmental Significance Database and SPRAT database; National Forest Inventory (NFI), ABARES datasets of extant and extinct vertebrate forest fauna, vascular forest plants and invertebrate forest fauna.

This table, together with other data for Indicator 1.2b, is available in Microsoft Excel via www.doi.org/10.25814/5bda82c8d76d4

Table 1.48: Reasons for the removal of forest-dwelling species from the national list of threatened species during the SOFR 2018 reporting period

Primary reason	Vertebrates	Invertebrates	Vascular Plants	Total	Proportion of total number delisted (%)
Revised taxonomy or no longer considered valid species	3	0	15	18	23
Improved knowledge base to justify change in status	0	0	20	20	26
No longer considered to be in decline	1	1	16	18	23
No identified threat	0	0	2	2	3
No longer meet current eligibility criteria	2	0	17	19	25
Total	**6**	**1**	**70**	**77**	**100**

Notes:

Refer to notes in Table 1.43 for an explanation of the determination of forest-dwelling species, and for inclusion of data for species found on forested islands.

For these data, the reporting period for SOFR 2018 is January 2013 (when data collection for the corresponding table in SOFR 2013 ceased) to August 2016 (when data collection for this table ceased).

For each delisted species, only one primary reason is given for delisting.

Source: ERIN Species of National Environmental Significance Database and SPRAT database; National Forest Inventory (NFI), ABARES datasets of extant and extinct vertebrate forest fauna, vascular and non-vascular forest plants and invertebrate forest fauna.

This table, together with other data for Indicator 1.2b, is available in Microsoft Excel via www.doi.org/10.25814/5bda82c8d76d4

Table 1.49: Forest-dwelling species added to the national list of threatened species during the SOFR 2018 reporting period

Taxa	Extinct	Critically Endangered	Endangered	Vulnerable	Total
Vertebrate fauna	0	8	10	15	33
Invertebrate fauna	0	3	3	1	7
Vascular plants[a]	0	17	8	3	28
Total	**0**	**28**	**21**	**19**	**68**

[a] Threatened plants include clubmosses, spikemosses, horsetails, ferns, gymnosperms (including conifers) and angiosperms (flowering plants).

Notes:

Refer to notes in Table 1.43 for an explanation of the determination of forest-dwelling species, and for inclusion of data for species found on forested islands.

For these data, the reporting period for SOFR 2018 is January 2013 (when data collection for the corresponding table in SOFR 2013 ceased) to August 2016 (when data collection for this table ceased).

Source: ERIN Species of National Environmental Significance Database and SPRAT database; National Forest Inventory (NFI), ABARES datasets of extant and extinct vertebrate forest fauna, vascular forest plants, and invertebrate forest fauna.

This table, together with other data for Indicator 1.2b, is available in Microsoft Excel via www.doi.org/10.25814/5bda82c8d76d4

relating to land clearing (agricultural and urban), mortality agents, unsuitable fire regimes, predation, grazing and invasive species impacts (Table 1.50). Threats or impacts from land-use change were a primary reason in 78% of new listings of forest-dwelling fauna, related primarily to agricultural and urban development, and land clearing not associated with forestry operations. Predation of fauna by introduced species, and unsuitable fire regimes, were identified as a primary threat category in 53% and 50% of the new fauna listings, respectively. Mortality agents, and small or localised populations, were primary threat categories for 45% and 40% of new listings of forest-dwelling fauna, respectively.

Threats in the categories of small or localised population, and mortality agents, were identified as primary threats for

Table 1.50: Species added to the national list of forest-dwelling threatened species during the SOFR 2018 reporting period, and categories of primary threats given as reasons for listing

Fauna species added to the national list of forest-dwelling threatened species						
Listing category	**Extinct**	**Critically Endangered**	**Endangered**	**Vulnerable**	**Total**	**Proportion of new listings (%)**
Number of added fauna species (vertebrate and invertebrate)	**0**	**11**	**13**	**16**	**40**	**100**
Category of primary threat[a]	**Number of added species for which primary threat in that category was specified[a]**					**Proportion of new listings with primary threat in this category (%)**
Land-use change and/or forest loss	0	9	7	15	31	78
Predation by introduced fauna	0	5	9	7	21	53
Unsuitable fire regime	0	2	8	10	20	50
Mortality agents	0	7	5	6	18	45
Small or localised population	0	7	4	5	16	40
Indirect invasive species impacts	0	3	3	7	13	33
Competition from introduced fauna	0	2	1	8	11	28
Climate effects	0	3	1	5	9	23
Hydrological change	0	4	1	2	7	18
Forest operations[b]	0	1	1	2	4	10
Disease and/or pathogens	0	1	1	1	3	8
Flora species added to the national list of forest-dwelling threatened species						
Listing category	**Extinct**	**Critically Endangered**	**Endangered**	**Vulnerable**	**Total**	**Proportion of new listings (%)**
Number of added flora species (vascular and non-vascular plants)	**0**	**17**	**8**	**3**	**28**	**100**
Category of primary threat[a]	**Number of added species for which primary threat was specified[a]**					**Proportion of new listings with this primary threat (%)**
Small or localised population	0	16	3	2	21	75
Mortality agents	0	13	4	3	20	71
Land-use change and/or forest loss	0	11	5	2	18	64
Invasive species impacts	0	12	2	2	16	57
Predation and grazing	0	11	2	2	15	54
Unsuitable fire regime	0	7	1	0	8	29
Hydrological change	0	5	1	1	7	25
Forest operations[b]	0	4	1	2	7	25
Competition from introduced flora	0	2	1	1	4	14
Disease and/or pathogens	0	0	3	1	4	14
Climate effects	0	0	1	0	1	4

[a] More than one primary threat may affect a species. Primary threats are described in footnotes to Table 1.45.

[b] 'Forestry operations' include silviculture, harvesting, forest roading, fire management and its effect, plantation operations and development, and indirect or off-site effects, including escaped plantation species.

Source: ERIN Species of National Environmental Significance Database and SPRAT database; National Forest Inventory (NFI), ABARES datasets of extant and extinct native vertebrate forest fauna, vascular forest plants and invertebrate forest fauna.

This table, together with other data for Indicator 1.2b, is available in Microsoft Excel via www.doi.org/10.25814/5bda82c8d76d4

listing in 75% and 71% of new listings of forest-dwelling flora species, respectively. Mortality agents were predominately human pressures (road maintenance, mowing, illegal collection, recreation, and chemical use) and genetic reasons. Land-use change and habitat loss was a primary reason in 64% of new flora listings; again, this related to agricultural and urban development and land clearing not associated with forestry operations. Threats in the categories invasive species impacts, and predation and grazing, were identified as primary threats in 57% and 54% of new listings of forest-dwelling flora, respectively (Table 1.50).

Forest operations were identified as primary threats in 10% (four species) of new listings of forest-dwelling fauna species, and 25% (seven species) of new listings of forest-dwelling flora species (Table 1.50).

- The four forest-dwelling fauna species were two invertebrates (*Micropathus kiernani* and *Oreixenica ptunarra*), the greater glider (*Petauroides volans*) and the Painted Honeyeater (*Grantiella picta*). In addition, forest operations were identified as a secondary threat in the listing of the mainland subspecies of the broad-toothed rat (*Mastacomys fuscus mordicus*).
- Of the seven newly listed forest-dwelling flora species for which forest operations were identified as a primary threat, four were orchids (*Corunastylis insignis*, *C.* sp. *Charmhaven* (NSW 896673), *Thelymitra adorata* and *T. hygrophila*). The other three species were a tree (*Eucalyptus macarthurii*), a shrub (*Pomaderris pilifera* subsp. *talpicutica*) and a spikemoss (*Selaginella andrewsii*). Three new listings of forest-dwelling flora had forestry operations listed as a secondary threat, namely two orchids (*Prasophyllum innubum* and *P. keltonii*) and a shrub (*Pomaderris vacciniifolia*).

Three case studies on individual threatened species are provided below on:

- the breeding success of the Swift Parrot (*Lathamus discolor*), and predation by the introduced (to Tasmania) sugar glider (*Petaurus breviceps*) (Case study 1.2)
- new approaches to survey and conservation of Leadbeater's possum (*Gymnobelideus leadbeateri*) (Case study 1.3), and
- detecting the presence of the black-footed tree-rat (*Mesembriomys gouldii*) in the Northern Territory (Case study 1.4).

Further case studies on threatened species are provided in Indicator 1.2c (Case study 1.7, reporting on monitoring the koala in New South Wales and Queensland) and in Indicator 1.3a (Case study 1.10, describing the conservation of four listed *Macadamia* species of importance to the horticultural industry).

Threatened ecological communities

At August 2016, the EPBC Act listed 76 threatened ecological communities, of which 41 are forest communities or contain significant proportions of forest. Three threatened ecological communities that are non-forest communities, but contain small proportions of forest, are not included in this total of 41 threatened forest communities. Threatened forest communities thus represent 54% of threatened ecological communities listed under the EPBC Act. This is an increase of 14 ecological communities from the 27 listed threatened ecological communities that contain forest reported in SOFR 2013, and is due to new listings.

Of the 41 listed threatened ecological communities that contain forest, 22 are Critically Endangered, 18 are Endangered and one is Vulnerable (Table 1.51).

Nine newly listed Critically Endangered ecological communities contain forest, as do four newly listed Endangered ecological communities (Table 1.51). In addition, one Endangered ecological community that included only small proportions of forest and that was not included as a threatened forest community in SOFR 2013 was included in SOFR 2018 based on reconsideration of information. These newly listed or newly included forest-containing ecological communities are found in New South Wales, South Australia, Victoria and Western Australia. Clearing resulting from agriculture, urbanisation, peri-urban development and mining, and consequential fragmentation, were the main reasons for all the new listings. Weeds, grazing by domestic stock, native animals and feral herbivores, and changed fire regime impacts including bushfires, were also identified as threats in all new listings.

Twenty-five threatened forest ecological communities occur in New South Wales, 12 in Queensland, eight in Victoria and six in Western Australia; the other states and territories each have five or fewer (Table 1.51). Figure 1.24 presents the

Table 1.51: Number of forest ecological communities listed under the EPBC Act, by jurisdiction

	Critically Endangered		Endangered		Vulnerable		Total	
Jurisdiction	SOFR 2013	SOFR 2018	SOFR 2013	SOFR 2018	SOFR 2013	SOFR 2018	SOFR 2013	SOFR 2018
ACT	1	1	0*	0	0	0	1*	1
NSW	8*	15	9*	10	0	0	17*	25
NT	0	0	1	1	0	0	1	1
Qld	6	6	6*	6	0	0	12*	12
SA	1*	2	2*	3	0	0	3*	5
Tas.	0	0	0	0	1	1	1	1
Vic.	4*	5	3	3	0	0	7*	8
WA	0	1	3	5	0	0	3	6
Australia	**13**	**22**	**14***	**18**	**1**	**1**	**28***	**41**

* Correction to numbers misreported in SOFR 2013.

Notes:

Data are current as at 01 August 2016, and are based on distribution information in the listing advice for each ecological community. Individual listed ecological communities can occur in one or more state or territory, so the figures for Australia are not the sum of the figures for individual jurisdictions.

Source: ERIN Communities of National Environmental Significance Database and listing data, www.environment.gov.au/cgi-bin/sprat/public/publiclookupcommunities.pl; National Forest Inventory (NFI), ABARES datasets of threatened ecosystems.

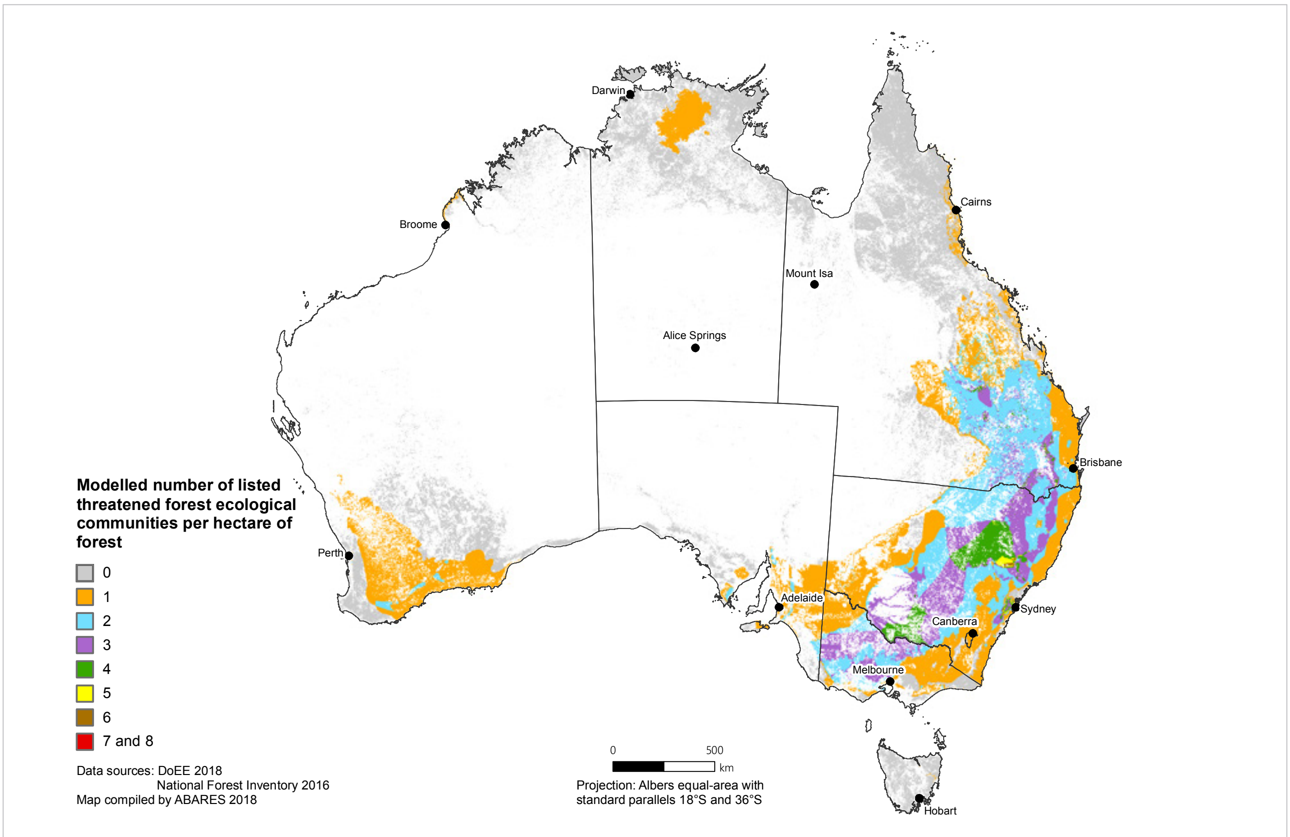
This table, together with other data for Indicator 1.2b, is available in Microsoft Excel via www.doi.org/10.25814/5bda82c8d76d4

modelled potential distribution of threatened forest ecological communities, shown as the number of listed threatened forest ecological communities that could occur in each unit area[74].

The threat categories for the historical and current threats listed for these 41 threatened forest ecological communities, based on listing and policy statements, are summarised in Table 1.52. Weeds, forest loss through agricultural clearance, grazing pressure (primarily by stock and macropods), fire (inappropriate fire management or inappropriate fire regimes) and fragmentation are each given as threats (reasons for listing) for 76% or more of the threatened forest ecological communities listed. Feral animal pressures, impacts of hydrological change, climatic impacts (drought and climate change) and forest loss through urbanisation are identified in more than half of the listings. Human pressures, including urban fringe impacts (rubbish, recreation pressure, roading impacts and poor management) and pollutants each appear in 51% or more of the listings. Diseases including dieback syndromes are identified in 41% of listings. Forestry operations appear in 32% of the listings (13 listings), with eight of the 13 referring to historical wood production operations in native forests, five referring to current forestry activities, two referring to plantation establishment, and one (the 'Brigalow (*Acacia harpophylla*) dominant and co-dominant ecological community'; Commonwealth of Australia 2013a) identifying current forest practice as a less significant threat primarily on private land[76].

States and territories have commenced regional studies on assessing strategies to manage cumulative impacts of threats, and on how best to implement strategies to manage these impacts on forest-dwelling threatened species and threatened forest ecological communities. An example is the study of threatened species and ecological communities in Queensland's brigalow forests, of which only 9% of its original 7 million hectares remain as small isolated remnants as a result of agricultural clearing and development since European settlement (Ponce Reyes et al. 2016).

Figure 1.24: Modelled distribution of listed threatened forest ecological communities



Note: the map results from the intersection between the modelled potential extent of threatened ecological communities listed under the EPBC Act and the 2016 forest extent (see Indicator 1.1a). The modelling of the extent of potential communities was undertaken by ERIN (Australian Government Department of the Environment and Energy) and included areas where the communities are known to occur, areas where they are likely to occur, and areas where they may occur. The number of communities per hectare was calculated by summing the number of listed threatened communities in each hectare of forest. Some threatened ecological communities are restricted in extent and cannot readily be visualised at the scale of this map. This map has been compiled from datasets with a range of scales and quality, and is therefore indicative only and not meant for local assessment.

This modelled distribution of listed communities may differ from state and territory reporting based on more detailed regional ecosystem maps and community surveys.

Source: ERIN Communities of National Environmental Significance Database[75], National Forest Inventory (NFI).

A higher resolution version of this map is available via www.doi.org/10.25814/5be3bc4321162

[74] Caveats are associated with maps of listed threatened ecological communities (see www.environment.gov.au/cgi-bin/sprat/public/publiclookupcommunities.pl).

[75] www.environment.gov.au/science/erin/databases-maps/ecnes

[76] Ecological communities may have more than one type of forestry activity listed as a threat.

Table 1.52: Threats to threatened forest ecological communities listed under the EPBC Act

Category of threat (historical and current)[a]	Number of listed communities for which a threat in that category was specified	Proportion of threatened forest ecological communities with a threat in that category (%)
Weeds[b]	38	93
Forest loss – agriculture[c]	37	90
Grazing pressures[d]	33	80
Fire pressures[e]	33	80
Fragmentation[f]	31	76
Feral animals[b]	28	68
Hydrological change[g]	25	61
Climatic impacts[h]	24	59
Forest loss – urbanisation[c]	21	51
Human pressures[i]	19	46
Disease[j]	17	41
Forestry operations[k]	13	32
Loss of ecological function[l]	9	22
Isolation – disconnection[f]	6	15
Small remnants[f]	6	15
Forest loss – mining[c]	6	15

[a] Threats to ecological communities were grouped into threat categories based on thematic grouping or key words found in threat descriptions. Descriptions of threatened forest communities reported in SOFR 2013 have been updated to accord with this approach. More than one threat may be given for an ecological community. The analysis was performed on the 41 forest ecological communities identified on Table 1.51.

[b] Threats due to pests and weeds were identified on 38 occasions, and are here listed in two categories, 'weeds' and 'feral animals'.

[c] Threats due to forest loss (forest conversion and forest clearing) were identified for 39 threatened ecological communities, and have been listed in three categories: 'agriculture', 'urbanisation' (urban and industrial development) and 'mining' based on the use of these key words. Plantation conversion and development is included in the threat category 'forest operations'.

[d] The threat category 'Grazing pressures' includes grazing by native animals, domestic stock, rabbits and feral stock.

[e] The threat category 'fire pressures' includes wildfire, deliberate fire (arson), hazard reduction burning, lack of fire and altered fire regimes associated with intensity, frequency, seasonality and patchiness of historical fire regimes.

[f] Threats relating to very small or fragmented ecosystems were identified for 34 threatened ecological communities; 'fragmentation', 'isolation-disconnection' and 'small remnants' were identified as categories using key words. Fragmentation is associated with the loss of spatial connectivity between forest areas. Isolation-disconnection groups threats to ecosystems where fragmentation or configuration of remnants was affecting the viability of the ecosystem. The threat category 'small remnants' identifies ecosystems where only small proportions of the ecosystem remain as remnants.

[g] The threat category 'Hydrological change' includes threats to ecosystems that cover salinity, flooding, changed drainage, acidification, reduced stream flow, and changes in water table and aquifers.

[h] The threat category 'Climatic impacts' includes threats due to climate change impacts, increases in incidence, duration or intensity of droughts, and storm or cyclonic damage.

[i] The threat category 'Human pressures' includes threats from inappropriate use of chemicals and machinery, road maintenance, recreation impacts, firewood collection, frequent human disturbance and rubbish dumping.

[j] The threat category 'Disease' covers threats such as disease agents, risks and syndromes including identified and unidentified disease, dieback (rural, insect derived, Bell Miner, and phytophthora dieback syndromes), and risk of disease from phytophthora and myrtle rust.

[k] The threat category 'Forestry operations' includes threats associated with the forest industry such as silviculture, harvesting, forest roading, fire management and its effect, plantation operations and development, and indirect or off-site effects, including escaped plantation species. Harvesting, thinning or logging on private forest land is included as a forestry operation. It does not include forest management and operations not associated with the forest industry, such as firewood collection, park management and maintenance of public road networks (such threats are included in 'human pressures').

[l] The threat category 'Loss of ecological function' includes degradation resulting in changing fauna and flora composition affecting the integrity of the ecosystem, and identified loss in ecosystem processes and functions.

Source: ERIN Species of National Environmental Significance Database, www.environment.gov.au/science/erin/databases-maps/snes; National Forest Inventory (NFI), ABARES datasets of threatened ecosystems. Data current at 01 August 2016.

This table, together with other data for Indicator 1.2b, is available in Microsoft Excel via www.doi.org/10.25814/5bda82c8d76d4

Case study 1.2: Breeding success of the Swift Parrot (*Lathamus discolor*) and effects of predation by sugar gliders (*Petaurus breviceps*)

The Swift Parrot (*Lathamus discolor*, Figure 1.25) is a small, largely nectar-feeding, fast-flying parrot which spends its winter in south-eastern mainland Australia before migrating to Tasmania in late winter/early spring to breed. This species was listed as Vulnerable under the Commonwealth *Endangered Species Protection Act 1992* and the Tasmanian *Threatened Species Protection Act 1995*, and was up-listed to Endangered at the commencement of the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and under the Tasmanian *Threatened Species Protection Act 1995* in 2000 due to small population size and loss of habitat. In 2016 the species was up-listed to Critically Endangered under the EPBC Act, following evidence of significant population declines as a result of nest predation, primarily by sugar gliders (*Petaurus breviceps*) which were introduced into Tasmania from Victoria at some point after 1835 (Campbell et al. 2018).

Nectar from Tasmanian blue gum (*Eucalyptus globulus*) and black gum (*E. ovata*) flowers is the primary food source for the Swift Parrot during its breeding season. Flowering is variable in space and time, and at any one locality it may be more than five years between significant flowering events (Stojanovic et al. 2015). Swift Parrots breed primarily in eastern Tasmania but breeding has also been recorded in isolated areas in northern Tasmania (Figure 1.26). Swift Parrots breed in tree hollows in mature eucalypts up to about 5 km from their foraging areas. They typically nest in large groups (e.g. up to 40 to 50 nests) covering large areas (~100 ha). Research by the Australian National University (ANU) has found that Swift Parrots prefer tree hollows with characteristics (e.g. a small entrance diameter and a deep cavity) that help to exclude predators by physically preventing access to the nest chamber (Stojanovic et al. 2012).

Early attempts to assess the population of breeding birds in Tasmania estimated 1,320 pairs (Brown 1989). Another survey, carried out during the 1995–96 breeding season following initial listing of the species, estimated 940 pairs. During the breeding seasons from 1999 to 2004, fixed-stationary observer techniques were used at 55 sites to estimate the density of Swift Parrots across the range of dry, grassy blue gum forest in eastern Tasmania (Saunders et al. 2010). More comprehensive breeding season surveys from 2004 to 2014 provided information on the annual variation in the spatial characteristics of breeding events. These surveys also confirmed the importance of wet forest habitats for breeding (Webb 2008). Surveys continued over the 2014–15, 2016–17 and 2017–18 seasons by researchers from the ANU as part of a project funded by the Australian

Figure 1.25: Male Swift Parrot (*Lathamus discolor*)

Continued

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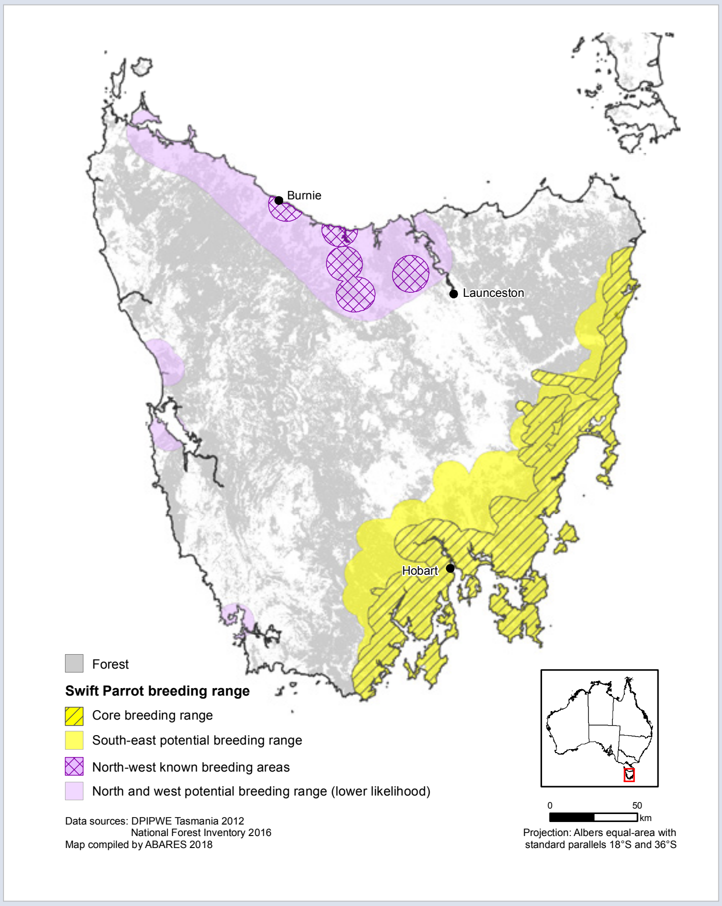
Figure 1.26: Swift Parrot breeding range



Note: Map shows the potential breeding range of the Swift Parrot in Tasmania, based on current information. The breeding range is divided into the core breeding range (the area, within the south-east potential breeding range, thought to be of highest importance for the maintenance of breeding populations), the south-east potential breeding range (areas in the south-east of Tasmania where breeding could occur based on the occurrence of breeding habitat and foraging habitat), north-west known breeding areas (sites in the north-west of Tasmania where nest sites are known to occur), and the north and west potential breeding range (areas in the north-west of Tasmania where breeding could occur based on the occurrence of small breeding habitat and foraging habitat, but is less likely to occur than areas in the south-east).

Source: SOFR 2013, National Forest Inventory (NFI), Tasmania Department of Primary Industries, Parks, Water and Environment; adapted from FPA and Threatened Species Section (DPIPWE) (2012).

Research Council. The results confirm clustering of breeding birds in discrete parts of their overall range driven by flowering patterns in a particular season (Webb et al. 2014; Stojanovic et al. 2015; Webb et al. 2017). In some years the area available for breeding was limited due to poor and localised flowering (Webb et al. 2017).

Historically, loss and alteration of habitat as a result of land clearing, forestry activities and wildfire was recognised as the main threat to the species. However, recently ANU researchers found that nest predation by the introduced sugar glider is also a major threat to the Swift Parrot (Stojanovic et al. 2014; Heinsohn et al. 2015), and that predation rates increase with increasing habitat loss and fragmentation (Stojanovic et al. 2014). Predation risk varies dramatically across the breeding range of Swift Parrots, depending on the presence of sugar gliders, and may have contributed to significant declines in the Swift Parrot population in recent years. Population Viability Analysis modelling suggests declines of >80% within a three-generation period (12–18 years) (Commonwealth of Australia 2016a).

Conservation efforts for Swift Parrots in forests outside of Tasmania's formal reserve system have evolved over the past 20 years with the increasing knowledge of the habitat requirements of the species. Conservation actions taken to mitigate impacts of forestry activities on the Swift Parrot vary according to the location (e.g. whether in an area known to be important for breeding), the type of forestry operation, and the local availability of breeding habitat for the species. Conservation actions include protection of known nest sites, pre-harvest surveys for breeding habitat, and exclusion from harvesting plans of nesting and foraging habitat in areas important for breeding. Forest planners also undertake training in the ecology, identification and management of Swift Parrots and their habitat. There has been increasing recognition of the need to account for the spatiotemporal variation in the availability of breeding habitat, and that there may be several years between use of a particular site by the species. Strategic conservation planning at the landscape level aims to ensure that adequate nesting habitat and foraging habitat is available to support the breeding population of Swift Parrots in any one year.

Recent conservation work has also focused on efforts to reduce predation by the sugar glider at nesting locations. The ANU research team is testing a range of nest protection approaches. Swift Parrots readily utilise nest boxes, and a network of nest boxes has been set up across the breeding range of the species, with devices designed to

Continues

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exclude or repel sugar gliders attached to some of these nest boxes. Such devices include mechanical doors affixed to the entrance, with a motor operated by an ambient light switch set to open during daylight hours and close at night. Preliminary results show that the resident nesting birds are not affected by such devices.

A Recovery Plan for the species has been in place since 1997. The current National Recovery Plan for the Swift Parrot was adopted in 2011 (Saunders and Tzaros 2011).

A new Swift Parrot recovery plan is being developed that will include conservation actions to reverse the trajectory of decline for this species, and address the recently recognised threat from sugar gliders. The primary actions will be to protect, as much as possible, existing breeding habitat and foraging habitat in high-risk areas, and to develop and implement strategies to reduce predation from sugar gliders.

Case study 1.3: Targeted surveys to improve conservation of Leadbeater's possum (*Gymnobelideus leadbeateri*)

Leadbeater's possum (*Gymnobelideus leadbeateri*, Figure 1.27) is a small arboreal possum found only in Victoria, where it is largely confined to the montane ash forests of the Central Highlands Regional Forest Agreement region, north-east of Melbourne. It was thought to be extinct after it disappeared from the few locations where it had been initially recorded, mostly around Western Port Bay, between 1867 and 1915. However, the species was rediscovered near Marysville in 1961, and has since attracted considerable community interest, being one of Victoria's faunal emblems. Leadbeater's possum is listed as Critically Endangered under the EPBC Act.

Key habitat requirements for Leadbeater's possum include large trees with hollows that are used as den sites, and a dense understorey or midstorey that provides both food and movement pathways. There are a range of threats to the species and its habitat. Extensive bushfires over the last century have changed the age structure of the montane ash forest, as ash trees are frequently killed by high-intensity fires, resulting in even-age regrowth forests. Fire-killed trees provide den sites, however those remaining from the 1939 bushfires are collapsing, leading to a shortage of suitable hollows in many areas (Lindenmayer et al. 2012). In addition to changing the forest structure, bushfires can cause mortality directly. Approximately one-third of the range of the species burnt during extensive bushfires in 2009, with subsequent surveys revealing that Leadbeater's possum had disappeared from most burnt areas, irrespective of fire intensity (Lindenmayer et al. 2013; Lumsden et al. 2013). Loss of critical habitat resources as a result of wood harvesting is also a threat to Leadbeater's possum, and about one-third of its potential habitat across the Central Highlands RFA region is available for wood harvesting (LPAG 2014a).

In 2014, in response to these threats to the species, the Leadbeater's Possum Advisory Group (LPAG) made 13 recommendations to support the recovery of the species, while maintaining a sustainable forest industry (LPAG 2014b). One of the key recommendations was to establish a timber harvesting exclusion zone of 200 m radius around all verified records of the species from 1998 onwards, to protect colonies and surrounding habitat. LPAG also recommended extensive targeted surveys be undertaken to rapidly locate more colonies for protection from timber harvesting. This required the development of an efficient, reliable and effective survey method to sample across the range of the species.

Automated cameras had been extensively used for ground-based surveys; however, they had rarely been used to survey arboreal mammals. The Arthur Rylah Institute for Environmental Research, Department of Environment, Land, Water and Planning[77], Victoria (ARI) designed surveys for Leadbeater's possum using cameras, and worked with arborists to install the cameras in trees, using creamed honey as a lure. Cameras were set on tree trunks at varying heights up to 47 m, targeting areas of well-connected vegetation where Leadbeater's possum were most likely to be moving or foraging. This approach was highly effective, and it was calculated that the method had a greater than 85% chance of detecting the species if it was were present at a site (Nelson et al. 2017).

ARI surveyed 438 sites between 2014 and 2017 using this method. In the first two years, surveys were very targeted, focusing on areas of State forest predicted to be more likely to contain Leadbeater's possum. These surveys were very successful, with Leadbeater's possum detected at 149 sites (52% of the sites surveyed; Nelson et al. 2017; Figure 1.28). While this approach maximised the likelihood of detecting the possums, due to the spatially targeted nature of the sampling it limited extrapolation of the occurrence of the species to other areas. In the third year, an alternative

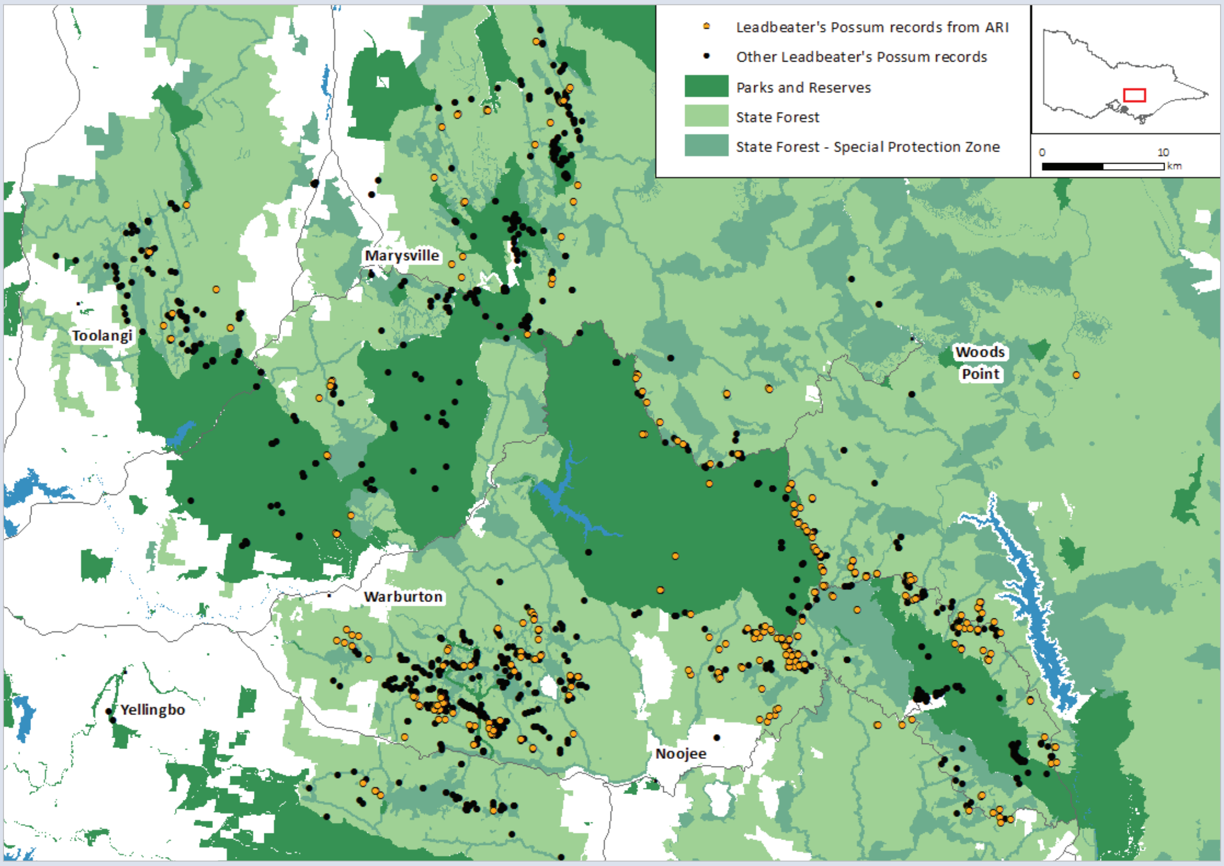
[77] Until January 2015, the Department of Environment and Primary Industries.

Continued

Continues

Figure 1.27: Leadbeater's possum (*Gymnobelideus leadbeateri*), which occurs in the montane ash wet forests of Victoria

Figure 1.28: Location of Leadbeater's possum records in Victoria, including recent records from Arthur Rylah Institute's targeted surveys



Source: Arthur Rylah Institute (ARI), showing site records to May 2017 in the Victorian Biodiversity Atlas.

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approach was taken, selecting sites randomly across the range of the species, including in parks and reserves in addition to State forest, and also sampling areas burnt during the 2009 bushfires. An additional 149 sites were surveyed in this way, with Leadbeater's possum located at 55 (37%) of these randomly selected sites. The species was recorded in forest of a wide range of age classes and disturbance histories, including both 1939 regrowth and younger stands of regrowth from fire or from timber harvesting.

This survey technique primarily records animals where they are foraging, and for colonies to use young regrowth forest there needs to also be suitable hollow-bearing trees nearby to provide denning sites. Some animals were recorded in forest stands burnt during the 2009 fires, encouragingly showing some level of recolonisation of these areas within eight years of the fires.

Timber harvesting exclusion zones have been established around all the ARI records of Leadbeater's possum, providing increased protection for 204 newly detected colonies and their habitat. Data from these extensive surveys have improved knowledge of the distribution of Leadbeater's possum and its use of habitat across its range, and are being used to update species distribution models to inform future conservation and management.

Source: Lindy Lumsden, Arthur Rylah Institute

Case study 1.4: Use of camera traps for assessing the presence of the black-footed tree-rat (*Mesembriomys gouldii*)

Black-footed tree-rats (*Mesembriomys gouldii*) are a forest-dependent species that occupy open and woodland forest of northern Australia tropical savannas, where they den in tree hollows or pandanus during the day and forage on the ground and in trees at night (Pittman 2003; Rankmore 2006). They are one of Australia's largest native rats, and eat fruits, supplemented by flowers (of *Grevillea* and *Eucalyptus*), insects and freshwater mussels (Morton 1992).

Three disjunct subspecies are recognised: *M. g. gouldii* inhabits the north-west Kimberley (Western Australia) and mainland Northern Territory, *M. g. melvillensis* is found on Melville Island (Northern Territory), and *M. g. rattoides* inhabits Cape York Peninsula (Queensland). Because of the decline of these subspecies across their range, coupled with on-going threats (habitat loss and fragmentation; habitat loss due to invasive exotic grasses; inappropriate fire regimes; and feral cat predation), all three subspecies were listed under the EPBC Act in 2015. The Kimberley and Northern Territory subspecies *M. g. gouldii* is listed as Endangered, and the other two subspecies are listed as Vulnerable. While black-footed tree-rats are considered uncommon to rare in the Kimberley and Queensland, they are still common but patchily distributed across the Top End of the Northern Territory (Figure 1.29).

It is essential to determine the presence of threatened species reliably prior to potential impacts of habitat loss or development, and wildlife surveys designed to detect these species can ensure adequate protection measures are in place. A consideration of the trade-offs between expense, survey effort and the needed accuracy and precision of survey results can optimise the value of wildlife surveys for monitoring and environmental management. Of particular importance is the concept of imperfect detection, where a species remains undetected in surveys even though it is present in the landscape. The probability of detecting a species with different sampling designs can be assessed using occupancy modelling. This approach is particularly useful when target species are rare or elusive, and there are competing priorities for threatened species management funding and resources.

Camera trapping has become the most widely used, cost-effective and low-impact means of reliably detecting terrestrial mammal species, because it can provide systematic and accurate data over prolonged survey periods without the requirement for live trapping (Gálvez et al. 2016). The advantages of camera trapping over conventional methods for species inventory, ecological and monitoring studies are well recognised (Meek et al. 2014; Smith et al. 2016). Camera traps are particularly suited to surveying forest mammals, and can provide systematic and accurate data over prolonged survey periods. Analysis of camera trap data across eight regions in the open and woodland forests of the Northern Territory (Figures 1.29–1.31) has allowed the determination of optimal number of cameras and deployment time required to reliably detect the presence of black-footed tree-rats (Risler 2017).

The outcomes of camera trap detectability research can incorporated into impact assessment guidelines to improve detectability and provide definitive and achievable methods for detecting the black-footed tree-rat. Such research is applicable across species and habitats and will serve to standardise survey design and methods, providing a greater knowledge base for natural resource management and species conservation and reduced the likelihood of imperfect detection.

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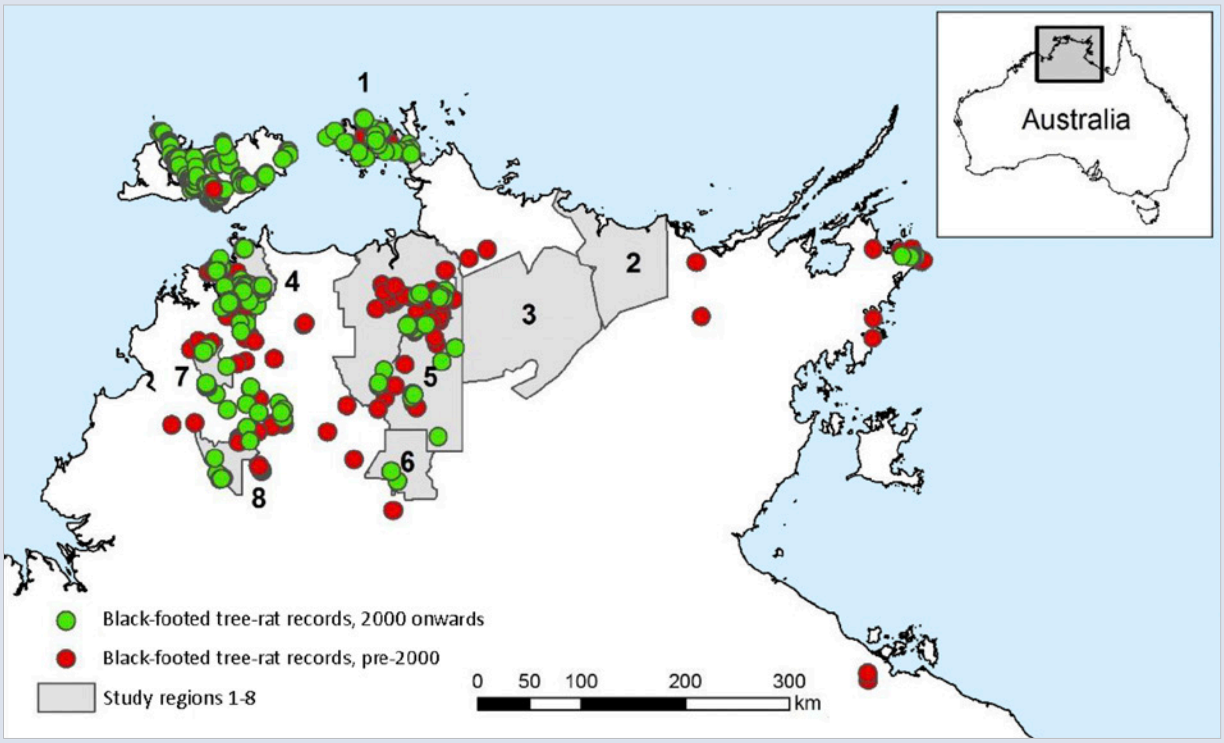
Figure 1.29: Distribution of black-footed tree-rat in the Northern Territory



Source: Northern Territory Government fauna atlas records overlaid on eight study regions (Risler 2017).

Figure 1.30: Setting up a camera trap, Northern Territory

Figure 1.31: Black-footed tree-rat photographed by the camera trap in Figure 1.30

Indicator 1.2c

Representative species from a range of habitats monitored at scales relevant to regional forest management

Rationale

This indicator provides broad habitat, population, and range information for representative forest dwelling flora and fauna. Evidence of changing ranges or densities of forest dwelling species can be used to guide forest management activities so that they are consistent with maintenance of forest biodiversity.

Key points

- There continues to be a lack of comprehensive knowledge and monitoring of the occurrence of representative species across land tenures and forest types, which limits the conclusions that can be drawn from available data.
  - Efforts to monitor forest-dwelling species vary across state and territory jurisdictions, and in some jurisdictions have diminished or been discontinued for certain taxa.
  - States and territories undertake separate monitoring for their own regulatory and research requirements, and their priorities may differ from national priorities.
- Birds are the taxonomic group with the largest number of programs in place to track population trends over time. Monitoring efforts of state and territory agencies for birds are supplemented by a large-scale investment by non-government organisations. A number of case-studies on monitoring programs are presented.
- Long-term monitoring programs such as ForestCheck in Western Australia and the Warra Long-term Ecological Research site in Tasmania contribute monitoring information supportive of continuous improvement of sustainable forest management in those states.

Forest-dwelling species are monitored under programs implemented by a range of different bodies, including state and territory forest management agencies, state and territory conservation agencies, the Terrestrial Ecosystem Research Network (TERN), universities, non-government organisations and private individuals. These programs have been established for a variety of reasons and at various scales; for example, university programs are often designed to address particular research questions, usually at a localised scale. The states and territories monitor forest-dwelling species to meet requirements specified by relevant legislation and/or sustainable forest management policies; priorities at the state and territory level may differ from those set at the national level. There are few examples of long-term monitoring programs across the full range of a forest-dwelling species.

Recognising the value of a structured, broad-based monitoring program in assisting long-term management, Western Australia established ForestCheck, a comprehensive approach to monitoring species in the state's south-western forests (McCaw et al. 2011; SOFR 2013 see Case study 1.3). ForestCheck is one of only a few programs in the world collecting regional-scale information on mosses, lichens, fungi and invertebrates, as well as the better known components of forest biodiversity (vertebrates and vascular plants) and Case study 7.7 reports current findings from ForestCheck. The work at the Warra Long-term Ecological Research (LTER) site in Tasmania is another example (see Case study 7.8).

Sustainable forest management requires an understanding of ecological trends over long time-scales. Long-term monitoring programs such as ForestCheck in Western Australia and the work at the Warra LTER site in Tasmania deliver some of that information and thereby contribute to continuous improvement of sustainable forest management in those states. Burns and Lindenmayer (2014, p.23) noted that "Long-term monitoring of birds, fungi, beetles and vascular plants in harvested and unharvested forest plots in southern Tasmania and south-western Australia showed that the recolonisation of harvested areas by different groups of flora and fauna varies markedly and depends, in part, on retained forest elements within the post-harvest area (e.g. habitat trees, logs and patches of intact forest)". This is an example of monitoring information on biodiversity and species that has been used to influence forest management practices. In general, there is more monitoring of species and their habitats on multiple-use public native forests than on other tenures.

Indicator 1.2c of SOFR 2013 provided several case studies as examples of outcomes of monitoring forest-dwelling species:

- the relocation of the threatened northern quoll (*Dasyurus hallucatus*) affected by the spread of cane toads (*Rhinella marina*) in the Northern Territory as part of the Island Ark program (SOFR 2013, p.100, Case study 1.5)
- breeding sites and populations of the threatened Swift Parrot (*Lathamus discolor*) (SOFR 2013, pp.101–2, Case study 1.6)
- incidence of a disease agent in the population of the threatened Tasmanian devil (*Sarcophilus harrisii*; SOFR 2013, pp.103–4, Case study 1.7), and
- plants and beetles along an altitudinal transect at the Warra LTER site in southern Tasmania (SOFR 2013, pp.105–6, Case study 1.8).

The Swift Parrot is included in SOFR 2018 as an example of monitoring of breeding success and the effects of predation (Case study 1.2 in Indicator 1.2b). In this Indicator, Case study 1.6 reports the monitoring of bat species in New South Wales, while monitoring the koala (*Phascolarctos cinereus*) in Queensland is reported in Case study 1.7, and in New South Wales with new methodologies in Case study 1.8. Case study 1.9 illustrates a cooperative monitoring program on the northern bettong (*Bettongia tropica*) by government, academic and non-government institutions in Queensland.

Species that are commercially harvested for non-wood forest products are also monitored. Harvesting of tree ferns (*Dicksonia antarctica*), common brushtail possum (*Trichosurus vulpecula*), Bennett's wallaby (*Macropus rufogriseus*) and Tasmanian pademelon (*Thylogale billardierii*) in Tasmania are examples (see Indicator 2.1d and FPA 2017a).

Stocks of commercial fisheries species that occur in forested waterways (freshwater, estuarine and/or mangroves), or use forested waterways as nursery habitat, are also monitored: examples are barramundi (*Lates calcarifer*) in Queensland (DAF 2017a), giant mud crab *Scylla serrata* and orange mud crab *S. olivacea* in the Northern Territory (DPIR 2017), and white banana prawn (*Fenneropenaeus merguiensis*) across coastal Northern Australia (Larcombe and Bath 2017).

Monitoring at state and territory level

Table 1.53 indicates the extent to which monitoring programs are in place for representative species in various taxonomic groups, by state and territory, and how the monitoring effort compares with that reported in SOFR 2013. This table is based on reporting by individual Commonwealth, state and territory agencies and therefore might not include all existing programs – in particular, programs carried out by tertiary institutions may not be recorded. Monitoring programs for forest-dwelling species are increasingly being coordinated through non-government organisations and universities in conjunction with government departments. For some particular taxonomic groups in some states and territories, effort and capacity has diminished over time or is non-existent, and some programs monitoring groups of taxa have discontinued (Table 1.53).

Since SOFR 2013, monitoring of representative species has increased significantly in the Australian Capital Territory, Northern Territory and Western Australia, particularly in parks and reserves. Monitoring of representative mammal, bird, invertebrates and vascular plants in Tasmania remained at similar levels to those reported in SOFR 2013, with no monitoring of reptiles, amphibians, fish and non-vascular plants, while effort has increased in monitoring threatened bird species. The Australian Capital Territory, Western Australia (including FORESTCHECK) and Tasmania (including the Warra LTER site) each have programs monitoring more than 500 representative forest-dwelling and forest-dependent species, including many invertebrate species. Figures 1.32 and 1.33 illustrate the monitoring results for beetles and birds from Warra. The other states and the Northern Territory each monitor less than 100 representative forest-dwelling and forest-dependent species in their jurisdictions.

A new monitoring program, the Western Australian North Kimberley Landscape Conservation Initiative monitoring and evaluation program, was established in 2011 to inform adaptive management of fire and feral cattle on conservation reserves in the North Kimberley region of Western Australia. The network of monitoring sites includes more than 90 sites on conservation lands, including in the Mitchell River, Drysdale River and Prince Regent national parks. Indicators of condition are mammal fauna composition and abundance, vegetation condition, and fire regimes (the latter characterised from satellite imagery). Rainforest patches are being monitored to assess changes in extent associated with fire and grazing impacts. Traditional owners are engaged in the monitoring, and work is integrated with complementary work being undertaken by traditional owners on adjoining lands. Monitoring results are collated and reported every two years; Corey and Radford (2017) is an example.

Monitoring effort continued in New South Wales, including increased monitoring of fauna through the WildCount program[78]. WildCount commenced in 2012 as a 10-year fauna monitoring program that uses motion-sensitive digital cameras at 200 sites across 146 parks and reserves in eastern New South Wales, and is expected to be able to detect changes in the occurrence of at least 12 birds and mammals. Some site-specific monitoring programs for threatened rainforest

[78] www.environment.nsw.gov.au/animals/wildcount.htm

Table 1.53: Taxonomic groups for which representative native species are being monitored, by jurisdiction

	Level of monitoring, and change in effort and capacity from that reported in *Australia's State of the Forests Report 2013*[a]															
Jurisdiction	Mammals		Birds		Reptiles		Amphibians		Fish		Invertebrates		Vascular plants		Non-vascular plants	
ACT	++	>	++	>	+	=	++	>	+	>	++	n	++	>	0	0
NSW[b]	++	>	++	=	0	0	+	<	++	>	+	=	++	=	+	=
NT	++	>	+	=	+	>	+	>	+	>	+[d]	>	+	>	0	0
Qld	++	>	+	=	+	=	+	<	+	<	+[d]	=	+	=	0	0
SA	+	<	++	=	+	<	+	<	+	=	0	0	++	<	0	0
Tas.	++	=	++	>	0	0	0	0	0	0	++	=	++	=	0	0
Vic.	++	>	++	>	0	D	+	=	+	<	+	=	++	>	0	D
WA	++	>	++	>	++	=	++	=	0	0	++	=	++	>	++	=
Australia[c]	+	=	++	=	++	=	++	=	++	<	+[e]	=	0	0	0	0

Level of monitoring	
0	No species in the taxonomic group is being monitored, or no data available on monitoring effort
+	At least one species of the taxonomic group is being monitored to detect changes in population size at a scale relevant to forest management
++	More than 10 species are being monitored to detect changes in population size at a scale relevant to forest management
Change in monitoring effort and capacity since SOFR 2013	
n	New program
>	Increased level
=	Stable level
<	Decreased level
D	Monitoring discontinued
0	No species in the taxonomic group is being monitored, or no data available on monitoring effort.

[a] MIG and NFISC (2013).
[b] Data incomplete for conservation estate in NSW.
[c] Includes species monitored across jurisdictions, and includes non-government mechanisms through BirdLife Australia (Birdata, birdata.birdlife.org.au/), FrogWatch and ReptileWatch (www.frogwatch.org.au and www.frogwatch.org.au/index.cfm?action=cms.page&section=2).
[d] Includes only the white banana prawn (*Fenneropenaeus merguiensis*) and/or mud crab (giant mud crab *Scylla serrata*, and orange mud crab *S. olivacea*), and no terrestrial invertebrates.
[e] Includes only the Murray crayfish (*Euastacus armatus*) monitored in the Murray–Darling Basin, and the mud crab fishery monitored in northern Australia, and no terrestrial invertebrates.

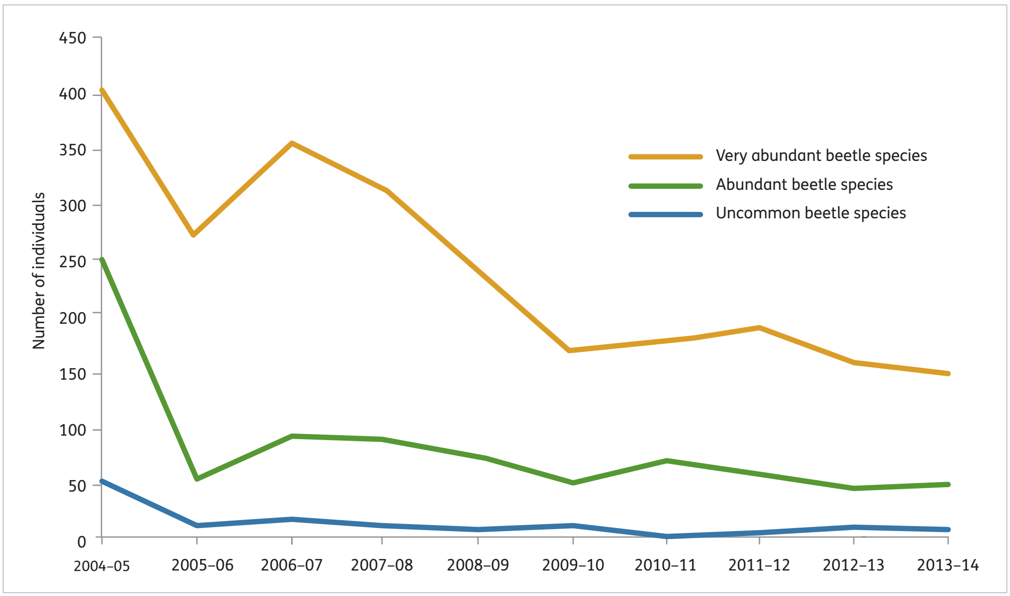
Notes:
Monitoring of introduced and invasive species are not included.
Studies of monitoring of forest ecosystems are not included.
Monitoring of fish includes Murray–Darling Basin and coastal freshwater waterways; forested estuarine waterways and mangrove ecosystems are included only for the Northern Territory and Queensland. Monitoring of waterbirds in the five forested "The Living Murray Icon Sites" in the Murray–Darling Basin is not included.
Source: Australian Government, state and territory agencies, and MIG and NFISC (2013).

This table, together with other data for Indicator 1.2c, is available in Microsoft Excel via www.doi.org/10.25814/5bda82c8d76d4

species (covering two amphibians, two mammals and a bird species) ceased in 2014 in specific locations in the New South Wales reserve system, due to the cessation of funding support from the Caring for Our Country (Commonwealth) program. Continuation of one long-term monitoring program monitoring the impacts of fire on cool temperate rainforest in north-eastern New South Wales (including vascular and non-vascular plants, birds and other fauna), which commenced in 1930, is uncertain as the program is now run on a volunteer basis. Targeted monitoring of fish species in forests has continued. A new monitoring program commenced in the reserve system in the far south-east corner of New South Wales, monitoring impacts of fox control programs and ecological burning on target species, including the threatened southern brown bandicoot (*Isoodon obesulus*) and long-nosed potoroo (*Potorous tridactylus*). In the Pilliga region of north-eastern New South Wales, a new bird monitoring program commenced in 2013, while examples of ongoing programs include monitoring the recovery of diurnal birds from intensive forest harvesting, and tracking bird diversity in response to eucalypt plantation establishment. Monitoring of representative species on New South Wales state forests (see for example Case study 1.6 on bat populations) remained stable during the SOFR 2018 reporting period.

Monitoring of representative species in the Northern Territory occurs across all taxonomic groups other than non-vascular plants. Since 1994, detailed vegetation and fauna sampling has been undertaken every five years using 220 permanent plots in Litchfield, Kakadu and Nitmiluk national parks; monitoring representative forest species is part of this sampling. Monitoring of small mammals and feral animals using Indigenous rangers in collaboration with government

Figure 1.32: Beetle abundance at Warra site WR008J[a]



Very abundant, >95th percentile of abundance; abundant, 75–95th percentile of abundance; uncommon, <75th percentile of abundance.

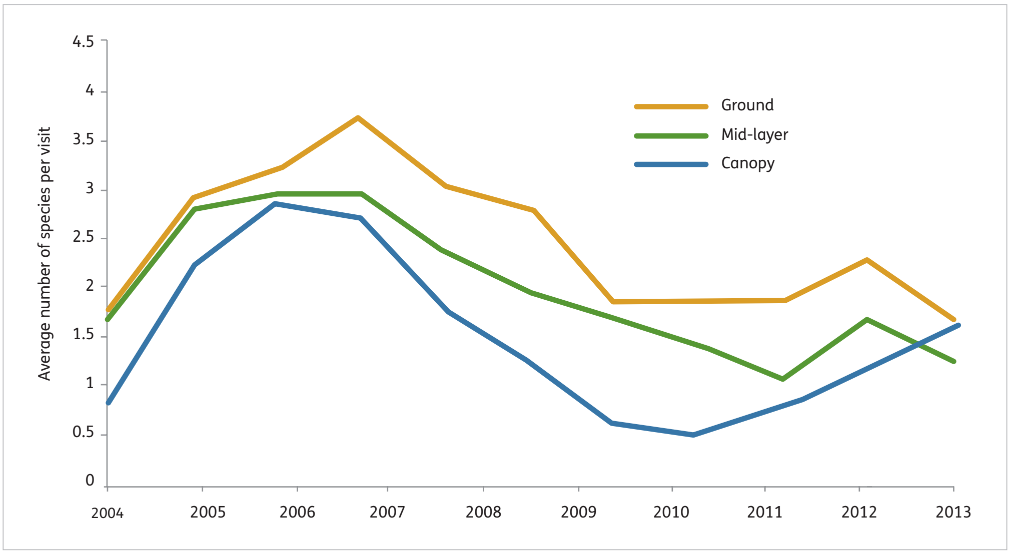
[a] WR008J is a control site.

Note: Data from monthly pitfall trap sampling done in coupe WR008J by Forestry Tasmania (now Sustainable Timber Tasmania) as part of ongoing monitoring of the Silvicultural Systems Trial (Baker et al. 2009). WR008J is one of the unharvested control sites of the Silvicultural Systems Trial.

Source: Sustainable Timber Tasmania.

The data used to create this figure, together with other data for Indicator 1.2c, are available in Microsoft Excel via www.doi.org/10.25814/5bda82c8d76d4

Figure 1.33: Average bird species per survey site visit at Warra site WR008J[a]



[a] WR008J is a control site.

Note: Data from annual birds surveys done in coupe WR008J by Forestry Tasmania (now Sustainable Timber Tasmania) as part of ongoing monitoring of the Silvicultural Systems Trial (Lefort and Grove 2009). WR008J is one of the unharvested control sites of the Silvicultural Systems Trial.

Source: Sustainable Timber Tasmania.

The data used to create this figure, together with other data for Indicator 1.2c, are available in Microsoft Excel via www.doi.org/10.25814/5bda82c8d76d4 and academic specialists is occurring in native forests on Indigenous lands.

Whilst monitoring of representative species of birds and fish in South Australia remained stable, South Australia reported that monitoring effort of representative species of amphibians, mammals, reptiles and vascular plants had declined during the SOFR 2018 reporting period. The number of forest-dwelling vascular plants being monitored reduced from >30 species in the SOFR 2013 reporting period to 25 in the SOFR 2018 reporting period; all 25 species are listed under the national EPBC Act. Similarly, monitoring of representative species of terrestrial forest-dwelling fauna in South Australia is now confined to a selection of threatened species listed under the EPBC Act: one amphibian, 11 birds, five mammals and two reptiles. Continuation of the monitoring of birds is increasingly reliant upon volunteers and community groups (the example of the Red-tailed Black-cockatoo is described below: Case Study 1.5). Monitoring of populations of listed and non-listed native fish species under the EPBC Act continued in the eastern forested environments of the Murray River in South Australia. As well, populations of the forest-dwelling threatened Yarra pygmy perch (*Nannoperca obscura*) continue to be monitored as a requirement of its recovery plan (Saddlier and Hammer 2010).

The majority of monitoring of representative species in Queensland occurs in protected areas of the reserve system. Since the SOFR 2013 reporting period, Queensland reports that monitoring of mammals has increased to >10 species, monitoring of birds, reptiles and vascular plants has remained stable at <10 species, while monitoring of amphibians and fish has declined. Monitoring has ceased of native fish populations in the Murray–Darling Basin in Queensland.

Victoria reported increased monitoring of mammals, birds and vascular plants, and discontinuation of monitoring of reptiles, non-vascular plants and *Galaxias* fish species. The monitoring of several amphibians continued at the level reported in SOFR 2013.

At the national level, the most comprehensive monitoring is in place for birds, driven by a national volunteer program coordinated by the non-government organisation Birdlife Australia, and supplemented by state and territory agency-specific programs. Birds are usually reasonably visible and hence amenable to direct monitoring, but this is not the case for all bird species, so innovative monitoring approaches are also required. In addition, a community partnership program in association with the non-government organisations FrogWatch and ReptileWatch[79] is active in Northern Australia (Kimberley region Western Australia, Northern Territory and North Queensland), and provides digital information on amphibian and reptile species through a biodiversity portal. FrogWatch programs also are carried out in southern Australia. Fauna-monitoring approaches involving non-government organisations generally involve work in collaboration with state and territory government agencies to develop comprehensive monitoring programs using public participation. Information material and supporting databases, such as the Atlas of Living Australia[80] and Australian Reptiles Online Database[81], support these monitoring activities.

Monitoring of native fish in the Murray–Darling Basin (covering four states and one territory) is continuing, and is coordinated by the Murray–Darling Basin Authority (an Australian government authority). However, it is occurring at a decreased level compared to that reported in SOFR 2013. During the SOFR 2008 and SOFR 2013 reporting periods, monitoring of fish populations in the basin was guided by the *Native Fish Strategy for the Murray–Darling Basin 2003–2013*[82], and its goal "to rehabilitate native fish communities in the Murray–Darling Basin back to 60 per cent of their estimated pre-European settlement levels after 50 years of implementation" (Murray–Darling Basin Ministerial Council 2003). Koehn et al. (2014b) and Lintermans et al. (2014) discuss the foundations and implementation of the strategy in the basin. However, the funding for strategy programs ceased after its initial 10-year period (Koehn et al. 2014a).

Monitoring of vegetation condition, fish and waterbirds, and intervention monitoring associated with environmental watering events in the Murray–Darling Basin, is now largely confined to the monitoring of "The Living Murray Icon Sites" (TLM Sites) along the Murray River. There are six icon sites, five of which are forested: Barmah–Millewa Forest and Gunbower–Koondrook–Perricoota Forest on the Victorian and New South Wales border on the Murray River, Hattah Lakes and Lindsay–Mulcra–Wallpolla Islands in northwest Victoria in the Murray River floodplain, and the Chowilla and Lindsay–Wallpolla Islands icon site located on the Murray River at the border of South Australia, New South Wales and Victoria (Hughes et al. 2016). Fish populations in these forested icon sites are reported to have improved or remained stable since the SOFR 2013 reporting period (Hughes et al. 2016). Monitoring sites in the Murray–Darling Basin outside of these icon sites have generally been discontinued, other than those located in the Australian Capital Territory. Monitoring of fish populations in forests in the headwaters of the Basin (in New South Wales, Queensland and Victoria) and along the Darling River and its tributaries (in New South Wales and Queensland) ceased after 10 years of implementation of the *Native Fish Strategy for the Murray–Darling Basin 2003–2013*.

79 www.frogwatch.org.au

80 The Atlas of Living Australia is Australia's national biodiversity database, receives support from the Australian Government through the National Collaborative Research Infrastructure Strategy (NCRIS), and is hosted by CSIRO. It is a node of the Global Biodiversity Infrastructure Facility (GBIF). It is used for research, environmental monitoring, conservation planning and management, reporting, education, and citizen science activities; see www.ala.org.au/

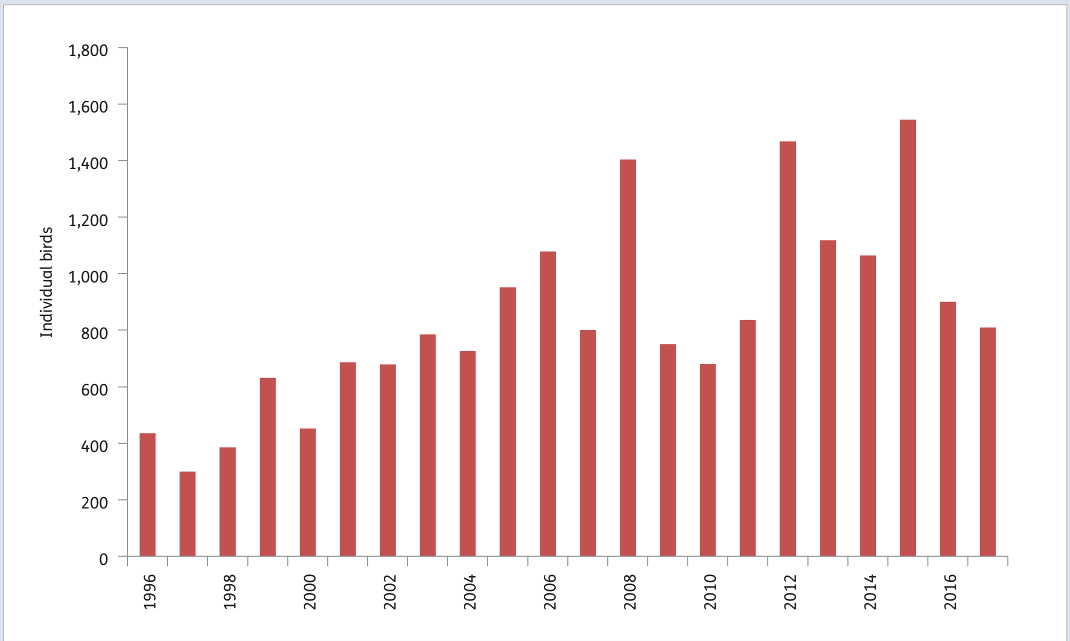
81 www.arod.com.au/arod

82 www.mdba.gov.au/sites/default/files/pubs/NFS-for-MDB-2003-2013.pdf

Case study 1.5: South-eastern Red-tailed Black-cockatoo

An example of a non-governmental monitoring program is the annual population count of the endangered south-eastern Red-tailed Black-cockatoo (*Calyptorhynchus banksii graptogyne*) that has taken place since 1996 across approximately 18,000 square kilometres of western Victoria and south-east South Australia. Counts have reported between 300 and 1,545 birds in the period to 2017 (Figure 1.34). Such counts provide a minimum number of birds in the population, determine patterns of habitat use and the location of large flocks, as well as indications of previous year's breeding success, and allow determination of trends over time in the population. This subspecies inhabits desert stringybark (*Eucalyptus arenacea*) and brown stringybark (*E. baxteri*) woodlands on the Glenelg, Wimmera and Naracoorte Plains, and adjacent woodlands of river red gum (*E. camaldulensis*), yellow gum (*E. leucoxylon*) and buloke (*Allocasuarina luehmannii*), and has a specialised diet, feeding primarily on stringybark and buloke seed. As a result of historical clearing, only 43% of the original suitable habitat in the region remains. The degraded condition of the remaining stringybark habitat, its patchy recovery, limited nesting hollows, fire impacts, and periodic scarcity of their preferred food supply are the main current threats to this subspecies. The small numbers of breeding pairs, continuing loss of dead hollow-bearing trees, lack of regeneration or retention of future hollow-forming trees, and declining health of scattered trees on private land are serious medium-term to long-term threats (SOFR 2013, Case Study 1.4).

Figure 1.34: Annual population counts (1996–2017) of the south-eastern Red-tailed Black-cockatoo (*Calyptorhynchus banksii graptogyne*)



Notes: The annual count covers stringybark forest in south-eastern South Australia and western Victoria, and is undertaken by volunteers on a single day in early May, on behalf of the Red-tail Recovery team and BirdLife Australia. Variation in counts between years can depend upon how dispersed individual birds and flocks are across the region on the counting day, which relates in turn to the fruiting pattern and seed crop of stringybark trees.

Source: SOFR 2013 Case study 1.4 updated with data from www.redtail.com.au/results.html.

Case study 1.6: Comparing bat populations between unlogged and regrowth forests

Bats are a diverse and ecologically important group of mammals. Most insect-eating bats ('microbats') are hollow-dependent, with females congregating in hollows of large trees to raise their young each spring. Annual banding of a small suite of bat species roosting in tree hollows at a study area in Chichester State Forest, northern New South Wales over 14 years (1999–2012) gave mark-recapture data that could be used to estimate survival, abundance and body condition (Law et al. 2018). Bats were captured in harp traps (Figure 1.35) in replicated catchments with different wood harvesting regimes, as well as over El Niño and La Niña weather cycles.

The study area comprises small catchments of unharvested forest and regrowth forest regenerating from Australian Group Selection harvesting in 1983. Riparian buffers were retained on creeks, and scattered old, hollow trees and unharvested rainforest were also retained in areas harvested. These and other environmental protections are now a standard requirement in wood production forests of NSW on public and private lands.

In total, 3,043 bats were banded, with a 32% re-trap rate, and a maximum time-to-recapture of nine years. A large portion of the bat population was resident in the area. The effect of logging history (unlogged forest compared to regrowth forest 16–30 years after logging) on apparent survival was minor and species-specific, with no detectable effect on survival for two species (chocolate wattled bat, *Chalinolobus morio*; large forest bat, *Vespadelus darlingtoni*), a small positive effect for one species (eastern forest bat, *V. pumilus*), and a small negative effect for one species (southern forest bat, *V. regulus)* (Figure 1.36). There was also no effect of logging history on the abundance or body condition of any of these species. Despite annual variation in abundance and body condition across the 14 years of the study, no relationship with logging or extreme weather was evident. Apparent survival of resident bats was not strongly influenced by weather patterns except for the smallest species (eastern forest bat). Annual banding continues, and the 2018 sample represents 20 years of monitoring in this project.

The study area is located in a high-elevation, wet sclerophyll forest that appears to be a climate refuge, which may have buffered bat population dynamics from weather extremes. The study supports the value of climate refuges in mitigating projected impacts of climate change, and demonstrates that carefully planned native forest harvesting with appropriate environmental protections can be compatible with managing sensitive taxa. Such long-term research is necessary to underpin and fine-tune sustainable forest management practices.

Figure 1.35: Harp trapping for bats in an unlogged catchment of Chichester State Forest, NSW

Continued

Figure 1.36: Bat species monitored at Chichester State Forest, New South Wales, and response of annual survival to logging and climate extremes

A Chocolate wattled bat, *Chalinolobus morio*. No effect of logging history on survival detected, no effect of climate on survival detected.

B Large forest bat, *Vespadelus darlingtoni*. No effect of logging history on survival detected, no effect of climate on survival detected.

C Southern forest bat, *V. regulus*. Small negative effect of logging history on survival, no effect of climate on survival detected.

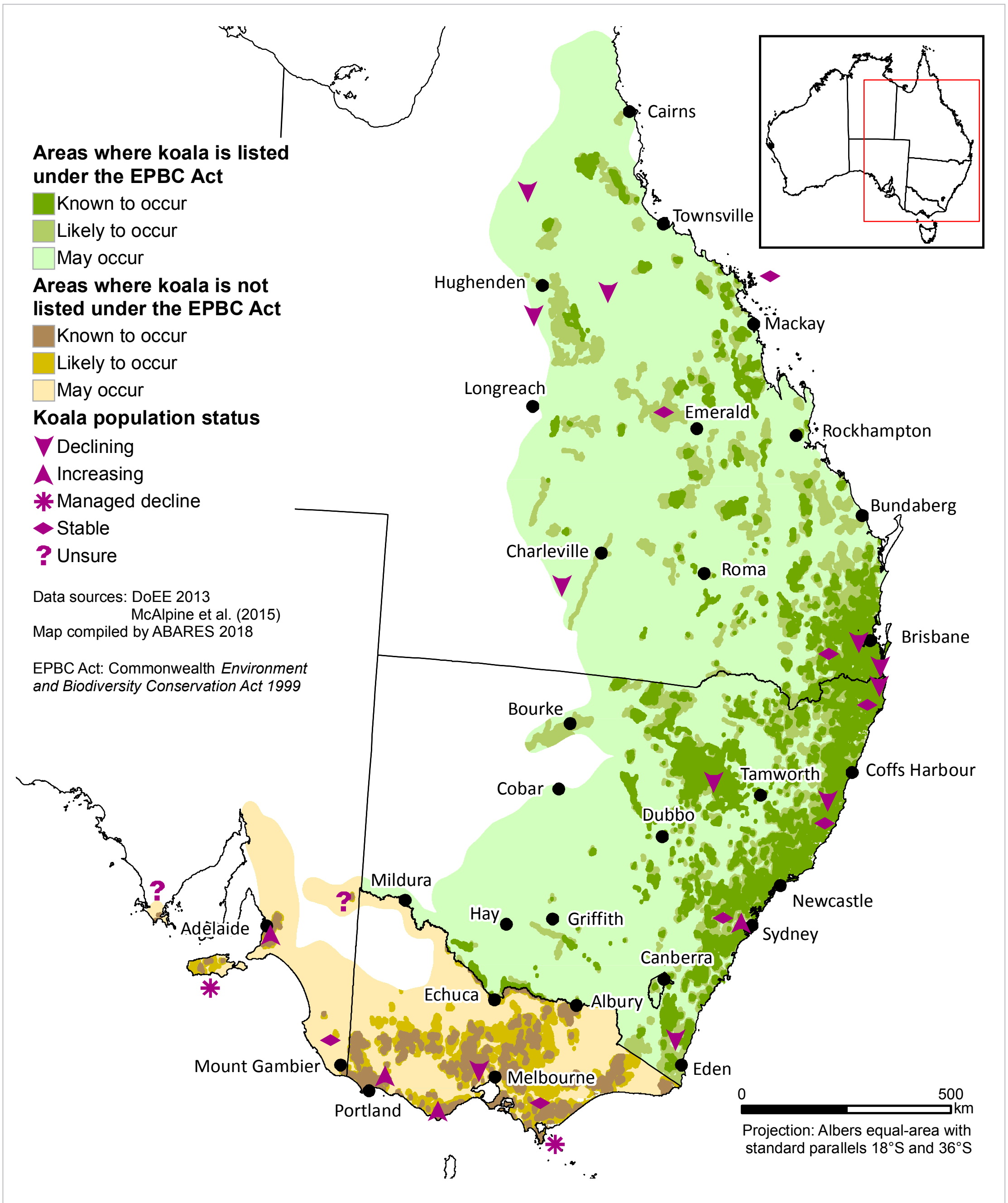
D Eastern forest bat, *V. pumilus*. Small positive effect of logging history on survival, negative effect of climate on survival detected in hot summers.

Koala

The koala (*Phascolarctos cinereus*) is one of the most distinctive and iconic wildlife species in Australia. Koalas occur in the Australian Capital Territory, New South Wales, Queensland, South Australia and Victoria. They inhabit a range of open and woodland forest and other woody non-forest vegetation communities containing their preferred food species from the genus Eucalyptus. Case Study 1.9 in SOFR 2013 provides a discussion of why koala populations in the Australian Capital Territory, New South Wales and Queensland (northern populations; Figure 1.37) were listed in May 2012 as Vulnerable under the EPBC Act. McAlpine et al. (2015) reports the regional population status and trends of koalas across the range of the species (see Figure 1.37).

Two case studies on the koala present current data on monitoring the species: Case study 1.7 in Queensland and Case study 1.8 in New South Wales.

Figure 1.37: Indicative distribution of the koala in Australia



Note: Koala distribution data are compiled using a range of datasets of varying quality and should only be used as a guide. The presence of the species or its habitat should be confirmed by using local information.

Source: Distribution data from ERIN, DoEE 2013; regional population status and trend data from McAlpine et al. (2015). Map compiled by ABARES 2018.

A higher resolution version of this map is available via www.doi.org/10.25814/5be3bc4321162

Case study 1.7: Monitoring koala populations in Queensland

Koalas and their habitat have been monitored on St Bees Island National Park off the coast of Mackay in Central Queensland since 1998 (Melzer et al. 2012). At that time, the tenure of the island was leasehold, but most of the island became national park in 2002. The monitoring program included 10 years of radio-tracking and 24-hour observations of individual animals. Data collected include population size, reproductive seasonality and success, social dynamics, day/night tree utilisation, ranging, tree and ecosystem use, and the relative contribution of different tree species to the diet. Habitat and population monitoring continues, with a census undertaken in most years, and fire and pest plant control trials are being established to inform future habitat management. The eradication of goats from the island commenced in 2007, to conserve significant ecosystems including koala habitat. Vegetation monitoring plots were established by the Queensland Parks and Wildlife Service (QPWS) prior to the commencement of the goat culling program, and have been monitored for approximately 10 years.

The koala population on St Bees Island has declined over the last 15 years from around 300 animals to less than 100 animals, with the greatest declines associated with the increased intensity and duration of dry seasons over recent El Niño events. Island vegetation is changing, with a general loss of grassy eucalypt woodlands and open forest. Rainforest elements (shrubs, small trees and lianes) and/or a dense *Lantana camara* shrub layer now dominate the midstorey, resulting in a loss of the herbaceous ground stratum. In places, rainforest community boundaries have expanded, stranding mature *Eucalyptus* trees. Burning has been successfully undertaken in grasslands, but there have been no successful ecological burns in the eucalypt communities. Despite the almost complete removal of goats from the island (over 3,000 removed to date), there is little or no successful establishment of *Eucalyptus*, *Corymbia* or *Allocasuarina* seedlings or recruitment of the eucalypt species (Queensland bluegum, *E. tereticornis*; poplar gum, *E. platyphylla*) that the koala feed upon on St Bees Island. Census data suggests that numbers of the introduced swamp wallaby (*Wallabia bicolor*) have increased following the removal of feral goats. Trials to develop landscape-scale management to redress lantana dominance commenced in 2017. A strategy for control of wallaby impacts is also being considered.

Koala monitoring in Minerva Hills National Park, south of Emerald in central Queensland, commenced in 1990 (Melzer 2005), and included radio-tracking and collecting similar data to those collected on St Bees Island. Koala populations and arboreal mammals continue to be monitored in Minerva Hills National Park.

In the region around Minerva Hills, koala abundance has declined dramatically, with local extinctions following droughts in the 2000s. The Minerva Hills National Park population persists at a low level (around 1 koala / 50 hectare). However, habitat quality has declined with extensive death of *E. tereticornis* in stream-fringing forest, as well as declines in canopy condition of other species. There is no evidence of natural regeneration of *E. tereticornis* or recovery of the stream-fringing forest. Repeat spotlight surveys along fixed transects have revealed an arboreal mammal community of abundant brushtail possum (*Trichosurus vulpecula*), some greater gliders (*Petauroides volans*), and occasional koala. The spotlighting data form a five-year baseline for future assessment. Some tree planting (inside and outside the park) has been undertaken to help redress the loss of koala fodder species; the success of the plantings is being monitored.

Case study 1.8: Researching the response of koalas to wood harvesting in New South Wales

Koalas are a cryptic species that are difficult to survey, especially in remote, tall forests. This has led to a poor knowledge-base about their status in forested areas away from peri-urban forests surrounding population centres.

The key threats to koalas have been identified as permanent tree cover loss by land clearing, increased housing near bushland, road traffic, dog attack, prolonged drought, and disease (McAlpine et al. 2015). However, the impact of native forest management and wood harvesting on koalas has been a frequent focus of community discussions about forestry practices. In 2015, a joint research project between the New South Wales Department of Primary Industries (DPI) and the Environment Protection Authority (EPA) produced a new habitat map to assist with better identifying important koala habitat in areas proposed for wood harvesting in north-east NSW (Law et al. 2017).

As part of the field validation of this habitat map, an innovative acoustic method for surveying koalas was trialled. Acoustic devices (SongMeters) are set at sites for one week to record male bellows during the breeding seasons. Recordings are scanned by Ecosounds software at the Queensland University of Technology (QUT) to identify koala bellows amongst other nocturnal sounds. Acoustic detection is proving to be a highly successful and efficient technique for recording koalas in forested areas where traditional surveys (visual counts, faecal pellet counts, community surveys and reported sightings) have had limited effectiveness. The success of trials of this new survey method led to an ongoing project involving systematic assessment and research into the status of koalas in forests and their response to wood harvesting.

A key aim of this research project is to determine if koala occupancy varies with harvest intensity and time since harvest. Acoustic surveys were undertaken during 2015–2017, targeting modelled high-quality habitat (Law et al. 2017) over an extensive area representing 1.6 million hectares of forested habitat for koalas in northern New South Wales. Sites were stratified by known harvest history, and included unharvested sites. A total of 170 sites were surveyed, making this one of the most comprehensive regional surveys for koalas in New South Wales. Preliminary results indicate unexpectedly high occupancy rates (an average of 65%) across a broad range of forests and amongst all successional ages and harvest intensities. Analysis is proceeding to allow a more comprehensive assessment of the response of koalas to wood harvesting. In addition, the three years of data collection will form the basis of an ongoing forest landscape monitoring program for koalas.

Koala and her joey in a eucalypt tree, New South Wales.

Case study 1.9: Monitoring the northern bettong *Bettongia tropica* in the Queensland Wet Tropics bioregion

The northern bettong (*Bettongia tropica*) has long been recognised as endangered, and considered as a species undergoing on-going decline. Through the Northern Bettong Recovery Group, and in partnership and cooperation with the Australian Wildlife Conservancy, James Cook University (JCU), the World Wide Fund for Nature (WWF) and the Threatened Species branch of Department of Environment and Science, Queensland Parks and Wildlife Service (QPWS) has been undertaking baseline data collection and monitoring to fill some of the key gaps in the knowledge necessary for the species recovery. Knowledge of the status of these northern bettong populations will assist in assessing the health of the tall open forest communities of the Wet Tropics bioregion.

Bettongia tropica (northern bettong).

A long-term population monitoring program (mark/recapture) in the Lamb Range (Davies Creek National Park, Dinden National Park and Danbulla State Forest), initiated by the QPWS in 2000 and continued by JCU and the WWF, suggests the local bettong population is stable. The status of the geographically isolated populations to the north (Windsor/Spurgeon Tablelands) and south (Koombooloomba and Paluma–Taravale/Mt Zero) is less certain, with no sightings recorded in the last 10–30 years despite reasonably extensive cage and camera trapping survey efforts. An intensive effort is being made to assess the presence or absence of northern bettongs in these areas as well as in potential habitat that has never been surveyed. These efforts recently led to the rediscovery of a population at Mt Spurgeon in the north of their known range, and plans are underway to assess its status. Unsuitable fire regimes (particularly fire exclusion, and irregular hot wildfires late in the dry season) are thought to be a significant contributing factor in the decline of this species.

A field guide for managing fire in northern bettong habitat was published in 2017 as part of the Caring for Country project (DEHP 2017). The guide was a joint effort by the Department of Environment and Heritage Protection[83], QPWS, JCU and WWF.

[83] From December 2017, the Department of Environment and Science.

Indicator 1.3a

Forest associated species at risk from isolation and the loss of genetic variation, and conservation efforts for those species

Rationale

This indicator assesses the risks to loss of forest genetic variation and describes the formal measures designed to mitigate this risk. A loss of genetic diversity in species can result in a decreased ability to adapt to future environmental change, and thus a higher risk of extinction.

Key points

- The number of forest-dwelling native fauna and flora for which data on genetic variation are available is still very small, although understanding of these species is increasing.
- Isolation and forest fragmentation have resulted in significant risks of loss of genetic variation in some species.
  - Genetic-related issues are identified in the listing statements for 173 (50%) of the 345 threatened forest-dwelling fauna (vertebrate and invertebrate animals) and for 747 (69%) of the 1,075 threatened forest-dwelling flora (vascular and non-vascular plants).
  - A total of 57% of Australia's threatened forest-dwelling fauna and flora species listed under the EPBC Act have small populations identified as a genetic risk factor. This comprises 43% of threatened fauna species, and 62% of threatened flora species.
- Formal efforts are being made to improve long-term genetic conservation outcomes by placing seed of threatened flora species into seed banks, and by increasing connectivity among patches of native vegetation.

The distributions of many Australian native species before European settlement are not well known. Historical records, expert opinion and analysis, evidence of major changes in species distributions, and incidental observations have been used to compile maps of, or to model, the former distributions of species. For example, the Comprehensive Regional Assessments (CRAs) used in Regional Forest Agreement (RFA) processes provided pre-1750 estimates of the extent of forest ecosystems across the 12 CRA regions. Estimates of the historical distribution of species are required to determine whether subsequent reductions in distribution could increase the risk of loss of genetic variation.

Risk to forest genetic variation

Species with a lower level of genetic variation are less able to respond to gradual or immediate threats, and so face a higher risk of extinction (see discussion in Saunders et al. 1998) although many other factors are relevant in individual species. In practice, it is difficult to determine how much of the genetic variation within a species has been lost historically. However, it is possible to identify whether certain species are becoming endangered by the increased isolation of specific populations due to habitat depletion and fragmentation, and by threatening biotic factors such as those discussed in Indicators 1.2b and 3.1a.

The process of forest fragmentation (see Indicator 1.1d), mainly caused by clearing for agricultural land use and urban expansion, is a significant contributor to a reduction in genetic variation of certain species. New or updated conservation advice and recovery plans for threatened plant populations that have become fragmented increasingly identify genetic inbreeding and reduced fecundity[84] as risks. This is because loss of genetic diversity can reduce the ability of species to adapt to change, and inbreeding depression can cause loss of fitness. Native populations at greatest risk and of greatest concern are those that are already small or fragmented and with high conservation value. Isolated remnant populations and island populations are also at greater risk of developing

[84] Fertility is the ability of an individual, population or species to reproduce sexually. Fecundity is a measure of the number of viable, fertile offspring produced that survive to reproductive age. Fecundity can increase or decrease in a population according to factors such as age distribution, availability of food or nutrients, or availability of mates or pollinators.

genetic inbreeding and risks of reduced fecundity over time (Furlan et al. 2012). Climate change, such as that predicted to result from an increasing atmospheric concentration of greenhouse gases, is also likely to contribute to a reduction in forest genetic variation (Doley 2010; Keenan 2017).

Changes over time in the genetic diversity of forest-associated flora have not been extensively measured, although a range of studies have documented genetic variation and the distribution of this variation within existing populations of species at a single point in time (see Broadhurst et al. 2017).

- These studies suggest that a reduction in range is less likely to cause significant loss of genetic variation in species with a high level of diversity within populations and a low level of diversity between populations. This type of population genetic structure has been found for most of the limited number of tree species that have been measured to date.
- A reduction in range is more likely to reduce genetic variation in species that exhibit low genetic diversity within populations and high variability between populations, such as that typically encountered in species with naturally restricted ranges (e.g. narrow-leaved mallee, *Eucalyptus angustissima*).

Knowledge of genetic variation in Australia's native species, and conservation measures to maintain that variation, are greatest in non-threatened species of economic importance for wood production in Australia and/or internationally (see Indicator 1.3b). Examples include shining gum (*E. nitens*, Hamilton et al. 2008; Southerton et al. 2010), southern or Tasmanian blue gum (*E. globulus*, Thavamanikumar et al. 2011; Carrillo et al. 2017; FPA 2017a) and blackbutt (*E. pilularis*, Sexton et al. 2010). Other than for native tree species of economic importance (Indicator 1.3b), the number of forest-dwelling species for which data on genetic variation are available has increased slowly since SOFR 2008 (see Broadhurst et al. 2017). Genetic variation and diversity of *Macadamia*, a tree genus of international importance as a food crop and with all four species listed as threatened, has been well researched (see Hardner et al. 2009 and Case study 1.10).

State and territory data

Tasmania has continued assessing the forest-dwelling species potentially at risk from isolation and loss of genetic variation as a result of past human-induced or natural events. Minimal data are available for the other states and territories.

As at 2016, a total of 392 forest-dwelling threatened and priority species in Tasmania were rated as potentially at risk from isolation and loss of genetic variation; 92% were vascular plants at potentially moderate and high risk (Table 1.54). This compares to the total of 277 forest-dwelling threatened and priority species in Tasmania that were rated as potentially at risk from isolation and loss of genetic variation in SOFR 2013.

Threatened species

The states and territories and the Australian Government maintain lists of threatened species; the Australian Government list is at the national level under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) (see Indicator 1.2b).

Species with populations that are low in numbers, small in geographic extent or fragmented, that have low genetic variability, or that have hybridisation and fecundity issues,

Table 1.54: Number of forest-dwelling threatened and priority species in Tasmania potentially at risk from isolation and loss of genetic variation, 2016

	Risk category			
Taxonomic group	**Potential high and moderate risk**	**Potential low risk**	**Unknown risk**	**Total**
Fish	5	5	0	10
Amphibians	2	0	0	2
Reptiles	0	0	2	2
Birds	7	5	0	12
Mammals	2	1	1	4
Total vertebrate fauna	**16**	**11**	**3**	**30**
Dicotyledons	242	23	0	265
Monocotyledons	71	4	0	75
Pteridophytes	20	0	0	20
Gymnosperms	2	0	0	2
Total vascular flora	**335**	**27**	**0**	**362**
Total all groups	**351**	**38**	**3**	**392**

Note: Level of risk was estimated qualitatively for vertebrate fauna and vascular plant groups (excluding orchids) that are listed as threatened in Tasmania, or are identified as Regional Forest Agreement priority species. Explanation of risks and a list of species is given in Appendix 1.3.a of FPA (2017a).

Source: Amended from FPA (2017a).

This table, together with other data for Indicator 1.3a, is available in Microsoft Excel via www.doi.org/10.25814/5bda82c8d76d4

have genetic-related reasons contributing to the listing of species as 'threatened'. Table 1.55 summarises the genetic-related reasons associated with listing forest-dwelling species on the national threatened species list under the EPBC Act. Genetic-related issues are identified for 173 (50%) of the 345 threatened forest-dwelling fauna, and for 747 (69%) of the 1075 of threatened forest-dwelling flora (vascular and non-vascular plants).

In 57% of Australia's threatened forest-dwelling fauna and flora species (43% of the threatened fauna species and 62% of the threatened flora species; Table 1.55), small populations were identified as being a genetic risk. Hybridisation, while a natural process, represents a genetic risk to 1% of Australia's forest-dwelling threatened fauna and flora.

For listed threatened forest-dwelling flora, genetic-related risks associated with fecundity were identified in 31% of listings, fragmented populations were identified as a risk in 26% of listings, and low genetic diversity was identified directly in 24% of listings.

Orchids and cycads have the highest rate of genetic-related risks. There are 198 threatened forest-dwelling orchid species, of which 73% have risks associated with small populations, 56% have fecundity issues, and 33% have genetic risks separately associated with fragmentation and low genetic diversity. Of the 14 threatened forest-dwelling cycad species, 93% had fecundity-related issues identified as genetic risks in their listing statements; of these, 86% identified illegal collection (which can reduce gene pool, availability of mates, and reproduction), 64% reported pollination-related issues and 29% recorded inbreeding issues.

For listed threatened forest-dwelling fauna, 10% or less of listings identified risk factors associated with fragmentation, low genetic diversity or fecundity. Of the threatened forest-dwelling invertebrates, 66% (25 listed species) had small

Table 1.55: Threatened forest-dwelling species in Australia with conservation concerns about isolation or genetic capacity

	Number of listed threatened species with genetic-related reasons associated with listing[a]						
Taxonomic group[b]	Small population[c]	Fragmented population	Low genetic diversity	Hybridisation	Fecundity issues	Total	Total number of species
Fresh-water algae	0	0	0	0	0		1
Cycads	5	1	5	0	13	13	14
Clubmosses and spikemosses	2	1	1	0	1	2	9
Flowering plants[d]	643	269	246	9	316	715	1,017
Conifers	2	1	1	0	2	2	4
Ferns	14	3	3	0	2	14	28
Whisk-ferns	1	0	0	0	0	1	2
Total flora	**667**	**275**	**256**	**9**	**334**	**747**	**1,075**
Proportion of total number of listed threatened flora species (%)	**62**	**26**	**24**	**1**	**31**	**69**	**100**
Mammals	36	15	10	0	13	48	109
Birds	51	8	7	2	13	61	95
Reptiles	20	6	0	1	3	21	40
Amphibians	15	1	0	0	2	15	33
Fish	2	0	0	0	1	3	30
Invertebrates	25	2	2	0	3	25	38
Total fauna	**149**	**32**	**19**	**3**	**35**	**173**	**345**
Proportion of total number of listed threatened fauna species (%)	**43**	**9**	**6**	**1**	**10**	**51**	**100**
All groups	**816**	**307**	**275**	**12**	**369**	**921**	**1,419**
Proportion of total number of listed threatened species (%)	**57**	**22**	**19**	**1**	**26**	**65**	**100**

[a] Includes species that have become extinct where a genetic reason was identified. Listed subspecies or races are reported as separate taxa.

[b] Fresh-water algae are Charophyta; clubmosses and spikemosses are Lycopodiophyta; whisk-ferns are Psilophyta.

[c] Includes populations low in numbers, small in geographic extent, or comprising only a few subpopulations (e.g. island species). Only populations with an identified genetic-related risk are included; that is, listed threatened species with small populations with no identified genetic risk associated with its small population are excluded.

[d] Orchidaceae taxonomy is being revised. Where SPRAT data has grouped subspecies/races of orchids for the purpose of a taxon identifier, the classification used by the national authority (the Australian Plant Census) has been retained and these subspecies/races are reported as separate taxa. Where the listing of a species has been updated, the updated information has been used.

Source: National Forest Inventory; listing statements on the Australian Government Department of the Environment and Energy database (www.environment.gov.au/biodiversity/threatened/index.html).

This table, together with other data for Indicator 1.3a, is available in Microsoft Excel via www.doi.org/10.25814/5bda82c8d76d4

populations listed as a genetic risk, with two recently listed species having fragmentation, low genetic diversity and fecundity reasons identified as additional genetic risks. A third, recently listed invertebrate (a butterfly) had illegal collection of adults identified as affecting the population's fecundity (reproductive success).

The Tasmanian devil (*Sarcophilus harrisii*) is listed as Endangered because of the threat posed by devil facial tumour disease, which also relates in part to the low level of genetic variation in the species (refer SOFR 2013 Case study 1.7). The koala (*Phascolarctos cinereus*) is listed as Vulnerable because of recent population decline and population fragmentation, resulting in population isolation and reduced genetic variation (refer SOFR 2013 Case study 1.9). Case study 1.10 discusses the genetic threats to the four threatened *Macadamia* species and their importance to the macadamia nut industry.

Formal measures to mitigate risk

Australia's Biodiversity Conservation Strategy 2010–2030 (NRMMC 2010) is a guiding policy framework for conserving the country's biodiversity, which includes genetic diversity. This framework uses a diverse mix of Australian, state, territory and local government approaches to biodiversity conservation, combined with private sector approaches. Formal measures are in place across state and territory jurisdictions to address the risk of loss of genetic variation in threatened species. These measures include recovery plans for threatened species, habitat restoration, wildlife corridors, engineered animal movement mechanisms (e.g. possum bridges), seed-collecting programs, management of habitat and populations under forest management systems (e.g. forest management plans and code of practice systems), and the national reserve system. The overall status of Australia's forest genetic resources is described in Indicator 1.3b.

Many species at risk are conserved ex situ by sample specimens found in botanic gardens and the National Arboretum. The National Macadamia Germplasm Collection, which was planted in three locations, provides ex situ conservation for representatives of three of the four threatened species of *Macadamia* (Hardner et al. 2004, 2009).

The Council of Heads of Australian Botanic Gardens (2008) identified seed banks as part of Australia's biodiversity risk mitigation strategy, and as having a key practical role in assisting with on-ground biodiversity recovery and management. The Australian Seed Bank Partnership was formed as a consequence of this, to mitigate risks to Australia's flora in the face of changing climates and other threats, with collaboration from Australia's leading botanical institutions, seed scientists and conservation and restoration experts[85]. The Partnership undertakes the collecting and banking of native seed for conservation, as well as developing enabling technologies and sharing the body of knowledge required to strengthen Australia's capacity to restore and connect landscapes and ecosystems through seed-based restoration. The work of the Partnership makes significant contributions to Australia's support of the Convention on Biological Diversity and *Australia's Biodiversity Conservation Strategy 2010–2030* (ASBP 2011) and contributes to genetic conservation of Australia's forest species (Indicator 1.3b).

Possum bridge to allow animals to move between forest fragments and maintain connectivity of populations.

[85] See asbp.ala.org.au/

Case study 1.10: Genetic conservation of *Macadamia* and its importance to the macadamia nut industry

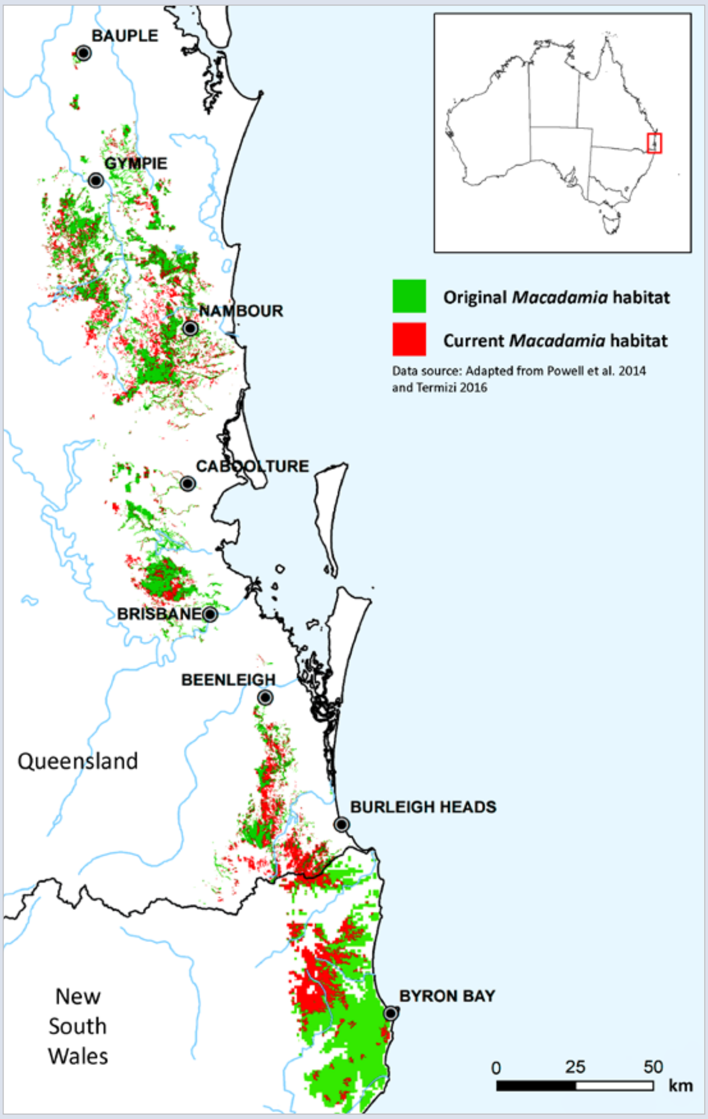
All four species in the genus *Macadamia*, family Proteaceae, are listed as threatened under the *Environment Protection and Biodiversity Conservation Act 1999*. Since 2009, a recovery plan has been operating for the four species (Costello et al. 2009) and a revised recovery plan is being drafted.

The four macadamia species are native to Australia and endemic to the coastal ranges and foothill forests of north-east New South Wales and south-east Queensland, within subtropical rainforest and sclerophyll forest containing subdominant subtropical rainforest. The natural distributions of the three vulnerable species, *Macadamia integrifolia*, *M. ternifolia* and *M. tetraphylla*, overlap.

The endangered *M. jansenii* is only known to occur in Bulburin National Park, Queensland, 150 km north of the nearest populations of the other species.

It is estimated that over 80% of wild macadamia trees have been lost since European settlement (Macadamia Conservation Trust[86]). Clearing of rainforest has also led to the fragmentation and isolation of rainforest remnants (Figure 1.38). This has decreased genetic diversity within remnants, especially in south-east Queensland, and decreased gene flow between remnants, although relatively high levels of genetic diversity still remain in *Macadamia* (Hardner et al. 2009). Sub-populations within each *Macadamia* species have differentiated genetically as

Figure 1.38: Current and historic distribution of *Macadamia* habitat



Note: 'Original *Macadamia* habitat' is modelled, 'Current *Macadamia*' habitat is a result of field surveys. The habitat of *M. jansenii* is not shown; this species occurs in a small area north of the illustrated map.

Source: adapted from Powell et al. 2014 and Ahmad Termizi et al. 2016.

[86] www.wildmacadamias.org.au

Continued

Continues

a result of past climate change, site adaptation and limited gene flow between populations (Hardner et al. 2009). Threats to the four *Macadamia* species include further habitat loss and fragmentation through vegetation clearing, inappropriate fire regimes, and weed invasion. Potential genetic threats are inbreeding among populations, loss of fertility as a result of isolation and habitat fragmentation (Powell et al. 2014), and introgression hybridisation of horticulture cultivars into wild population genetic stocks (O'Connor et al. 2015).

Macadamia nuts are traditionally a valuable food and cultural resource for Indigenous peoples. Early European settlers also recognised their food value, and commenced planting *M. integrifolia* and *M. tetraphylla* on farmland as single trees grown from seeds of local wild stock in the 1860s (Costello et al. 2009). Through tree breeding and genetic improvement, macadamia nuts have become a highly valued international commercial food crop. Macadamia nuts are commercially grown in Brazil, Colombia, Costa Rica, Guatemala, Israel, Kenya, Malawi, New Zealand, South Africa, Swaziland, Thailand, United States and Zimbabwe (South Africa DAFF 2014). Macadamia industries in developing countries are contributing to poverty reduction and sustainable development of these countries. *Macadamia* spp. are forest genetic resources contributing to food security domestically and globally, and are listed under the International Treaty on Plant Genetic Resources for Food and Agriculture (Singh et al. 2013).

Hardner et al. (2009) reviewed the domestication of macadamia, and the genetic linkages to wild populations. Macadamia were first commercialised in Hawaii from Australian genetic material. The Hawaiian cultivars underpin the genetic stock grown as an international food crop (Peace et al. 2008). However, the diversity of this germplasm is low compared to that of wild populations of the species.

Macadamia integrifolia and *M. tetraphylla* and their hybrids are also grown commercially in Australia, with 98% of trees being *M. integrifolia* (Keogh et al. 2010). Australia is the world's leading producer of macadamia nuts, providing 35% of the world supply, with Australia's industry worth $200 million per year (Horticulture Innovation Australia 2016). The area planted to macadamia orchards (which are not reported as forest) has increased from 17,000 hectares in 2010 (Keogh et al. 2010) to 28,000 hectares in 2017, with 53% of the area of orchards in New South Wales, 47% in Queensland and a small area in Western Australia[87]. Hawaiian cultivars are estimated to represent 80% of the growing stock planted in Australian commercial orchards (Ahmad Termizi et al. 2016).

The in situ conservation of wild populations of the four *Macadamia* species is important for biodiversity conservation of the species, as well as an important source of genetic traits to improve the genetic stock of orchard material used in the domestic and global macadamia nut industry. Current work by the Macadamia Conservation Trust[88] is capturing the genetic material found in natural and planted trees. Further domestic and international breeding of commercial macadamia nut that aims to broaden the genetic base will rely on access to genetic material found in the Australian native populations of *Macadamia*.

The National Macadamia Germplasm Collection established in 2001 is an ex situ conservation collection that contains a large sample of the genetic variation of the three vulnerable species, planted as orchards. The collection will also provide source material for introduction of new genetic material into future breeding programs (Peace et al. 2001; Hardner et al. 2009).

[87] Australian Tree Crop Response Map, Horticulture Innovation Australia. Data downloaded from www.arcgis.com/home/webmap/viewer.html?webmap=17213a10236f465590fe80d4298e5256

[88] www.wildmacadamias.org.au

Indicator 1.3b

Native forest and plantations of indigenous timber species which have genetic resource conservation mechanisms in place

Rationale

This indicator uses the coverage and implementation of formal genetic resource conservation mechanisms as a measure of the degree to which timber species' genetic resources are managed and conserved.

Key points

- The genetic resources for all Australian native forest species are conserved in situ in Australia's native forests. Genetic resources for some tree species are also conserved in arboreta, seed banks, seed orchards and plantations.
  - Most states and territories have guidelines and management plans for conservation of the genetic diversity of species in native forests, often as part of broader programs for biodiversity conservation.
  - The Australian, state and territory governments, research organisations, seed banks, arboreta, seed orchards and the private forestry sector, together with their tree-breeding and genetic improvement programs, all contribute to the conservation and sustainable management of forest genetic resources.
- Tree-breeding and genetic conservation and/or improvement programs exist for at least 48 native (indigenous) wood-producing and oil-producing species and varieties.
  - Between 2011 and 2016, there was a reduced investment in breeding of native tree species, with some programs closed, and some previously established provenance/progeny trials and seed orchards retained but no longer monitored.
  - A small number of non-commercial endangered species are conserved ex situ through infrastructure (arboreta and seed orchards) associated with tree breeding and improvement programs.
- Restoration plantings are also contributing to the conservation of the genetic resources for forest tree species.
- New research on forest species genetics has included the sequencing of the eucalypt genome, and the testing of provenances of species suitable for climate adaptation and ecological restoration.
- Some native forest species from Australia are a dominant part of the hardwood plantation industry in many other countries, and a component of the genetic resources for these species is located overseas.

Native forests in Australia contain a diverse range of tree, shrub and groundcover species, with the forest composition and dominant species varying with geographic location and climate. This indicator considers conservation of native forest genetic resources broadly, then considers conservation and breeding of native wood production species used in plantations.

Conservation of native forest genetic resources

In situ conservation

In situ conservation of forest biodiversity, both in multiple-use public native forests and in protected areas such as nature conservation reserves and national parks, is the primary mechanism for conservation of forest genetic resources in Australia.

Conservation of a representative sample of forest communities is expected to conserve both the component species, and a representative sample of genetic variation across the range of each species. Therefore, the level of conservation of forest genetic resources is linked to the level of conservation of forest biodiversity. State governments have developed a set of criteria that include broad benchmarks for the in situ conservation of forest biodiversity (see Indicator 1.1c). The Commonwealth and state and territory governments also monitor the National Reserve System with regard to agreed targets, and register species and ecological communities that are at threat. The *National Reserve System Strategy 2009–2030*[89] includes the following national targets:

- core areas established for the long-term survival of threatened ecosystems and threatened species habitats in each of Australia's bioregions by 2030.
- critical areas for climate change resilience, such as refugia, to act as core lands of broader whole-of-landscape-scale approaches to biodiversity conservation by 2030.

Most states and territories have guidelines and management plans for conserving the genetic diversity of native forest species of commercial significance during wood harvesting. In the regeneration of native forest after wood harvesting, the aim is to maintain local gene pools and the approximate composition and spatial distribution of all species present before harvesting. For example, codes of forest practice in Victoria and Tasmania require harvested native forest to be re-sown or regenerated with a species mix that approximates the natural mix of canopy trees present before harvest, with seed to be sourced either from the stand to be harvested or from the nearest similar ecological zone ('seed zone') (DEPI 2014b; FPA 2015b). Management plans may also include specifications for selection of seed, elite or plus trees of good form and health. In Western Australia, silvicultural guidelines specify the seed sources to be used in the rehabilitation of log landings within all harvested coupes and areas cleared for bauxite mining in jarrah (*Eucalyptus marginata*) forest.

Ex situ conservation

In addition to forest reservation, a range of organisations, including the Australian Tree Seed Centre (ATSC), Forestry Corporation of NSW, Sustainable Timber Tasmania and the Queensland Government, have established ex situ seed orchards and undertaken conservation plantings for several rare and endangered tree species. Species in these conservation seed orchards include Queensland western gum (*E. argophloia*), Barber's gum (*E. barberi*), Camden white gum (*E. benthamii*), Brooker's gum (*E. brookeriana*), Morrisby's gum (*E. morrisbyi*), spinning gum (*E. perriniana*), Risdon peppermint (*E. risdonii*), varnished gum (*E. vernicosa*) (Singh et al. 2013), blackwood (*Acacia melanoxylon*), Wally's wattle (*A. pataczekii*) and lemon myrtle (*Backhousia citriodora*). Case study 1.12 describes conservation work on the rare New South Wales species Camden white gum.

During the reporting period, a conservation planting of Miena cider gum (*E. gunnii* ssp. *divaricata*) in Tasmania was destroyed by possums, and the main wild population of the rare Tasmanian endemic *E. morrisbyi* underwent a dramatic decline. Conservation strategies for *E. morrisbyi* are now being coordinated by a recovery group consisting of DPIPWE, University of Tasmania, NRM South[90], the Royal Tasmanian Botanic Gardens, and volunteers. The University of Tasmania has established conservation plantings of this species.

In Australia, native forest genetic resources are also conserved in seed banks, grafted plantings, plantations and biodiversity plantings. Australian forest genetic resources are generally highly accessible, and a very large amount of material has been collected, stored and dispersed throughout Australia and the world (Singh et al. 2013).

Seed banks

Seed banks are an important tool for safe and efficient storage of wild and improved plant genetic material, but require a sound understanding of seed harvest, storage and germination requirements (ASBP 2016). For those species for which seed can be dried and stored, seed banks prolong seed viability and maximise its availability for future research and planting. The ATSC, based in Canberra, maintains a national collection of seeds of more than 800 tree and shrub species in some 77 genera, including more than 240 *Acacia*, 19 *Allocasuarina*, 10 *Casuarina*, 21 *Corymbia*, 280 *Eucalyptus* and 35 *Melaleuca* species. It provides a high-quality, ex situ sample of Australia's tree and shrub genetic diversity. Initially, the ATSC collected and stored seed mostly on a population or provenance basis, but more of its seed is now collected from individual parent trees. These genetically distinct acquisitions are important for ex situ genetic resource conservation.

State, regional and private organisations also maintain seed collections, including state and Australian government botanic gardens, and the Australian PlantBank which was opened

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89 www.environment.gov.au/land/nrs/publications/strategy-national-reserve-system

90 www.nrmsouth.org.au/

in 2013 at the Australian Botanic Garden, Mount Annan, NSW. The Australian Seed Bank Partnership is a national collaboration between nine seed banks within botanic gardens across Australia, plus three flora-focused organisations. Seed collections in the Partnership include some timber tree species and a wide range of threatened and endangered species. For the majority of the species, the seed bank is the only ex situ conservation mechanism. The Partnership has projects to increase banking of seed from threatened species and from those species susceptible to myrtle rust (see Indicators 1.3a and 3.1a). The seed collections may be used in the future to strengthen or re-establish populations at threat or where localised extinction has occurred (ASBP 2016). Translocation to locations less conducive to myrtle rust may be considered for some species (DoEE 2016a).

Greening Australia also maintains seed collections of species to be used for revegetation purposes[91]: there is a country-wide collection (Nindethana Australian Seeds) which offers over 3,000 species, and 5–6 regional collections (about 40–50 species each), including forest tree and understorey species. Greening Australia and some private organisations also manage seed production areas (SPAs) to produce seed for biodiversity plantings. Greening Australia's largest SPA provides up to 150 understorey species used for restoration of grassy woodlands, largely on cleared agricultural land.

Many Australian organisations, including botanic gardens, continue to contribute to global collections of Australian native forest genetic materials. Since the early 1960s, the ATSC has supplied more than 200,000 certified seed lots from more than 1,000 tree or shrub species to researchers in more than 100 countries. Australia is also a partner in the Millennium Seed Bank Partnership, the largest ex situ conservation project in the world, which is run by the United Kingdom's Royal Botanic Gardens, Kew[92]. At the end of 2015, seed from 35,386 species had been collected as part of the Millennium Seed Bank Partnership goal of banking 25% of the world's flora. Australian partners in Australia's Seed Bank Partnership contributed around 18% of these collections.

Biodiversity plantings

Genetic conservation is also achieved by ensuring that good quality seed from known and appropriate locations and parentage is used in conservation plantings. Several guidelines exist to encourage best practice in seed collection, handling and storage[93], tissue culture, cryopreservation and restoration plantings, including the choice of material that anticipates climate change (Offord and Meagher 2009; SERA 2017; Hancock et al. 2016). Restoration plantings (those where the original source of the planted material is known with certainty) are increasingly contributing to the conservation of forest genetic resources. Greening Australia is currently working with university researchers on provenance selection suited to future climate change scenarios, to inform seed collection for biodiversity plantings. For example, the University of Tasmania and Greening Australia have planted provenance trials of cabbage gum or snowgum (*E. pauciflora*) and black gum or swamp gum (*E. ovata*) in Tasmania in order to test suitability for future climate change scenarios (see Prober et al. 2016).

Genetic diversity research

Information on the genetic diversity and genetic structure of species can be used to inform species management, tree improvement programs, conservation policy, and conservation activities. More than 80 Australian forest flora species have been examined over the past four decades for population genetic variation using molecular or non-molecular techniques. The genetic diversity of several native forest and plantation timber species has been analysed for traits such as variability in wood characters and disease susceptibility, to inform tree breeding strategies. Only a small number of threatened species have been investigated (see for example, Broadhurst et al. 2017).

The reference genome sequence for eucalypts was released during the reporting period by an international consortium, including Australians, working on flooded gum (*E. grandis*) (Myburg et al. 2014). An understanding of the eucalypt genome is expected to improve studies of comparative and evolutionary biology, as well as eucalypt adaptation, and accelerate breeding for productivity and wood quality. The subtropical eucalypt *E. grandis* and the temperate eucalypt southern (Tasmanian) blue gum (*E. globulus*) are key species for tree breeding effort worldwide.

Conservation and use of plantation genetic resources

A substantial proportion of the genetic base of Australian native forest trees used in commercial plantations is conserved in forest in reserves. Much of the genetic base has also been brought into seed collections, tree improvement and breeding programs and seed orchards (plantations specifically planted and managed for seed production).

Table 1.56 lists the key indigenous plantation species (timber and essential oils) in Australia for which seed collections are available for research and commercial purposes (wild-collected seed or improved through tree breeding). These seed collections ensure that the provenance (locality) or parentage of the seed is recorded.

Some collections of plantation genetic resources are held by forest industry agencies and companies, and some by industry cooperatives and research organisations. Most of these organisations are listed in Table 1.57.

Australia's forest genetic resources play an important role in maintaining and improving plantation forest productivity by conserving the original genetic variation in species, and

91 www.greeningaustralia.org.au/services-native-seed/

92 www.kew.org/science/collections/seed-collection/about-millennium-seed-bank; brahmsonline.kew.org/msbp/Where/Australia

93 See www.greeningaustralia.org.au/florabank for example

Table 1.56: Plantation species with reproductive material available in seed collections in Australia[a]

Species	Type of seed material[b]
Acacia auriculiformis	improved
A. crassicarpa	improved
A. mangium	improved
A. melanoxylon	improved
Acacia other species	wild
Araucaria cunninghamii	improved
Casuarina cunninghamiana	wild
C. obesa	wild
Casuarina various species	wild and improved
Corymbia citriodora ssp. *citriodora*	improved
C. citriodora ssp. *variegata*	improved
C. henryi	improved
C. maculata	improved
C. torelliana	cultivated
Eucalyptus argophloia	improved
E. astringens	wild
E. benthamii	improved
E. biturbinata	wild
E. botryoides	improved
E. camaldulensis ssp. *simulata*	improved
E. camaldulensis var. *camaldulensis*	improved
E. camaldulensis var. *obtusa*	improved
E. cladocalyx	improved
E. cloeziana	improved
E. dunnii	improved
E. globulus	improved
E. grandis	improved
E. kochii	wild
E. leucoxylon	wild
E. longirostrata	wild
E. loxophleba ssp. *lissophloia*	improved
E. moluccana	wild
E. nitens	improved
E. occidentalis	improved
E. pellita	improved
E. pilularis	improved
E. polybractea	improved
E. saligna	improved
E. sieberi	improved
E. sideroxylon	improved
E. smithii	improved
E. tereticornis ssp. *tereticornis*	improved
E. tricarpa	improved
E. viminalis	wild
Eucalyptus other species	wild
Grevillea robusta	improved
Santalum album	improved
S. lanceolatum	improved
S. spicatum	wild and cultivated

through providing source material from which desirable traits can be observed and selected. This can occur through selection of tree genotypes of higher growth rate and improved wood quality; selection of genotypes that are better adapted to projected warmer and drier conditions (Byrne et al. 2013); or selection of genotypes that are resistant or tolerant to existing pests and diseases, or that may be resistant or tolerant to future pests and diseases and changing climatic conditions.

Tree improvement and breeding

Tree-breeding and/or improvement programs exist for at least 48 native (indigenous) wood-producing and oil-producing species and varieties (summed across Tables 1.56–1.59).

A range of private companies and state research organisations in Australia manage tree improvement and breeding programs for native wood-supply species grown in plantations (Table 1.57), including through industry cooperatives such as the Southern Tree Breeding Association (STBA). Although breeding populations are maintained mainly for improving commercial wood production, they have an important role in conserving species genetic resources. Plant breeding strategies require a base population with wide-ranging genetic diversity. In Australia, seed for this base population is normally collected from native forest in a range of locations (known as provenances).

The Southern Tree Breeding Association (STBA), formed in 1983, runs a cooperative national tree improvement program for southern (Tasmanian) blue gum (*Eucalyptus globulus*), and provides a database and quantitative analytical services for shining gum (*E. nitens*) and other plantation species. The program for *E. globulus* has been running since the amalgamation in 1994 of genetic material and data from eight selection and breeding programs previously managed by individual organisations. Grafted trees of *E. globulus* have been planted in the National Genetic Resource Centre for plantation forestry at Mount Gambier, South Australia, which was launched in August 2005 with support from the Australian and South Australian governments. Control-pollinated *E. globulus* seed is collected and stored in refrigerators, and diversity is maintained in numerous field trials spread across temperate Australia. The TREEPLAN® genetic evaluation system[94] is being used to update genetic values for *E. globulus* and *E. nitens*.

Table 1.56: Notes

[a] Formal seed collections as listed here are collections made from representative or high-quality trees from known provenances or parents, and are stored in facilities under controlled conditions to maximise seed longevity. This table presents key plantation species and does not include many other species collected for genetic conservation, research, revegetation or international purposes, or seed collected for prompt use by some forestry and revegetation organisations without long-term storage.

[b] For species with improved seed, collections of wild seed from selected provenances are also available.

Source: organisations listed in Table 1.57 as well as the Australian Government Department of the Environment and Energy (Australian Seed Bank Partnership); Northern Territory Department of Primary Industries and Resources; Victorian Department of Environment, Land, Water and Planning; and Western Australian Department of Biodiversity, Conservation and Attractions.

[94] www.stba.com.au/page/treeplan

Table 1.57: Plantation species in tree improvement or breeding programs in Australia

Species	Agency
Acacia melanoxylon	CSIRO, PIRSA, Sustainable Timber Tasmania
Araucaria cunninghamii	HQPlantations Pty Ltd
Corymbia citriodora subsp. *citriodora*	CSIRO, Queensland DAF
C. citriodora subsp. *variegata*	Queensland DAF[a], Seed Energy
C. henryi	CSIRO, Queensland DAF
C. maculata	CSIRO, Australian Low Rainfall Tree Improvement Group[b], PIRSA, Seed Energy
C. torelliana	Queensland DAF
Eucalyptus argophloia	Queensland DAF, CSIRO, Forestry Corporation of NSW[c]
E. astringens	PIRSA
E. benthamii	CSIRO
E. biturbinata	Queensland DAF
E. botryoides	PIRSA
E. camaldulensis	Australian Low Rainfall Tree Improvement Group, CSIRO, PIRSA, Queensland DAF
E. cladocalyx	Australian Low Rainfall Tree Improvement Group, PIRSA, Seed Energy
E. cloeziana	Queensland DAF
E. dunnii	CSIRO/Forestry Corporation of NSW (jointly), SeedEnergy, Queensland DAF
E. globulus	Southern Tree Breeding Association, Australian Bluegum Plantations, HV Plantations, PIRSA, Sustainable Timber Tasmania, WA Plantation Resources (WAPRES)
E. grandis	Queensland DAF
E. leucoxylon	PIRSA
E. longirostrata	Queensland DAF
E. nitens	Private industry, Sustainable Timber Tasmania, HV Plantations
E. occidentalis	CSIRO, Australian Low Rainfall Tree Improvement Group, PIRSA
E. pilularis	Queensland DAF
E. polybractea	Private industry
E. regnans	Sustainable Timber Tasmania
E. saligna	CSIRO, Seed Energy
E. sieberi	CSIRO
E. sideroxylon	CSIRO, Australian Low Rainfall Tree Improvement Group
E. smithii	CSIRO, Australian Bluegum Plantations, WA Plantation Resources
E. tereticornis	Queensland DAF
E. tricarpa	CSIRO, Australian Low Rainfall Tree Improvement Group
Grevillea robusta	CSIRO/Queensland DAF (jointly)
Melaleuca uncinata	PIRSA
Santalum album	Quintis (not Australian provenances)
S. lanceolatum	University of the Sunshine Coast
S. spicatum	Forest Products Commission (WA)

CSIRO, Commonwealth Scientific and Industrial Research Organisation; PIRSA, Primary Industries and Regions South Australia

[a] Until 2012, the Queensland Department of Agriculture, Fisheries and Forestry (DAFF).

[b] The Australian Low Rainfall Tree Improvement Group was formed in 1999 as a partnership between CSIRO and several industry and state forestry organisations in southern Australia. Although external funding ceased in 2009, a range of trials established under this group remain managed by the host organisations.

[c] Until January 2013, Forests NSW.

Source: Information was sourced from replies to data requests sent to plantation owners and managers listed in this table as well as the STBA; Northern Territory Department of Primary Industries and Resources; Victorian Department of Environment, Land, Water and Planning; and Western Australian Department of Biodiversity Conservation and Attractions.

Various state forestry management agencies also maintain tree improvement programs (Table 1.57). With the exception of *E. globulus*, *E. nitens*, *Corymbia* species, selected eucalypts and *Santalum spicatum*, investment in native species tree breeding decreased between 2011 and 2016. Some programs were closed, with plus trees, seed orchards and/or provenance/progeny trials retained but no longer monitored. The numbers of active trials for key species are shown in Table 1.58. A wider range of species is held in seed orchards (Table 1.59) than represented in current tree improvement programs.

The Queensland Department of Agriculture and Fisheries (DAF)[95] manages a range of seed orchards for producing improved seeds of *Eucalyptus* and *Corymbia*. Current tree breeding and improvement research is focused on Gympie messmate (*Eucalyptus cloeziana*) and spotted gums (*Corymbia citriodora* subsp. *citriodora*, *Corymbia citriodora* subsp. *variegata*, *C. henryi* and *C. torelliana*) as well as lemon myrtle (*Backhousia citriodora*), and on determining species susceptibility to myrtle rust (see Indicator 3.1a). Seed orchards of brown salwood (*Acacia mangium*), thick-podded salwood (*A. crassicarpa*) and large-fruited red mahogany (*Eucalyptus pellita*) in Queensland were lost due to cumulative damage from cyclones Larry (2006) and Yasi (2011). Also in Queensland, tree breeding undertaken by HQ Plantations focuses on hoop pine (*Araucaria cunninghamii*, with full and half-sib crosses from existing seed orchards) and a small number of eucalypt species.

Forestry Corporation of NSW[96] manages two seed orchards of blackbutt (*E. pilularis*) that have been retained from a previous tree improvement and breeding program. Hardwood tree improvement is now limited to seed collection from historic blackbutt seed orchards, and maintaining a register of plus trees.

Sustainable Timber Tasmania[97] and its predecessors have maintained a shining gum (*E. nitens*) breeding program for 40 years (Hamilton et al. 2008), producing seed and seedlings for sawlog plantations. They also maintain an active southern (Tasmanian) blue gum (*E. globulus*) breeding program. In Western Australia, the Forest Products Commission has an active breeding program for native sandalwood, *Santalum spicatum*.

Table 1.58: Tree improvement trials for main species in Australia (trials under active management)

		Provenance trials		Progeny trials		Clonal testing and development	
Species	**Plus trees[a]**	**No. of trials**	**No. of provenances**	**No. of trials**	**No. of families**	**No. of tests**	**No. of clones tested**
Araucaria cunninghamii	876 first-generation	20	50	~100	~900	–	–
Corymbia hybrids	0	–	–	20	500	15	30
C. citriodora	n.a.	3*	~15	3*	~80	–	–
C. maculata	n.a.	~7*	~15	~7*	~150	-	-
Eucalyptus cloeziana	25	–	–	1	–	1	–
E. dunnii	449	–	–	3	260	–	–
E. globulus	n.a.	102	>29	148	>5,903	656	120
E. grandis	115	–	–	–	–	–	–
E. nitens	n.a.	2	–	8	13	600	–
E. pilularis	352	–	–	–	–	–	–
E. polybractea	–	>1	>10	2	89	1	12
E. smithii	–	3	–	5	349	0	0
Eucalyptus hybrids	n.a.	4	–	–	–	~10	~100
Santalum album	115	2	–	6	115	–	–
S. lanceolatum	–	2	–	–	–	–	–
S. spicatum	–	1	6	1	100	–	–
Cathormion umbellatum (host to sandalwood in WA)	4	1	6	–	–	–	–

–, not available; n.a., not applicable; *, combined provenance-progeny trial listed under both headings

This table shows the main species in tree improvement programs as at June 2016 for which trial data are available.

[a] Number of plus trees (superior trees) listed if program is beginning and only first-generation seed orchards have been established, or if the program is ending and only plus trees are retained.

Source: Status as at June 2016, based on consultation with organisations listed in Table 1.57 as well as the STBA and the Western Australian Department of Biodiversity, Conservation and Attractions; data for *Araucaria cunninghamii* are from SOFR 2013.

This table, together with other data for Indicator 1.3b, is available in Microsoft Excel via www.doi.org/10.25814/5bda82c8d76d4

[95] Until February 2015, Department of Agriculture, Fisheries, and Forestry.

[96] Until January 2013, Forests NSW.

[97] Until July 2017, Forestry Tasmania.

Table 1.59: Plantation species in seed orchards in Australia

Species	Seed orchards Number	Generation[a]	Area (hectares)
Araucaria cunninghamii	9	1, 1.5, 2, 3	25
Corymbia citriodora subsp. *citriodora*	1	1	2.3
C. citriodora subsp. *variegata*	12	1 and 1.5	>27
C. henryi	2	1	2
C. maculata	9 (including 1 CSO)	1 or 2	15.06
C. torelliana	2	1	3
Eucalyptus argophloia	3 SSO	1,2	4
E. biturbinata	1	1	0.5
E. benthamii	5	1,2	~10
E. botryoides	3	1	2.76
E. camaldulensis	3	1	>1.81
E. cladocalyx	10	1	9.38
E. cloeziana	2	1	7
E. dunnii	13 (including 1 CSO)	1,1.5, 2	>21.0
E. globulus	23 (including at least 1 CSO)	1, 1.5, 2, 3 and 4	>43.2
E. grandis	6	1, 1.5	>9.04
E. kochii	22	1	–
E. loxophleba ssp *lissophloia*	15	1	>2.25
E. loxophleba ssp *gratiae*	1	1	–
E. marginata	2	1	3.17
E. moluccana	1 CSO	n.a.	–
E. nitens	7	1	>12
E. occidentalis	10	1	5.58
E. pilularis	9 (including 1 CSO)	1	15
E. polybractea	21 (including 1 CSO)	1	>3.42
E. saligna	7	1	12.85
E. sideroxylon	1	1	0.44
E. smithii	2	1	6
E. tricarpa	3	1	1.13
Grevillea robusta	2	1,1.5	1.25
Santalum album[b]	5	1	26
S. lanceolatum	2	1	0.4
S. spicatum	5	1	8.77

–, no data; CSO, clonal seed orchard; SSO, seedling seed orchard; n.a., not applicable

[a] Generation refers to first, second, third, etc. breeding cycle in the seed orchard. An entry of 1.5 indicates the orchard is a mix of first-generation seed (wild seed) and improved seed from a first-generation seed orchard.

[b] *S. album* is native to northern Australia, Timor and India. The seed orchards in Australia are unlikely to contain any local provenances.

Source: Status as at June 2016, based on consultation with organisations listed in Table 1.57.

This table, together with other data for Indicator 1.3b, is available in Microsoft Excel via www.doi.org/10.25814/5bda82c8d76d4

Other genetic conservation mechanisms

Aside from currently active tree breeding programs, timber species are conserved in arboreta, plantations, and some species trials and seed orchards that have been retained from earlier tree breeding research. Arboreta and private collections focus on species that are widely cultivated, including species of *Eucalyptus*, *Corymbia* and *Acacia*.

The ATSC has a number of provenance progeny tests (many in partnership with state governments and private growers) that serve as repositories of genetic material for species including thick-podded salwood (*Acacia crassicarpa*), brown salwood (*A. mangium*), the spotted gums (*Corymbia citriodora* ssp. *variegata*, *C. henryi* and *C. maculata*), river red gum (*E. camaldulensis*), sugar gum (*E. cladocalyx*), Dunn's white gum (*E. dunnii*), swamp yate (*E. occidentalis*), large-fruited red mahogany (*E. pellita*), Sydney blue gum (*E. saligna*) and red ironbark (*E. sideroxylon* and *E. tricarpa*) (Singh et al. 2013).

Various forestry agencies have retained some species trials and seed orchards although the formal breeding program has been closed. For example, Western Australia has a rich history of testing many native species for timber and eucalypt oil production, including the eucalypts powderbark wandoo (*Eucalyptus accedens*), narrow-leaved mallee (*E. angustissima*), southern mahogany (*E. botryoides*), river red gum (*E. camaldulensis*), sugar gum (*E. cladocalyx*), karri (*E. diversicolor*), southern (Tasmanian) blue gum (*E. globulus*), pointed-bud mallee (*E. horistes*), York gum (*E. loxophleba*), mottlecah (*E. macrocarpa*), jarrah (*E. marginata*), yellow stringybark (*E. muelleriana*), swamp yate (*E. occidentalis*), blackbutt (*E. pilularis)*, blue-leaved mallee (*E. polybractea*), red mahogany (*E. resinifera*), Sydney blue gum (*E. saligna*), salmon gum (*E. salmonophloia)*, red ironbark (*E. sideroxyloni* and *E. tricarpa*), manna gum (*E. viminalis*), wandoo (*E. wandoo*), river red gum hybrids (*E. camaldulensis* x *E. globulus* and *E. camaldulensis* x *E. grandis*) and spotted gums (*Corymbia maculata* and *C. calophylla*), as well as swamp sheoak (*Casuarina obesa*). Some trials and seed orchards still exist although they are no longer actively managed.

Mallee eucalypt species have been widely planted in Western Australia and inland New South Wales for carbon abatement, salinity management and oil production. The Western Australian Department of Environment and Conservation (DEC)[98] owns seed orchards for blue-leaved mallee (*E. polybractea*) and York gum (*E. loxophleba* subsp. *lissophloia*), although the breeding programs for these species have been closed. Work on blue-leaved mallee selections for improved oil production (e.g. Doran et al. 2016; Tables 1.58 and 1.59) is being carried out by private industry.

Sandalwood plantations in Australia comprise Indian sandalwood (*Santalum album*, using introduced provenances from India, Timor and Indonesia) and, more recently, the native species Australian sandalwood (*S. spicatum*). Seed of *S. spicatum* is harvested from native stands and increasingly from cultivated stands in the Western Australian wheatbelt[99] (see also Table 1.56). Tree breeding work by private industry and the Forest Products Commission WA is aiming to improve selections of *S. album* and *S. spicatum*, respectively, for productivity and oil yield. The University of the Sunshine Coast has established an initial trial of the Queensland native species northern or Cape York sandalwood (*S. lanceolatum*) (Case study 1.11).

Normally, seeds are collected from native forest whenever new genetic material is needed for tree breeding programs. However, seed from several provenances of some eucalypts is no longer available in situ due to a combination of forest loss and protection of populations within conservation reserves (with associated restrictions on commercial seed collection). Some important parts of the genetic material for southern (Tasmanian) blue gum (*E. globulus*) and shining gum (*E. nitens*) are now held only in existing Australian plantations and special-purpose field trials.

Gene flow from plantations

Gene flow from plantations of non-local trees into surrounding native forest could change the genetic make-up of local populations of native trees through a phenomenon called 'introgression'. This involves infiltration of genes from one species or provenance into another through hybridisation (Potts et al. 2001). A number of species in their native habitat have been identified as susceptible to hybridisation with nearby plantations, including swamp peppermint (*Eucalyptus rodwayi*), alpine cider gum (*E. archeri*), and spinning gum (*E. perriniana*) (with shining gum *E. nitens*); black gum or swamp gum (*E. ovata*) (with southern (Tasmanian) blue gum, *E. globulus*; FPA 2011b); spotted gum (*Corymbia citriodora* ssp. *variegata*) (with cadaghi, *C. torelliana*; Wallace and Leonhardt 2015; Shepherd and Lee 2016); and Queensland western white gum (*E. argophloia*) (with a variety of species; Randall et al. 2016). In the case of *Corymbia*, there are some first generation (F1) crosses in the native stands, but not many second generation crosses occur (Wallace and Leonhardt 2015; Shepherd and Lee 2016).

Tasmania has guidelines to reduce the risk of genetic contamination of native stands, particularly where the susceptible species are of high conservation value, through risk assessment, regular monitoring for flowering and hybrid seedlings, and careful decisions regarding replanting of plantations. Other strategies used by the forest industry include careful selection of species and provenances; manipulation of flowering times and flower abundance; and silvicultural practices such as isolation distances, the use of buffer zones of non-interbreeding species, and closer planting to reduce the area of crowns able to produce flowers.

[98] The Department of Environment and Conservation (DEC) was formed on 1 July 2006 by the amalgamation of the Department of Environment and the Department of Conservation and Land Management (CALM). CALM conducted a breeding program on several mallee species for some years. Components of the Department of Environment and Conservation (existed 1 July 2006–30 June 2013) subsequently became the Department of Parks and Wildlife (2013–2017), which has now been absorbed into the Department of Biodiversity, Conservation and Attractions (from 1 July 2017).

[99] www.sandalwood.org.au

International collaboration and engagement

Australia collaborates with tree breeding scientists and forestry organisations in other countries, particularly those with similar climates or where Australian species are planted, to exchange knowledge, seed and tree breeding selections or when collaborators are using integrated genetic evaluation platforms (TREEPLAN® and DATAPLAN®) developed and managed in Australia. For example, the Queensland Department of Agriculture and Fisheries is collaborating with South Africa and Brazil on *Corymbia* species that are suitable for plantations in cerrado, savannah and hot dry regions of 1,000–1,200 mm rainfall. The Forestry Program of the Australian Centre for International Agricultural Research (ACIAR) funds international collaborative projects in Indonesia, Papua New Guinea, Pacific islands, Vietnam, Laos, Nepal and Eastern Africa that address priority development themes, including germplasm conservation, improvement and distribution. The web-based genetic evaluation platform of the STBA also services tree breeding programs in China, France and Sweden, fostering international collaboration between tree breeding scientists on advanced-generation plantation species.

Australia is a party to many international organisations, agreements, treaties, conventions or trade agreements that are directly or indirectly relevant to genetic resource conservation (Singh et al. 2013). These include:

- the Food and Agriculture Organization of the United Nations and its Commission on Genetic Resources for Food and Agriculture
- the United Nations Forum on Forests
- the Convention on Biological Diversity
- the World Intellectual Property Organization and its Intergovernmental Committee on Intellectual Property and Genetic Resources, Traditional Knowledge and Folklore
- the International Union for the Protection of New Varieties of Plants, established under the International Convention for the Protection of New Varieties of Plants
- the Convention on International Trade in Endangered Species of Wild Fauna and Flora; and
- the International Plant Protection Convention.

In January 2012 Australia signed the 'Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization', which sits within the Convention on Biological Diversity, and is now developing its approach to implementation and ratification. The Nagoya Protocol establishes a legally binding framework for biotechnology researchers and other scientists to gain access to genetic resources. It also establishes a framework for researchers and developers to share any benefits from genetic resources, or traditional knowledge associated with those resources, with the provider country. The Protocol came into force on 12 October 2014. One of the mechanisms for implementing the Nagoya Protocol is the international Access and Benefit-sharing Clearing-House, which is a platform for exchanging information on access and benefit-sharing. The clearing house will exchange information on protocols, permits and permitted uses of genetic resources in different countries and jurisdictions. This will help to facilitate compliance, and provide evidence that genetic resources and associated traditional knowledge were acquired with prior informed consent and on mutually agreed terms.

Eucalyptus nitens seed orchard, Upper Castra, Tasmania, containing grafted clones of high-ranking genotypes selected for growth, basic density and Kraft pulp yield. Source: Sustainable Timber Tasmania.

Case study 1.11: Tree breeding work on northern sandalwood (*Santalum lanceolatum*)

Northern sandalwood (*Santalum lanceolatum*) grows in open forest and woodland forest, and is harvested in Queensland for sandalwood oil production. It is also used traditionally by north Queensland Aboriginal groups to repel insects (by burning wood or leaves), and for stomach upsets (bark and leaves). Local Aboriginal workers were involved in harvesting the wood in the early 1860s, in exchange for flour and tobacco. The wood was shipped to Thursday Island, Singapore or China. However, the industry collapsed in the 1940s (Wharton 2009). In the Cape York Peninsula, *S. lanceolatum* is locally endangered. There is very little regeneration and seed production, and the adult population is sparsely distributed in small clumps that may be clonal.

A University of the Sunshine Coast project, funded by ACIAR, has three goals:

- to conserve this locally endangered species
- to work with the local Aboriginal community to encourage caring for country including protection of this locally endangered species, and
- to select/breed sandalwood trees for potential commercial use.

The project has worked with Cape York communities over the past five years to evaluate the performance of about 30 different Cape York sandalwood trees. Two grafted seed orchards have been planted in north Queensland (Bamaga and Walkaman Research Station) with about 30 individuals in each, to produce seed for research and for plantation development (Figure 1.39). Although young, the seed orchard at Bamaga produced a large seed crop in 2015, and demonstration trials at Bamaga are planned. The long-term aim is that Cape York sandalwood can be used for commercial plantings or enrichment plantings, and a local industry developed to provide regional employment.

Figure 1.39: Young progeny trial of northern sandalwood (*Santalum lanceolatum*) in north Queensland

Case study 1.12: Conservation planting of Camden white gum (*Eucalyptus benthamii*)

The Camden white gum (*Eucalyptus benthamii*) is a medium-to-tall riverine forest tree restricted to the Nepean River and tributaries near Camden in New South Wales. Up to 6,500 individuals occur in Kedumba Valley in Blue Mountains National Park, and much smaller numbers are found in other locations on private land and public reserves. In 2002, the three populations were estimated to contain 10,000, 400 and 18 individual trees respectively (Skinner 2002).

Camden white gum was listed as vulnerable under the *Environment Protection and Biodiversity Conservation Act 1999* in July 2000, due in part to its restricted distribution, the threat from land clearing and urban development, and loss of some populations due to the construction of the Warragamba Dam in 1933[100]. The species is of domestic interest for conservation, and is one of the 'big ten' eucalypt species in plantation usage internationally (see Harwood 2011; Grattapaglia 2016). The species has recently emerged as an important pulpwood species in Latin American countries such as Uruguay, because of its cold tolerance combined with rapid growth and an ability to grow well in climates with a summer-uniform rainfall distribution (Harwood 2011). It is also grown in southern China and the southern USA (Bush et al. 2016).

The Australian Tree Seed Centre currently holds seed from the majority of the genetic resources available for this species. Genetic analysis of the three populations found increased inbreeding and inter-species gene flow, a loss of rare alleles from the smallest population, and possible reduced seed set and seed viability in two populations, suggesting the species is at risk of inbreeding due to population fragmentation (Butcher et al. 2005).

Camden white gum is conserved ex situ in two seed orchards at Deniliquin, NSW and one at Kowen, ACT, and a conservation forest planted at the National Arboretum in Canberra (Figure 1.40)[101] (Larmour 1993; Gardiner and Larmour 1995). Grafting of isolated, wild trees into a clonal gene bank and seed orchard is currently underway (Bush et al. 2016). In 2014, the Australian Government published conservation advice on Camden white gum to highlight the actions that can be taken to reduce threats to the species, including seeking conservation agreements for populations on private land, surveying for additional populations, managing any changes to hydrology and riverine flooding that could affect natural regeneration of the species, and ensuring the species is considered in any plans to enlarge Warragamba Dam.

Figure 1.40: Conservation planting of Camden white gum (*Eucalyptus benthamii*) at the National Arboretum, Canberra

[100] www.nationalarboretum.act.gov.au/living-collection/trees/tree-descriptions/forests-and-trees/forest-30; www.nationalarboretum.act.gov.au/living-collection/trees/tree_stories/camden_white_gum

[101] Ibid

Criterion 2

Maintenance of productive capacity of forest ecosystems

Plantation pine forest, Queensland.

Criterion 2 Maintenance of productive capacity of forest ecosystems

A key goal of sustainable forest management is to maintain the productive capacity of native and plantation forests. This allows provision of the forest goods and services used by society without compromising the ability of future generations to meet their own needs. The five indicators comprising Criterion 2 therefore aim to provide insights into whether Australia's native forests and commercial plantations used to produce wood and non-wood products are managed in a way that maintains their capacity to continue to produce those products in the long term.

Indicators 2.1a and 2.1b deal with the area of native forests available for wood production and the area of commercial plantations, how these areas have changed over time, and the annual area harvested by jurisdiction and by silvicultural system.

The main wood products harvested from Australia's native forests are high-quality sawlogs for solid wood products, and pulplogs for paper, cardboard, fibreboard and related products. Increasingly, logs are also used to produce peeled veneer for wood-based panel products. Native forests managed for wood production include areas of multiple-use public forests, but exclude areas that do not carry commercial species, or are unsuitable, inaccessible, or excluded by regulatory requirements such as for the protection of soil, water, flora and fauna, recreation and other values. Some areas of leasehold and private native forests are also available for wood production. The annual area of native forest that is harvested in each jurisdiction is reported in Indicator 2.1a according to the silvicultural system applied to each area.

Commercial plantations are the plantations managed for commercial wood production that are reported through Australia's National Plantation Inventory. Indicator 2.1b presents data on the changes over time in the area, species mix and ownership of Australia's commercial plantation estate.

Indicator 2.1c compares the volume of sawlogs harvested from native forests in each jurisdiction, with the harvest volumes determined to be sustainable. Permitted sawlog harvest volumes are set according to a calculated annual sustainable yield or allowable cut, derived from the area of forest

Landscape mosaic of radiata pine plantations and native forests, Bombala, New South Wales.

available for harvest, forest type and age class, standing wood volume, terrain, accessibility, and growth and yield data. Sustainable yield values also take into account restrictions on harvesting within the area available for harvest that are imposed by codes of forest practice, and by other rules and regulatory frameworks established to ensure the protection and maintenance of biodiversity and soil and water resources. Indicator 2.1c also reports on the harvest of softwood and hardwood plantation sawlogs and pulplogs, and on the forecast availability of sawlog and pulplog harvests from plantations over future decades.

Non-wood forest products are products other than wood that are derived from forests. The diverse range of non-wood forest products harvested from Australia's forests includes honey, wildflowers, seeds, animals, and sandalwood used to produce aromatic oil, and is summarised in Indicator 2.1d. These products are regionally and locally significant sources of employment, and are increasing in their commercial importance. Many Aboriginal and Torres Strait Islander peoples (referred to in SOFR 2018 as Indigenous peoples) rely to varying degrees on the use of non-wood forest products for customary purposes (e.g. medicine and livelihood) and commercial purposes (e.g. bushfoods, art and craft).

Harvesting wood from native forests is permitted only if systems are in place for forest regeneration, as the regeneration of a new forest stand is critical to maintaining the productive capacity of the forest. Data on the area of harvested forest that is regenerated successfully in a defined time period, and on the re-establishment of harvested plantations, are reported in Indicator 2.1e.

This icon indicates data, maps or graphics from *Australia's State of the Forests Report 2018* that are available for electronic download. Data used in figures and tables in this criterion, together with higher resolution versions of maps and other graphical elements, are available via www.doi.org/10.25814/5bda8a9ed76d5 and www.doi.org/10.25814/5be3bc4321162.

Indicator 2.1a

Native forest available for wood production, area harvested, and growing stock of merchantable and non merchantable tree species

Rationale

This indicator reports the capacity of forests to sustainably produce wood to meet society's needs into the future. The area of native forest available for wood production, the nature of the growing stock, and the area harvested over time provide means to demonstrate the sustainability of forest management.

Key points

- This indicator reports on four separate metrics:
  - the area of native forest on which wood production is not legally restricted or prohibited
  - the area of native forest on leasehold, private and multiple-use public forest tenures that is available and suitable for commercial wood production
  - the net harvestable area of multiple-use public native forest when additional local restrictions are taken into account
  - the annual area of multiple-use public native forest harvested.
- In 2015–16, the total area of native forest in Australia not legally restricted or prohibited from wood harvesting was 83.6 million hectares.
  - This area comprises predominantly leasehold forest, private forest, and multiple-use public forest. Within this area, the area from which trees may be legally harvested is substantially smaller due to regulatory exclusions or prescriptions.
  - Wood harvesting of native forests is not permitted in nature conservation reserves in any jurisdiction in Australia. No commercial harvesting is carried out in native forests in the Australian Capital Territory or South Australia.
- The extent of native forest that is available and suitable for commercial wood production was 28.1 million hectares in 2015–16. This figure excludes areas that are unsuitable for wood production or in which wood production is not economically viable.
  - The extent of native forest that was available and suitable for commercial wood production was 37.6 million hectares in 2005–06, and 29.3 million hectares in 2010–11.
  - This decline over time is a consequence of several factors, including reclassification of forest as non-forest based on improved mapping techniques for SOFR 2013, changes in forest tenure, transfers of multiple-use public native forests to the nature conservation reserve system, and continuing increases in the areas of multiple-use public native forest to which harvesting restrictions apply.
  - A total of 6.3 million hectares of public native forests were available and suitable for commercial wood production in 2015–16. Of this, 3.8 million hectares are of moderate, high or very high commerciality and are concentrated in the higher rainfall areas of south-west, south-east and eastern Australia.
  - A further 21.8 million hectares of leasehold and private tenure forests were also potentially available and suitable for commercial wood production. However, much of these forests are of low commerciality, are isolated from markets, are forests where harvesting is not operationally feasible or financially viable, or are used predominantly for grazing or for other purposes by the land owner or manager.
- The net area available and suitable for commercial wood production in multiple-use public native forests when additional local restrictions are taken into account (the net harvestable area) is 5.0 million hectares (12% of the total area of public native forests across all public tenures).
  - Harvesting in multiple-use public native forests is subject to strict requirements, exclusions and restrictions at the scale of individual operations, to maintain and manage non-wood values.
  - The net harvestable area of public native forests has declined by 50% from the 10.1 million hectares reported in 1995–96.
  - This decrease mostly resulted from transfer of areas of multiple-use public native forest to the nature conservation reserve system as a part of the Regional Forest Agreement process.

Continued

Continues

Key points

- The average annual area of multiple-use public native forests harvested in Australia in the period 2011–12 to 2015–16 was 78 thousand hectares.
  - This is a 24% decrease from the annual average of 102 thousand hectares for the period 2006–07 to 2010–11, which in turn was a 21% decrease from the annual average of 129 thousand hectares for the period 2001–02 to 2005–06.
  - The total area harvested on multiple-use public native forests in 2015–16, 73 thousand hectares, is 1.5% of the net harvestable area of public native forest, and 0.75% of the total area of multiple-use public native forest.
  - Of the area of multiple-use public native forest harvested over the period 2001–02 to 2015–16, 83% was harvested by using selection silvicultural systems (selection harvesting, native cypress pine harvesting and commercial thinning), 13% by clearfelling silvicultural systems (clearfelling, fire-salvage clearfelling, and intensive silviculture with retention), 4% by shelterwood systems, and 0.2% by variable retention systems.

The emphasis of this indicator is the area of native forests available for wood production, that is, the area in which harvesting is *not legally restricted*[102]. For the purpose of reporting for SOFR 2018, the term "not legally restricted" is confined to five national forest tenure categories: leasehold forest, multiple-use public forest, other Crown land, private forest and unresolved tenure. The sixth national forest tenure category, nature conservation reserve, is considered to be legally restricted from harvesting.

Harvesting is also subject to various forms of regulation on tenures where it is "not legally restricted", including codes of practice, management plans, and requirements to manage the forest for multiple values. Reasons for these restrictions include conservation and management of biodiversity and heritage, and protection of water supplies (see Indicators 7.1a and 7.1b). By regulation, no commercial harvesting is carried out in native forests in the Australian Capital Territory or South Australia. In Australia, the area of native forest available for wood production is therefore a function of tenure, legislation and regulation, as well as economic constraints.

The area of native forests available for wood production is one determinant of the potential domestic supply of wood-based products, and as such is an important input for calculating the sustainable yield of wood from native forests (see Indicator 2.1c).

This indicator also reports on the area of native forest harvested by jurisdiction, year and silvicultural system. The rationale for the indicator also refers to growing stock, which is the total volume of wood in all living trees in a forest at a given time. This is because increases or decreases in growing stock can indicate (among other things) the sustainability of resource use. However, limited data are available across Australia on current growing stock in native forests.

The Resource Assessment Commission (1992) compiled estimates of the growing stock of standing commercial wood, but no national estimates have been made since that work. Subsequent estimates of available growing stock have been and are used to estimate sustainable harvesting levels in multiple-use public native forests in New South Wales, Tasmania, Victoria and Western Australia, and for Tasmanian private forests (see Indicator 2.1c). However, updated data on available growing stock are not available for this indicator in SOFR 2018, and little information is available on the growing stock of non-merchantable tree species (tree species that do not produce saleable products).

Native forest area available for wood production

The major source of Australia's native timber and wood-based products is multiple-use public forests in New South Wales, Queensland, Tasmania, Victoria and Western Australia; forests on land with leasehold and private tenure also contribute to supply in some of these states. Supplies from leasehold and private tenures in the Northern Territory are limited and only occur periodically. Supplies also come from other Crown land in Queensland, and supplies may occur from land in unresolved tenure in New South Wales, Northern Territory and Queensland once the status of tenure is resolved.

Native forest not legally restricted from harvesting

Commercial wood harvesting is legally restricted or prohibited on nature conservation reserve tenure, on informal reserves (see Indicator 1.1c) on all other tenures, on private and leasehold forest that is under conservation covenant or reserved by other mechanisms, and on other Crown land where harvesting is inferred to be legally restricted as a result of government policy. Harvesting is not legally restricted on all other land. In previous SOFR reporting periods, all areas of the tenure categories 'other Crown land' and 'unresolved tenure' were regarded as legally restricted from wood harvesting, but relevant areas of these tenure categories are now included as not legally restricted (Table 2.1), although they are not included in commerciality assessments (see Table 2.2).

[102] The Montreal Process guideline for this indicator (Montreal Process Working Group 2001) defines forest available for wood production as "forest land where wood product extraction is not legally restricted. For example, parks and other areas removed from harvest for protective purposes (i.e. soil protection) is legally restricted. Where harvesting is not legally restricted on private or public land and owners do or do not have a management intent to harvest, all this land would still be considered available for harvest".

In 2015–16, the gross area of native forest in Australia not legally restricted or prohibited from wood harvesting was 83.6 million hectares (Table 2.1), which is 63% of Australia's total area of native forest. Within this area, the area from which trees may be legally harvested is substantially smaller due to regulatory exclusions or prescriptions. The largest areas of native forest not legally restricted from wood harvesting are in Queensland (41.9 million hectares comprising mostly leasehold and private forest), followed by the Northern Territory and New South Wales (17.2 million hectares and 12.6 million hectares respectively, again comprising mostly leasehold and private forest). The area of multiple-use public native forest not legally restricted from wood harvesting totals 8.1 million hectares across Australia.

In 2000–01, the area of native forest not legally restricted from wood harvesting was 119.8 million hectares, 74% of Australia's native forests at that time (SOFR 2003). This area decreased in absolute terms to 112.6 million hectares in 2005–06, but increased in proportional terms to 76% of Australia's native forests (SOFR 2008). SOFR 2013 reported a further decrease to 82.6 million hectares not legally restricted from harvesting in 2010–11, and to 67% of Australia's native forest. However, changes in the methodology underlying determination of Australia's forest area and tenure mean that the figures for the area and proportion of native forest not legally restricted from wood harvesting cannot readily be compared over time.

The Tasmanian Special Species Management Plan (DSG 2017) indicates that conditional access for the harvest of Tasmanian special-species timbers may be granted to Future Potential Production Forest Land (classified for SOFR 2018 under the national forest tenure 'Other Crown land') as well as Conservation Areas, Regional Reserves and Public Reserves (classified for SOFR 2018 as the national tenure 'Nature conservation reserve'). These areas are here treated as legally restricted from harvesting until harvesting approval is given.

Forests across all tenures, but particularly multiple-use public native forest, are increasingly managed for a range of values, such as soil and water protection, flora and fauna protection, and conservation, as well as or instead of wood production. This trend of changing use has contributed to continuing increases in the legal restrictions on the use of multiple-use public native forests for wood harvesting.

Forest available and suitable for commercial wood production

The area of native forest not legally restricted from wood harvesting substantially overestimates the area actually available to timber and wood-processing industries, because it includes forests that are unsuitable for wood harvesting or in which wood harvesting is not economically (commercially) viable, as well as forests that are excluded from harvesting on account of management intent, or as a result of local operational prescriptions and restrictions.

Between 1960 and 1990, data were provided by state and territory agencies to Australian Government agencies on the areas of native forest that were both commercially available and commercially suitable for wood production from multiple-use public forests, leasehold and private forests. Such reporting was not continued after 1992. Subsequently, Davey and Dunn (2014) undertook a national assessment of merchantability and productivity of native forests, with these parameters together giving commercial suitability; then intersected this spatial coverage with areas available for commercial harvesting on the leasehold, private and multiple-use public forest estate (to give commercial availability); and then produced a map of native forests available and suitable for commercial wood production, by their level of assessed commerciality. Forest 'available and suitable' for commercial harvesting is forest with a commerciality rating of very low, low, moderate, high or very high (Davey and Dunn 2014).

Figure 2.1 shows the national distribution of native forest areas by their assessed level of commerciality as at June 2016.

Table 2.2 shows the estimated area of native forest that is available and suitable for wood harvesting in 2006, 2011 and 2016, categorised by its commerciality rating, and separately for the tenures leasehold forest, private forest and multiple-use native public forest. A small amount of commercial harvesting may occur in native forest on other tenures, such as 'other Crown land' and 'unresolved tenure' (see Table 2.1), but commercial forest in those tenures is not considered in this analysis.

For 2006, as reported in SOFR 2008, a total of 37.6 million hectares of native forest was assessed as available and suitable for commercial wood production, which was 33% of the 112.6 million hectares of forest in these tenures. Of this area, 9.9 million hectares were of moderate, high or very high commerciality (not shown).

SOFR 2013 reported that, in 2011, the estimated area of native forest available and suitable for wood harvesting had decreased to 36.6 million hectares, which was 40% of the 92.1 million hectares of native forest in the tenures leasehold, private and multiple-use public native forest. However, this value was an overestimate because of an analytical error relating to the reclassification of forest as non-forest based on improved mapping techniques for SOFR 2013, and a revised estimate is shown in Table 2.2. The estimate is now that 29.3 million hectares of native forest were available and suitable for commercial wood production in 2011 (Table 2.2), which was 32% of the 92.1 million hectares of native forest in these tenures, and 8.3 million hectares less than the 2006 estimate. Of this 29.3 million hectares of commercial forest as at 2011, 8.1 million hectares were of moderate, high or very high commerciality (not shown).

Around 6.5 million hectares of the reduction in reported area from 2006 was attributed to the reclassification of forest as non-forest based on improved mapping techniques for SOFR 2013. The remaining 1.8 million hectares of the reduction in area from 2006 was attributed to forest becoming unavailable for wood production as a result of increased reservation (as a combination of formal and informal reserves, management prescriptions, and conservation covenants on private land) (ABARES, unpublished).

Table 2.1: Area of native forest that is or is not legally restricted from wood harvesting, by tenure and jurisdiction, 2015–16 ('000 hectares)

National forest tenure	Total native forest	Legally restricted from wood harvesting	Not legally restricted from wood harvesting: ACT	NSW	NT	Qld	SA	Tas.	Vic.	WA	Total	Proportion not legally restricted from wood harvesting (%)
Leasehold forest	47,246	4,922	0	3,973	8,276	26,180	0	0	0	3,894	42,323	90
Multiple-use public forest	9,772	1,639	0	1,318	0	2,826	0	503	2,144	1,342	8,133	83
Nature conservation reserve	21,719	21,719	0	0	0	0	0	0	0	0	0	0
Other Crown land	11,042	10,656	0	0	0	386	0	0	0	0	386	3
Private forest	41,031	9,079	0	7,212	8,841	11,812	0	708	945	2,435	31,952	78
Unresolved tenure	805	32	0	77	37	659	0	0	0	0	773	96
Total	**131,615**	**48,047**	**0**	**12,581**	**17,153**	**41,863**	**0**	**1,211**	**3,088**	**7,671**	**83,567**	**63**

Notes:
Legal restrictions on wood harvesting apply in all native forests in the ACT and SA; on nature conservation reserves; on informal reserves on all other tenures; on private and leasehold forest that is under conservation covenant, or regulated or reserved by other mechanisms (see Indicator 1.1c); and are presumed to apply to areas of 'other Crown land' that is not available to commercial wood harvesting.
Wood harvesting on Tasmania's Future Potential Production Forest Land is currently restricted through regulation and is classed here as 'Other Crown land' and legally restricted from harvesting.
Tenures are national tenure categories (see Introduction and Indicator 1.1a) and may not coincide with state or territory tenure categories.
Totals may not tally due to rounding.
Source: ABARES.

This table, together with other data for Indicator 2.1a, is available in Microsoft Excel via www.doi.org/10.25814/5bda8a9ed76d5

As at 2016, the estimated area of native forest available and suitable for wood harvesting had decreased to 28.1 million hectares, which was 29% of the 98.0 million hectares of native forest in the tenures leasehold, private and multiple-use public native forest (Table 2.2). This was a further decrease of 1.3 million hectares from the corrected figure for 2011. While there were tenure changes during the reporting period (Indicator 1.1a), most of the decrease was a result of further reservation or protection of native forests, as well as the reclassification as non-commercial of a small area of forests previously classified as being of very low commerciality (Table 2.2). Of this 28.1 million hectares of commercial forest as at 2016, 7.7 million hectares were of moderate, high or very high commerciality (not shown).

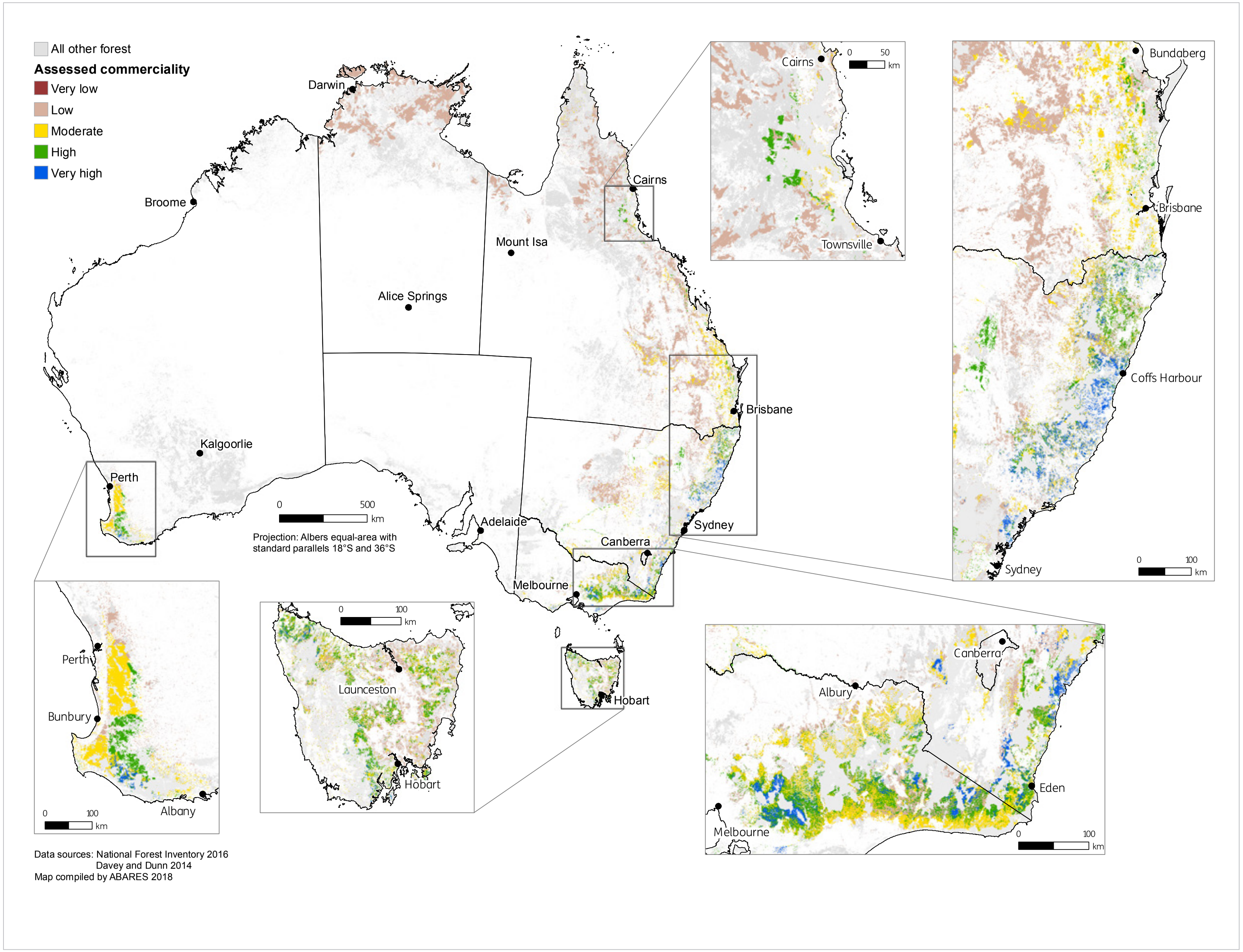
A longer-term view of the changes in the area of native forest available and suitable for wood production is provided in Figure 2.2.

Of the 28.1 million hectares of commercial native forest as at 2016, 6.3 million hectares (22%) is on multiple-use public forest tenure (Table 2.2). This is 64% of the 9.8 million hectares of multiple-use public native forests. The balance of the commercial native forest is on leasehold and private tenure forests (8.2 million hectares and 13.6 million hectares, respectively), but comprises a smaller proportion of the area of forest on these tenures (17% and 33%, respectively).

Of the 7.7 million hectares of native forests of moderate, high or very high commerciality as at 2016, 3.8 million hectares (50%) is on multiple-use public forest tenure (Table 2.2). These forests of moderate, high or very high commerciality are concentrated in the higher rainfall areas of south-west, south-east and eastern Australia (Figure 2.1). A much smaller proportion of the area of leasehold and private tenure forests (8% and 1%, respectively) is of moderate, high or very high commerciality.

A large part of the native forest on leasehold and private land that is available and suitable for commercial wood production contributes minimally to commercial wood supply. This is due to those forests being of low commerciality, being isolated from markets, being forests where harvesting is not operationally feasible or financially viable, or being used predominantly for grazing or for other purposes by the land owner or manager. Commercial harvests in the Northern Territory and northern Queensland are especially limited because of accessibility and remoteness.

Figure 2.1: Australia's native forest available and suitable for commercial wood production, 2016



Notes: Native forest 'available and suitable' for harvesting is native forest with a commerciality rating of very low, low, moderate, high or very high, assessed across the leasehold, private and multiple-use public forest estate (but not other tenures). 'All other forest' on this map includes native forest of limited, possible or no commerciality; sandalwood; forest of unknown floristics and structure; conservation reserves where harvesting is excluded, including on private land by conservation covenant, regulation or other mechanism; plus forests on formal nature conservation reserves, other Crown land, or land of unresolved tenure.

No forest was assessed as very low commerciality in 2016: the small areas of forest assessed as very low commerciality for SOFR 2013 in Victoria are now regarded as non-commercial based on the findings of Forest Solutions (2013).

Source: Davey and Dunn (2014); National Forest Inventory, ABARES.

A higher resolution version of this map is available via www.doi.org/10.25814/5be3bc4321162

Table 2.2: Australia's native forest available and suitable for commercial wood production, by commerciality rating, 2006, 2011 and 2016

		Area ('000 hectares)									
				Commercial forest (forest available and suitable for harvesting)							
				Wood commerciality rating							
Reporting year	Tenure[a]	Total forest[b]	Non-commercial forest and forest legally restricted from harvesting[c]	Very low	Low	Moderate	High	Very high	Total[d]	Proportion of total forest that is commercial[e] (%)	Proportion of total forest that is of moderate, high or very high commerciality[f] (%)
2006 (SOFR 2008)	Leasehold forest	65,132	51,155	4	12,790	845	308	30	13,977	21	2
	Multiple-use public forest	9,410	2,194	84	2,203	2,496	1,784	649	7,216	77	52
	Private forest	38,099	21,652	42	12,567	2,428	1,013	396	16,447	43	10
	Total	**112,641**	**75,001**	**130**	**27,561**	**5,769**	**3,105**	**1,075**	**37,640**	**33**	**9**
2011 rev[g] (revised from SOFR 2013)	Leasehold forest	48,533	38,206	0	9,399	627	277	23	10,327	21	2
	Multiple-use public forest	10,159	3,919	72	2,435	1,956	1,283	494	6,240	61	37
	Private forest	33,394	20,613	38	9,335	2,099	925	384	12,781	38	10
	Total	**92,086**	**62,739**	**110**	**21,170**	**4,682**	**2,485**	**901**	**29,347**	**32**	**9**
2016 (SOFR 2018)	Leasehold forest	47,246	39,094	0	7,596	390	164	2	8,151	17	1
	Multiple-use public forest	9,772	3,476	0	2,465	2,063	1,284	484	6,296	64	39
	Private forest	41,031	27,421	0	10,346	2,049	840	374	13,611	33	8
	Total	**98,049**	**69,991**	**0**	**20,407**	**4,502**	**2,289**	**861**	**28,058**	**29**	**8**

[a] The existence of commercial forest on the tenure categories 'other Crown land', 'nature conservation reserve', and 'unresolved tenure' is not considered in this analysis, even though harvesting is not legally restricted on some areas of 'other Crown land' and 'unresolved tenure' (see Table 2.1).

[b] Figures for total forest in each tenure category are from Indicator 1.1a for 2006 (SOFR 2008), 2011 (SOFR 2013) and 2016 (this SOFR), using the forest coverages available at those times. Areas of forest of various commerciality ratings at those dates were obtained by overlaying these coverages and the commercial forest layer described in Davey and Dunn (2014).

[c] 'Non-commercial forest and forest legally restricted from harvesting' includes forest of limited, possible or no commerciality; sandalwood (not associated with other commercial species); forest of unknown floristics and structure; and conservation reserves on private and public land where harvesting is excluded by conservation covenant, regulation or other mechanisms. Forests on formal nature conservation reserves, other Crown land and land of unresolved tenure are not included on this table.

[d] 'Total' Commercial forest is the sum of the areas of forest of very low, low, moderate, high and very high commerciality.

[e] The proportion of the total area of forest in a tenure category that is classified as very low, low, moderate, high or very high commerciality.

[f] The proportion of the total area of forest in a tenure category that is classified as moderate, high or very high commerciality.

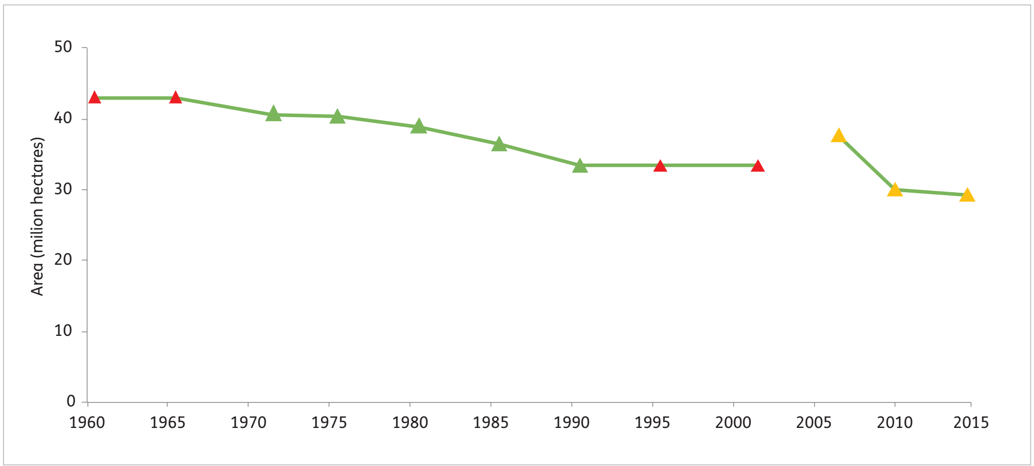
[g] '2011 rev' data are a revision of the figures published in SOFR 2013.

Totals may not tally due to rounding.

Source: Davey and Dunn (2014), ABARES.

This table, together with other data for Indicator 2.1a, is available in Microsoft Excel via www.doi.org/10.25814/5bda8a9ed76d5

Figure 2.2: Australia's native forests available and suitable for commercial wood production, 1960–2016



Notes:

Only leasehold, private and multiple-use public forest is considered in this analysis.

Green data points are derived from tabular data provided by state and territory agencies to Australian Government agencies and used for reporting in Resource Assessment Commission (1992). Red data points are estimates based on those tabular data and ancillary historical data. Yellow data points are based on the spatial assessment of forest commerciality reported in Davey and Dunn (2014) (as corrected) and the various SOFR forest coverages (Table 2.2). Methodological changes caused the increase after 2001. Spatial data was incomplete and poor for the first yellow data point.

Source: Resource Assessment Commission (1992), Davey and Dunn (2014), and ABARES (including historical forest resource datasets and publications from the Bureau of Agricultural Economics and the Commonwealth Forestry and Timber Bureau).

The data used to create this figure, together with other data for Indicator 2.1a, are available in Microsoft Excel via www.doi.org/10.25814/5bda8a9ed76d5

Net harvestable area of forest

The net harvestable area is the area used as the basis of sustainable yield calculations for multiple-use public native forests. The net harvestable area represents the net area of available and suitable forest on multiple-use public native forest land after allowing for local and/or operational constraints on wood harvesting. Net harvestable area is determined by subtracting the following areas from the gross available multiple-use public native forest area:

- areas within multiple-use forests that are reserved for nature conservation, water and heritage purposes, and/or are zoned for management purposes that do not permit wood harvesting
- forest exclusions resulting from the application of conditions in codes of forest practice or other regulatory instruments
- forests determined to have operational constraints (e.g. roading access) or to be non-merchantable – that is, to be not suitable for wood production because of the age, size and species of trees, or because they have been damaged by fire or disease.

Only a proportion of these regulatory or environmental exclusions can be mapped in advance of forest operations. Some prescriptions such as for riparian zones, fauna and flora exclusion areas, and for protection of rare, fragmented or dispersed values, are applied as a result of field observation during preparation of a site for wood harvest.

The net harvestable area of public native forest was 5.0 million hectares in 2015–16, which was a decline of 0.52 million hectares (9%) from the area reported in SOFR 2013, and a decline of 5.1 million hectares (50%) from the 10.1 million hectares reported in 1995–96 (Table 2.3). The decline over this period includes reductions resulting from the implementation of Regional Forest Agreements in four states that saw significant areas of multiple-use public native forest transferred to the nature conservation reserve system (Davidson et al. 2008). The net harvestable area of public native forest in 2015–16 is 12% of the area of public native forest in Australia, compared to 22% in 1995–96.

In New South Wales, the net harvestable area of public native forest declined from 2.35 million hectares in 1995–96 to 1.02 million hectares in 2015–16 (Table 2.3), a reduction of 57%. The 0.21 million hectare reduction in net harvestable area between 2010–11 and 2015–16 was not due to new prescriptions or large transfers of land into nature conservation reserves, but rather to application of net harvest modifier models (FCNSW 2016b) that incorporate new data on the relationship between mapped exclusions and actual exclusions in coastal forest harvesting operations.

In Tasmania, the net harvestable area of public native forest decreased from 0.81 million hectares in 1995–96 (36%) to 0.56 million hectares in 2010–11 (23%) (Table 2.3). This was due to the reallocation of areas of multiple-use public native forest as nature conservation reserves during implementation of the 1997 Regional Forest Agreement and the 2005 Tasmanian Community Forest Agreement, and to changes to provisions in the Tasmanian *Forest Practice Code* (Davey 2018a; FPA 2012). The net harvestable area of public native forest further decreased to 0.38 million hectares (15%) in 2015–16, a reduction of 0.19 million hectares, in the implementation of the 2013 Tasmanian Forest Agreement and the extension to the Tasmanian Wilderness World Heritage Area in 2013 (FPA 2012, 2017a).

Table 2.3: Net harvestable area of public native forest[a], and proportion of total public native forest[a], by jurisdiction, 1995–96 to 2015–16

State	Net harvestable area of public native forest	1995–96	2000–01	2005–06	2010–11	2015–16
NSW	Area ('000 hectares)	2,352	1,516	966[b]	1,229[b]	1,020
	Proportion of total NSW public native forest (%)	35	20	12	16	12
Qld	Area ('000 hectares)[c]	3,186	2,340	2,178	2,030	1,921
	Proportion of total Qld public native forest (%)	40	26	27	22	22
Tas.[d]	Area ('000 hectares)	811	787	607	563	376
	Proportion of total Tas. public native forest (%)	36	35	27	23	15
Vic.	Area ('000 hectares)	2,555	1,010	930	835	824
	Proportion of total Vic. public native forest (%)	41	15	14	13	12
WA	Area ('000 hectares)	1,157	904	848	848	849
	Proportion of total WA public native forest (%)	6	6	7	7	6
Total	**Area ('000 hectares)**	**10,061**	**6,557**	**5,528**	**5,505**	**4,989**
	Proportion of total public native forest (%)	**22**	**14**	**13**	**14**	**12**

[a] Public native forest comprises the tenures multiple-use public native forest, nature conservation reserve and other Crown land. Data do not include harvestable areas on leasehold or private lands accessible to public forest agencies for wood harvesting.

[b] The increase in the reported net harvestable area for NSW public native forests between 2005–06 and 2010–11 resulted from use of a new standardised methodology and a corporate geo-database.

[c] Data for Queensland are net harvestable area on multiple-use public native forest only, but not other Crown land or unresolved tenure.

[d] Data for net harvestable area for Tasmania for 1995–96 to 2010–11 apply to all state forests (multiple-use public native forest) and other Crown land available for harvesting. Data for 2015–16 are only for Permanent Timber Production Zone Land managed by Forestry Tasmania (now Sustainable Timber Tasmania) and not for other public tenures.

Note: Area statements of public forest reported in SOFR 1998, 2003, 2008, 2013 and 2018 are used to calculate proportion of total public native forest.

Source: State and Territory government agencies, including FPA (2007, 2012, 2017a), Forest Practices Board (2002) and DSE (2003, 2008); ABARES.

This table, together with other data for Indicator 2.1a, is available in Microsoft Excel via www.doi.org/10.25814/5bda8a9ed76d5

In Victoria, the net harvestable area of public native forest decreased from 2.55 million hectares in 1995–96 to 0.82 million hectares in 2015–16, a decrease of 68% (Table 2.3). There were several reasons for this decrease: some multiple-use public native forest was transferred to nature conservation reserves, some forest became unavailable due to changes in prescriptions in the *Victorian Code of Practice for Timber Production* and to changes in special protection zones, and some forest was reassessed as unsuitable for wood production because of operational constraints and a lack of merchantable wood (DEPI 2014d).

In Western Australia, the net harvestable area of public native forest declined from 1.16 million hectares in 1995–96 to 0.85 million hectares in 2005–06 (Table 2.3), a decrease of 27%. This was a result of the transfer of parts of the multiple-use public native forest estate to nature conservation reserves, and the introduction by the Western Australian Government of a policy for the protection of old-growth forests. The net harvestable area has remained unchanged from 2005–06 to 2015–16.

In 1999, the Queensland Government signalled a phase-out of harvesting in public native forest in south-east Queensland in favour of wood production from hardwood plantations and private native forests (SOFR 2008); subsequent planning processes excluded harvesting from further areas of public native forests. This has resulted in the steady decrease in the net harvestable area of public native forest from 3.2 million hectares (40%) in 1995–96 to 2.0 million hectares (22%) in 2010–11, a decline of 36%. With a change in Queensland Government policy, the phase-out of harvesting was terminated in 2012 (SOFR 2013). The net harvestable area has decreased by a further 0.11 million hectares since 2010–11.

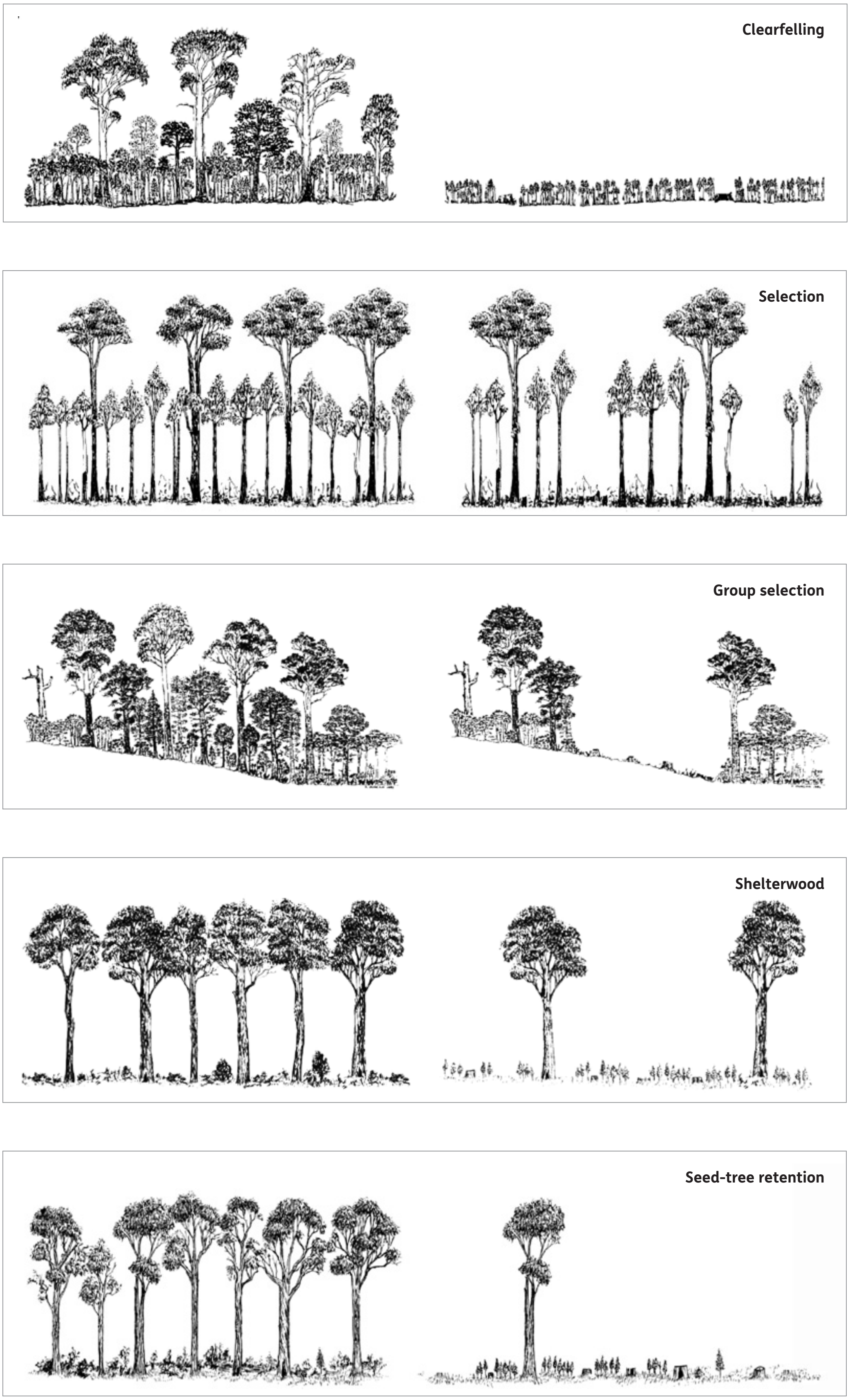
No estimates of the net harvestable area of private and leasehold forests in any jurisdiction were available for SOFR 2018. An estimated 0.36 million hectares (27%) of Victoria's private and leasehold forests were available and suitable for timber production in 2000–01 (DSE 2003). By June 2014, under the private native forestry property vegetation plan (PNF PVP) approval process, 0.55 million hectares of private forests in New South Wales (7% of NSW private forests) had been approved for sustainable harvest of timber resources (NSW OEH 2016b), the majority (73%) of which area was in north-eastern New South Wales.

Area of native forest harvested for wood

While limited data are available on the area of private native forests harvested annually in Australia, agencies managing public forests report annually or five-yearly on the area of forest that is harvested and regenerated under various silvicultural systems (Figure 2.3). Some data are also available for the area harvested in private forests in Tasmania and leasehold forests in Queensland.

The area of multiple-use public native forest harvested in Australia is summarised by silvicultural system in Table 2.4, and by jurisdiction in Table 2.5. Nationally, the total area harvested annually has declined steadily from 141 thousand hectares in 2001–02 to 73 thousand hectares in 2015–16, a 48% decrease. The mean annual harvest area in various

Figure 2.3: Silvicultural systems used in Australia's native forests



Source: Adapted from original artwork by Fred Duncan in Wilkinson (1994).

A higher resolution version of this graphic is available via www.doi.org/10.25814/5be3bc4321162

Table 2.4: Area (hectares) of silvicultural systems used in multiple-use public native forest in Australia

	Silvicultural system[a]										
Reporting year	Clear-felling[b]	Fire salvage (clear-felling)[b]	Intensive silviculture with retention[b]	Shelter-wood	Variable retention[c]	Selection[d,e]	Native cypress pine silviculture[d,e]	Commercial thinning[d]	All systems	Cleared for mining[f]	Total area harvested
2001–02	10,607	100	7,958	7,920	0	68,968	29,576	14,952	140,081	630	140,711
2002–03	11,184	400	6,546	6,500	0	67,631	29,767	14,684	136,712	390	137,102
2003–04	10,440	1,800	5,862	4,330	38	60,112	33,075	12,995	128,652	–	128,652
2004–05	9,680	600	5,118	4,310	39	56,146	29,693	12,747	118,333	500	118,833
2005–06	7,580	900	5,719	2,870	0	60,755	30,954	9,895	118,673	340	119,013
2006–07	8,310	500	4,855	2,780	342	64,411	25,120	10,478	116,796	600	117,396
2007–08	6,710	1,500	3,566	3,040	413	61,302	38,200	12,039	126,770	920	127,690
2008–09	5,410	1,000	3,662	2,700	336	40,193	21,300	12,261	86,862	690	87,552
2009–10	3,900	3,000	4,508	5,260	190	43,139	27,450	8,622	96,069	990	97,059
2010–11	3,880	2,850	6,877	3,890	330	30,792	22,512	6,993	78,124	1,250	79,374
2011–12	2,668	290	4,040	3,590	70	30,655	29,311	6,298	76,922	1,360	78,282
2012–13	3,597	440	3,053	4,800	270	30,995	32,210	8,253	83,618	790	84,408
2013–14	2,936	320	3,776	3,390	47	30,554	27,684	4,921	73,628	1,390	75,018
2014–15	3,014	310	3,381	2,770	415	35,974	27,910	3,333	77,107	910	78,017
2015–16	3,291	266	3,382	3,180	150	27,576	30,678	3,544	72,067	1,140	73,207
Annual mean, 2001–02 to 2005–06 (SOFR 2008 reporting period)	**9,898**	**760**	**6,241**	**5,186**	**15**	**62,722**	**30,613**	**13,055**	**128,490**	**372**	**128,862**
Annual mean, 2006–07 to 2010–11 (SOFR 2013 reporting period)	**5,642**	**1,770**	**4,694**	**3,534**	**331**	**47,959**	**26,916**	**10,079**	**100,924**	**890**	**101,814**
Annual mean, 2011–12 to 2015–16 (SOFR 2018 reporting period)	**3,101**	**325**	**3,526**	**3,546**	**190**	**31,151**	**29,559**	**5,270**	**76,668**	**1,118**	**77,786**
Annual mean, 2001–02 to 2015–16	**6,214**	**952**	**4,820**	**4,089**	**179**	**47,277**	**29,029**	**9,468**	**102,028**	**793**	**102,821**
15-year total as proportion of 15-year total for all silvicultural systems (%)	**7**	**1**	**5**	**4**	**0.2**	**48**	**25**	**10**	**100**		

–, not separately reported.

[a] Some silvicultural systems are illustrated in Figure 2.3.

[b] Clearfelling, fire-salvage clearfelling and intensive silviculture with retention are all clearfelling silvicultural systems. Intensive silviculture with retention includes areas harvested with seed-tree and/or habitat-tree retention, and alternate coupe harvesting. Variable retention silviculture is not a clear-felling system, and is reported separately.

[c] Variable retention silviculture is a silviculture system implemented in wet forests as an alternative to clearfelling systems with the explicit goal of maintaining species, habitats and structural features.

[d] Selection, native cypress pine silviculture and commercial thinning are all selection silvicultural systems.

[e] For the SOFR 2018 reporting period, Queensland data includes harvest figures for native forests with Crown timber rights on the national tenure categories leasehold forest and other Crown land (area figures given in footnotes to Table 2.5).

[f] Jarrah forests in Western Australia that are harvested as part of clearing for bauxite mining are shown as 'cleared for mining'.

Notes:

No harvesting of native forest is permitted from public forests in the Australian Capital Territory, Northern Territory or South Australia.

Data for the years 2009–10 and 2010–11 have been updated since SOFR 2013.

Source: Data provided by NSW, Qld, Tas., Vic. and WA.

This table, together with other data for Indicator 2.1a, is available in Microsoft Excel via www.doi.org/10.25814/5bda8a9ed76d5

SOFR reporting periods fell from 129 thousand hectares in period 2001–02 to 2005–06, to 102 thousand hectares in the period 2006–07 to 2010–11 (a 21% decrease), then further to 78 thousand hectares in the period 2011–12 to 2015–16 (a further 24% decrease). The total area harvested on multiple-use public native forests in 2015–16, 73 thousand hectares, is 1.5% of the net harvestable area of public native forest, and 0.75% of the total area of multiple-use public native forest.

Tasmania, Victoria and Western Australia use clearfelling as a silvicultural system to promote native forest regeneration in certain forest types. Annual clearfelling data of native forests in Table 2.4 include native forest regenerated to native forest and, in Tasmania, native forest converted to plantation during the period 2001–02 to 2010–11 (the conversion of native forest to plantations on public land in Tasmania was phased out by 2010). Salvage of fire-damaged native forest stands using clearfelling systems in Victoria and Tasmania, and areas clearfelled in association with bauxite mining in Western Australia, are reported separately (Table 2.4). Intensive silviculture with retention includes areas harvested with seed-tree and/or habitat-tree retention, practised in Tasmania, Victoria and Western Australia, and alternate coupe harvesting in the Eden region of New South Wales.

Variable retention silviculture is a silviculture system implemented in wet forests as an alternative to clearfelling systems, and with the explicit goal of maintaining species, habitats and structural features (Baker and Read 2011). Table 2.4 reports variable retention silviculture separately; this type of silviculture commenced in Tasmania in 2003 and in Victoria in 2013. A shelterwood silvicultural system used for nurturing and promoting regeneration in specific forest types is primarily practised in Western Australia and also in Tasmania.

Of the area of multiple-use public native forest harvested over the period 2011–12 to 2015–16, 86% was harvested by using selection systems, 9% by clearfelling systems, 5% by shelterwood systems, and 0.2% by variable retention systems (Table 2.4). The annual average area harvested by clearfelling systems (clearfelling, fire-salvage clearfelling and intensive silviculture with retention) decreased from 17 thousand hectares in 2001–02 to 2005–06 (13% of the total area harvested), to 12 thousand hectares in 2006–07 to 2011–12 (12% of the total area harvested), to 7 thousand hectares in 2011–12 to 2015–16 (9% of the total area harvested) (Table 2.4).

New South Wales, Queensland, Tasmania, Victoria and Western Australia apply selection harvesting silvicultural systems, including group or gap selection, Australian group selection, single-tree selection (including light, moderate and heavy selection systems and diameter-limit cutting), and mixtures of group selection and single-tree selection, based on the known regeneration responses of the different forest types.

Native cypress pine silviculture (applied in New South Wales and Queensland) and commercial thinning of regrowth stands (applied in New South Wales, Tasmania, Victoria and Western Australia) also both use selection harvesting techniques; these are reported separately (Table 2.4).

Table 2.5 reports the area harvested from multiple-use public native forest annually, and the annual means for the three most recent SOFR reporting periods and for the 15-year period 2001–02 to 2015–16, by jurisdiction. New South Wales and Queensland together contributed 78% of the area of multiple-use public native forest harvested in Australia in the SOFR 2018 reporting period 2011–12 to 2015–16. Over the three SOFR reporting periods, New South Wales and Queensland each contributed more than one-third of the area of multiple-use public native forest harvested in Australia.

The mean annual area of multiple-use public native forest harvested continues to decrease in the SOFR 2018 reporting period, with a 24% decline nationally between the SOFR 2013 period (101,814 hectares) and the SOFR 2018 period (77,786 hectares), and all states other than Queensland reporting declines between these periods (Table 2.5). Tasmania experienced a 64% decrease in the mean annual area harvested between the SOFR 2013 period (11,218 hectares) and the SOFR 2018 period (4,020 hectares), while New South Wales, Victoria and Western Australia experienced decreases of 36%, 25% and 16%, respectively. Queensland also experienced a decline (by 26%) in the mean annual area of multiple-use public native forest harvested between these two periods when harvest areas on native forests with Crown timber rights are excluded.

The *Forest Management Plan 2014–2023* for south-western Western Australia (CCWA 2013) discusses the sustainability of wood volumes and growing stock of jarrah, karri and marri forests (*Eucalyptus marginata*, *E. diversicolor* and *Corymbia calophylla*, respectively), and Western Australia has a long history of reporting the annual area of forest harvested for wood (Table 2.6). The average annual harvested area of jarrah (*Eucalyptus marginata*), karri (*E. diversicolor*) and wandoo (*E. wandoo*) forest types decreased from 30,180 hectares in 1976–80 to 7,938 hectares in 2011–15, a 74% reduction. The majority of harvesting occurred using selection and shelterwood silvicultural systems.

Table 2.5: Forest area (hectares) harvested annually from multiple-use public native forest in Australia

Reporting year	NSW[a]	Qld[b]	Tas.	Vic.	WA	Total
2001–02	50,351	47,700	14,900	10,500	17,260	140,711
2002–03	49,062	48,300	16,900	8,500	14,340	137,102
2003–04	45,337	48,400	17,090	8,100	9,725	128,652
2004–05	42,523	41,100	17,500	7,600	10,110	118,833
2005–06	43,233	47,700	12,500	7,800	7,780	119,013
2006–07	44,806	43,900	11,520	6,900	10,270	117,396
2007–08	52,960	44,200	12,990	7,800	9,740	127,690
2008–09	27,952	32,500	12,370	6,400	8,330	87,552
2009–10	38,499	32,300	8,710	5,900	11,650	97,059
2010–11	27,484	28,200	10,500	5,800	7,390	79,374
2011–12	27,444	34,000	2,590	5,398	8,850	78,282
2012–13	31,221	35,000	4,190	5,427	8,570	84,408
2013–14	23,807	35,000	3,610	4,481	8,120	75,018
2014–15	22,235	40,000	4,700	4,332	6,750	78,017
2015–16	17,878	38,000	5,010	4,819	7,500	73,207
Annual mean, 2001–02 to 2005–06 (SOFR 2008 reporting period)	46,101	46,640	15,778	8,500	11,843	128,862
Annual mean, 2006–07 to 2010–11 (SOFR 2013 reporting period)	38,340	36,220	11,218	6,560	9,476	101,814
Annual mean, 2011–12 to 2015–16 (SOFR 2018 reporting period)	24,517	36,400	4,020	4,891	7,958	77,786
Annual mean, 2001–02 to 2015–16	36,319	39,753	10,339	6,650	9,759	102,821
15-year total as proportion of 15 year total for all systems (%)	**35**	**39**	**10**	**6**	**9**	**100**

[a] Total area planned for harvest in New South Wales multiple-use native forests. Table 2.17 in Indicator 2.1e reports the net area harvested in the context of regeneration assessment.

[b] For the SOFR 2018 reporting period, also includes harvest areas on Queensland native forests with Crown timber rights on the national tenure categories leasehold forest and other Crown land (2011–12, 7,500 hectares; 2012–13, 7,500 hectares; 2013–14, 10,000 hectares; 2014–15, 7,500 hectares; 2015–16, 16,000 hectares).

Notes:

For all jurisdictions except NSW, the area reported is the area harvested under the silvicultural system used in the harvesting event.

Other than the Queensland figures for the years identified above, the harvesting figures are from multiple-use public native forest or tenures that the Crown treats (or treated) as multiple-use public native forest.

Harvest areas include areas harvested before plantation establishment (Tas.) and bauxite mining (WA).

No harvesting of native forest is permitted from public forests in the ACT, NT or SA.

Source: Data provided by NSW, Qld, Tas., Vic. and WA.

This table, together with other data for Indicator 2.1a, is available in Microsoft Excel via www.doi.org/10.25814/5bda8a9ed76d5

Table 2.6: Average area (hectares) of multiple-use public native forest harvested in Western Australia

Period	Selection, shelterwood and other harvest[a] (jarrah and wandoo)	Clearfelled or partially cut (karri)	Thinned[b] (karri)	Total
1976–80	27,340	2,792	48	30,180
1981–85	23,244	1,722	322	25,288
1986–90	18,266	1,330	656	20,252
1991–95	14,236	1,788	124	16,148
1996–2000	19,436	1,668	180	21,284
2001–05	11,032	724	608	12,364
2006–10	7,486	508	962	8,956
2011–15	6,980	318	640	7,938

[a] Includes harvesting for a range of silvicultural objectives, including thinning, selection and shelterwood silviculture systems in jarrah and wandoo forest, and jarrah forest harvested before being cleared for bauxite mining.

[b] Thinning of regrowth karri forests.

Source: SOFR (2013), Western Australian Department of Biodiversity, Conservation and Attractions.

This table, together with other data for Indicator 2.1a, is available in Microsoft Excel via www.doi.org/10.25814/5bda8a9ed76d5

Indicator 2.1b

Age class and growing stock of plantations

Rationale

This indicator uses the area, age class and growing stock of native and exotic species plantations to assess the volume of timber that Australia's plantation forests can supply now and into the future.

Key points

- The area of commercial plantations managed for wood production in Australia in 2014–15, as reported in *Australian plantation statistics 2016*, was 1.97 million hectares.
  - This commercial plantation area was lower than the 2.02 million hectares reported for 2010–11. This change reflects a combination of plantation land that was not commercially productive being converted to agricultural or other land uses, and revisions of area figures on land use by plantation managers (for example by including plantation land that was fallow between rotations)
  - The reduction in the area of commercial plantations between 2010–11 and 2014–15 was 44 thousand hectares.
- Of the total commercial plantation estate area in 2014–15, 52% was planted with softwood species, 47% with hardwood species, and less than 1% with mixed and other species.
  - As at 2014–15, there were 997 thousand hectares of commercial plantations in their first rotation (the period from first planting to first harvest), 641 thousand hectares in their second, third or fourth rotation, and 335 thousand hectares where the rotation is unknown.
  - The area of commercial softwood plantations increased by 1% between 2010–11 and 2014–15, while the area of commercial hardwood plantations decreased by 5%.
- The area proportion of Australia's commercial plantation estate where the trees are privately owned increased from 76% to 79% between 2010–11 and 2014–15, while the proportion where the trees are owned by government organisations decreased from 24% to 21%.
  - The ownership structure of the privately owned commercial plantation estate shifted towards institutional investors over this period, with institutional investor ownership of commercial plantations increasing from 31% to 50%.

Commercial plantations provided over 85% of Australia's total log harvest in 2014–15 (see Indicator 2.1c). Growing trees in commercial plantations, harvesting logs, and processing them into sawnwood, paper and paperboard, panels and other wood products, generates substantial regional employment (see Indicator 6.5a). Commercial plantations provide the raw material for major rural industries, even though they occupy only a small part of the rural land estate (see Indicator 1.1a).

Until the 1990s, most commercial plantations established in Australia were pines and other softwood species grown to produce sawnwood. Many were planted on land where there had previously been native eucalypt forests. Most commercial plantations established over the past 20 years have been hardwood plantations (mainly eucalypts) grown to produce pulplogs. New commercial plantations during this period have been generally established on cleared agricultural land, because the clearing of native vegetation (including native forests) for new plantation development is now either prohibited or significantly restricted by state and territory legislation and policies.

The rationale for Indicator 2.1b identifies 'growing stock' – the total volume of wood in all living trees in a forest at a given time, often referred to as 'standing volume' – as an indicator of potential wood supply from commercial plantations. Growing stock is not usually measured in Australia, but ABARES, under the auspices of the National Plantation Inventory (NPI), develops forecasts of merchantable plantation log supply every five years (see Indicator 2.1c).

Plantation areas and values

The area of Australia's commercial plantation estate from 1940, including data from before the establishment of the NPI in 1995, is shown in Figure 2.4. Non-commercial plantations and other planted forests are reported separately, under the 'Other forest' category in Indicator 1.1a.

The first data for the NPI were collected in 1995, with the first comprehensive map-based report published in 1997, which reported that Australia had just over 1 million hectares of plantations. The area of plantations almost doubled from 1990 to 2015 (Figure 2.4), with hardwood plantations accounting for most of that expansion. Government policies and programs and joint government/industry initiatives, such as *Plantations for Australia: the 2020 Vision* (Private Forestry Consultative Committee 2002), were important in identifying and facilitating the removal of impediments to plantation development over this period.

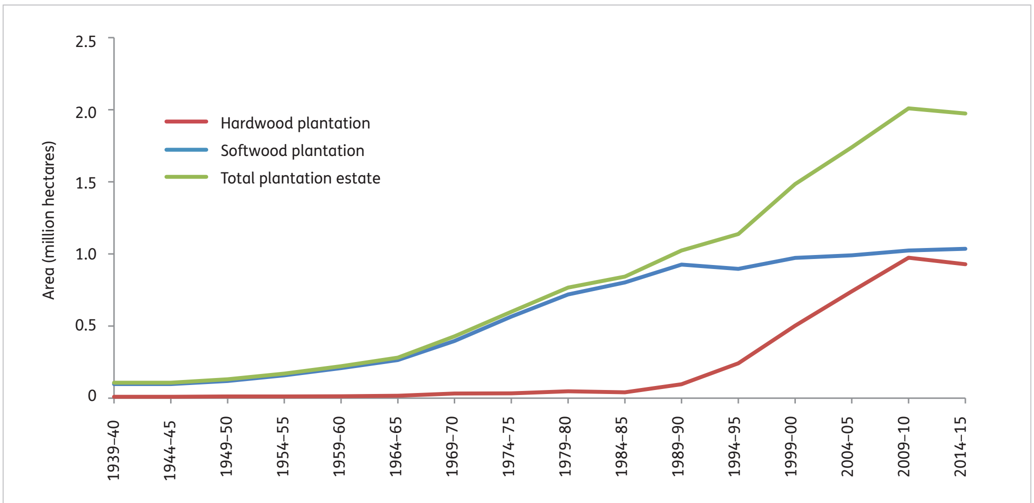
The commercial plantation estate decreased from 2.02 million hectares in 2010–11 to 1.97 million hectares in 2014–15 (Figure 2.4) as a result of plantation growers and managers returning unproductive plantation land to agriculture or to landholders on the expiration of hardwood plantation lease arrangements. The area of commercial softwood plantations increased by 1% between 2010–11 and 2014–15, while the area of commercial hardwood plantations decreased by 5%.

The 2014–15 area data for commercial plantations reported in this indicator are taken from *Australian plantation statistics 2016* (ABARES 2016b), which is the most recent spatial update of Australia's commercial plantation estate. More recent tabular data on plantation areas as at June 2016 are available in *Australian plantation statistics 2017 update* (Downham and Gavran 2017), and as at June 2017 in *Australian plantation statistics 2018 update* (Downham and Gavran 2018), but differ only slightly from the figures reported here. The area figures reported in SOFR 2018 Indicator 1.1a also differ slightly from those reported in *Australian plantation statistics 2016*, due to conversion of the vector format dataset used in Australian plantation statistics 2016 to the raster format dataset used for area analyses in SOFR 2018 (see Indicator 1.1a).

Australia's total commercial plantation estate in 2014–15 comprised 1.04 million hectares of softwood plantations, 0.928 million hectares of hardwood plantations, and 9.7 thousand hectares classified in the 'mixed and other' category (plantations of mixed hardwood and softwood species, and plantations for which species were not reported). A total of 52% of the total commercial plantation forest area is softwood plantations (primarily exotic pines), 47% is hardwood plantations (primarily eucalypts), and less than 1% is 'mixed and other' plantations.

Figure 2.5 shows the distribution of plantation establishment (first rotation) and re-establishment (second and subsequent rotations) by five-year period, from prior to 1970 to 2011–15. After 1990, re-establishment of exotic softwood plantations (funded mainly by government investment) was augmented by establishment of new hardwood plantations of a range of eucalypt species (funded mainly by private-sector investment).

Figure 2.4: Australia's commercial plantation area, 1939–40 to 2014–15

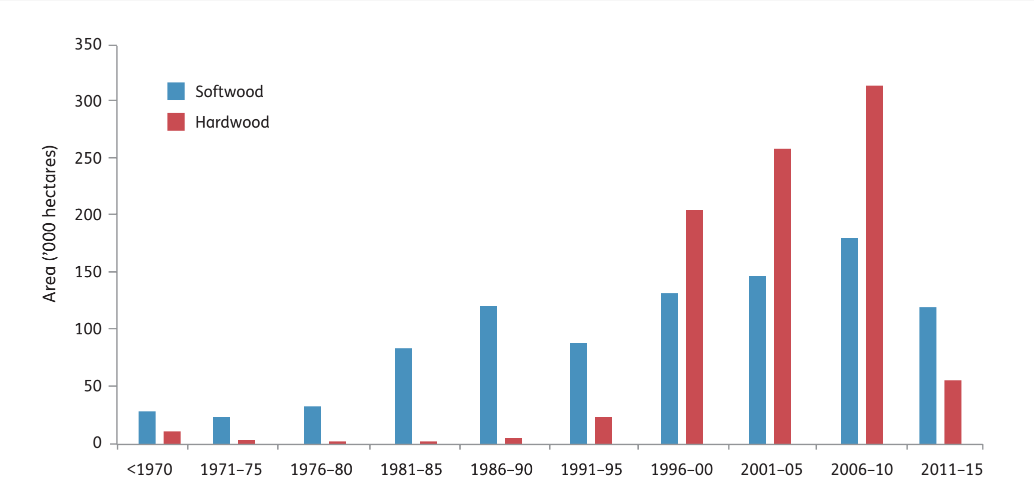


Note: Total plantation estate data for 1999–2000 to 2014–15 also include plantations in the 'Unknown or mixed' category.

Source: Bureau of Agricultural Economics, Commonwealth Forestry and Timber Bureau, National Plantation Inventory, ABARES (2016).

The data used to create this figure, together with other data for Indicator 2.1b, are available in Microsoft Excel via www.doi.org/10.25814/5bda8a9ed76d5

Figure 2.5: Area of commercial plantation establishment and re-establishment by five-year period, to 2011–15



Note: Plantation establishment refers to establishment of first-rotation plantations on sites not previously carrying plantation; plantation re-establishment refers to establishment of second and subsequent plantation rotations on sites previously carrying plantations.
Source: ABARES (2016b), National Plantation Inventory.

The data used to create this figure, together with other data for Indicator 2.1b, are available in Microsoft Excel via www.doi.org/10.25814/5bda8a9ed76d5

Table 2.7: Area of commercial plantation estate, and proportions by jurisdiction, 2014–15

	Commercial softwood plantations	Commercial hardwood plantations	Total plantation estate
Total area ('000 hectares)	1,035	928	1,973
Proportion by jurisdiction (%)			
Australian Capital Territory	0.7	0	0.4
New South Wales	30	9	20
Northern Territory	0.2	5	2
Queensland	19	4	12
South Australia	12	6	9
Tasmania	7	25	16
Victoria	22	21	21
Western Australia	10	30	19

Notes: Includes plantations where type is unknown. Totals may not tally due to rounding.
Source: ABARES (2016b).

This table, together with other data for Indicator 2.1b, is available in Microsoft Excel via www.doi.org/10.25814/5bda8a9ed76d5

Table 2.7 shows the total area of Australia's commercial plantation estate (softwood, hardwood and total) in 2014–15, and the proportions by jurisdiction. Victoria had the largest area proportion of the national commercial plantation estate (21%), including 22% of the national commercial softwood plantation area and 21% of the national commercial hardwood plantation area. New South Wales had the next largest area proportion of the national commercial plantation estate (20%), followed by Western Australia (19%) and Tasmania (16%).

In 2014–15, there were 997 thousand hectares of commercial plantations (mainly hardwoods) in their first rotation, 641 thousand hectares of commercial plantations (mostly softwoods) in their second, third or fourth rotation (the majority of which are in their second rotation), and 335 thousand hectares of commercial plantations where the rotation is unknown (Table 2.8).

Commercial softwood plantations are managed for sawlogs with rotation lengths between 25 and 35 years. The majority of commercial hardwood plantations are managed for pulplogs with rotation lengths between 10 and 15 years. The remaining commercial hardwood plantations are managed for sawlogs and are generally grown on longer rotations of between 25 and 45 years.

Figure 2.6a and Figure 2.6b show the area of plantations as at 2014–15, in commercial plantations managed for sawlog and pulplog production respectively, by age class. The majority of softwood plantation trees as at 2014–15 were planted between the periods 1981–85 and 2011–2015; almost all commercial plantations managed for sawlogs are softwood plantations. The majority of commercial hardwood plantation trees as at 2014–15 were planted between the periods 1996–2000 to 2006–10; the majority of commercial plantations managed for pulplogs are hardwood plantations.

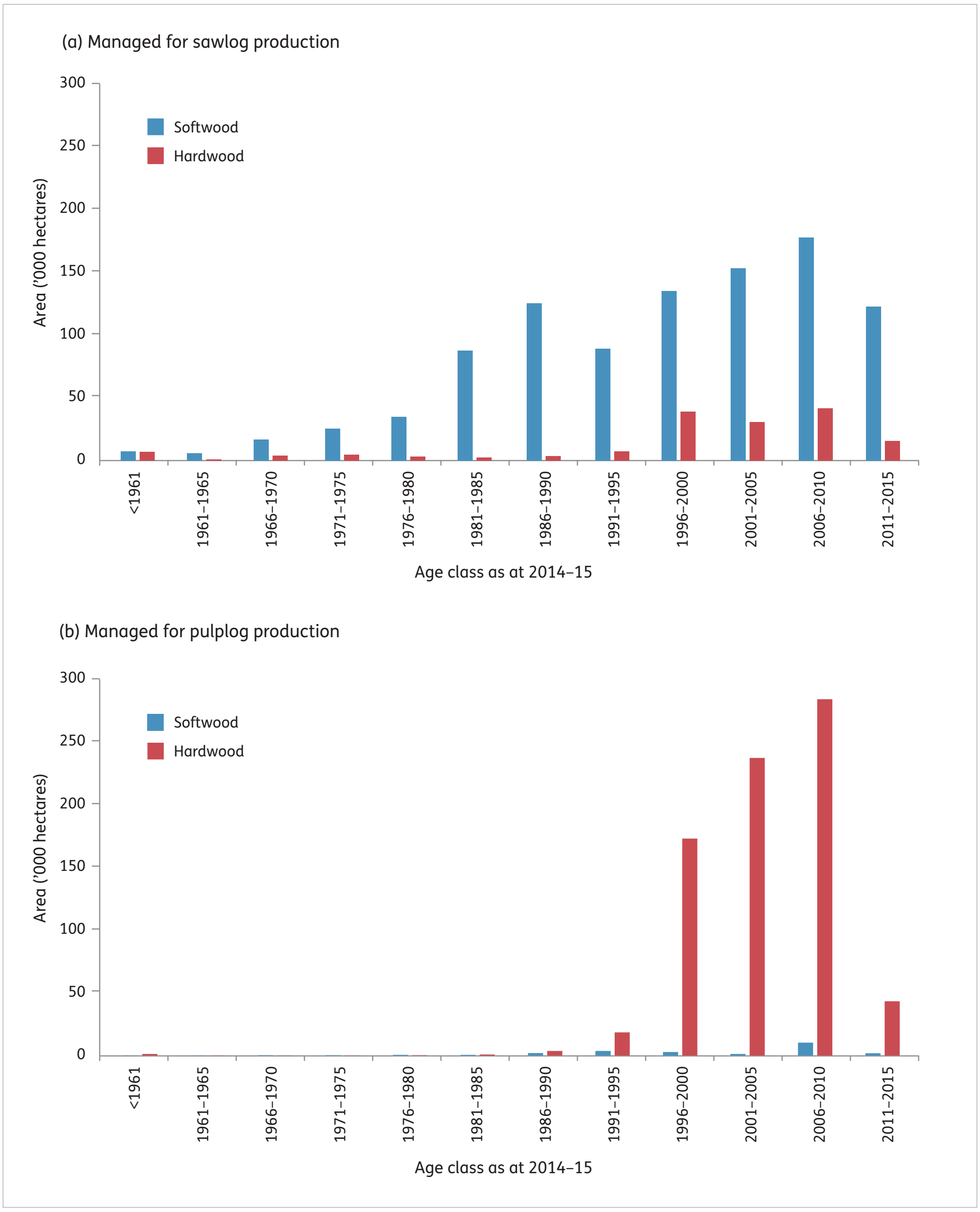
Table 2.8: Area of components of Australia's commercial plantation estate, by type and rotation, 2014–15

	Area ('000 hectares)			
Rotation	Softwood	Hardwood	Mixed and other categories	Total
1	358	630	9	997
2	447	142	0.5	589
3	45	6	0	51
4	1	0	0	1
Unknown	185	150	0	335
Total	1,035	928	10	1,973

Notes: 'Unknown' is where information is unavailable about the rotation. Totals may not tally due to rounding.
Source: ABARES (2016b).

This table, together with other data for Indicator 2.1b, is available in Microsoft Excel via www.doi.org/10.25814/5bda8a9ed76d5

Figure 2.6: Area of Australia's commercial plantation growing stock, 2014–15, by age-class



Note: Plantations of unknown age and harvested plantations awaiting re-establishment are not included.
Source: National Plantation Inventory.

The data used to create this figure, together with other data for Indicator 2.1b, are available in Microsoft Excel via www.doi.org/10.25814/5bda8a9ed76d5

Commercial plantation ownership

Ownership of plantation trees

Figure 2.7 depicts the proportion of area of Australia's commercial plantation estate at 2014–15, by tree and land ownership categories and by age class. In 2014–15, the majority of commercial plantations (an average of 65% across all age classes) were under private tree ownership. Commercial plantations with publicly owned trees averaged 33% across all age classes, and commercial plantations with jointly owned trees averaged 2%.

During the period from 2010–11 to 2014–15, there was a progressive change in commercial plantation ownership (specifically, ownership of plantation trees) from public to private owners. Over this period, the area proportion of Australia's commercial plantation estate that was privately owned increased from 76% to 79%, while the proportion owned by government organisations decreased from 24% to 21% (Table 2.9).

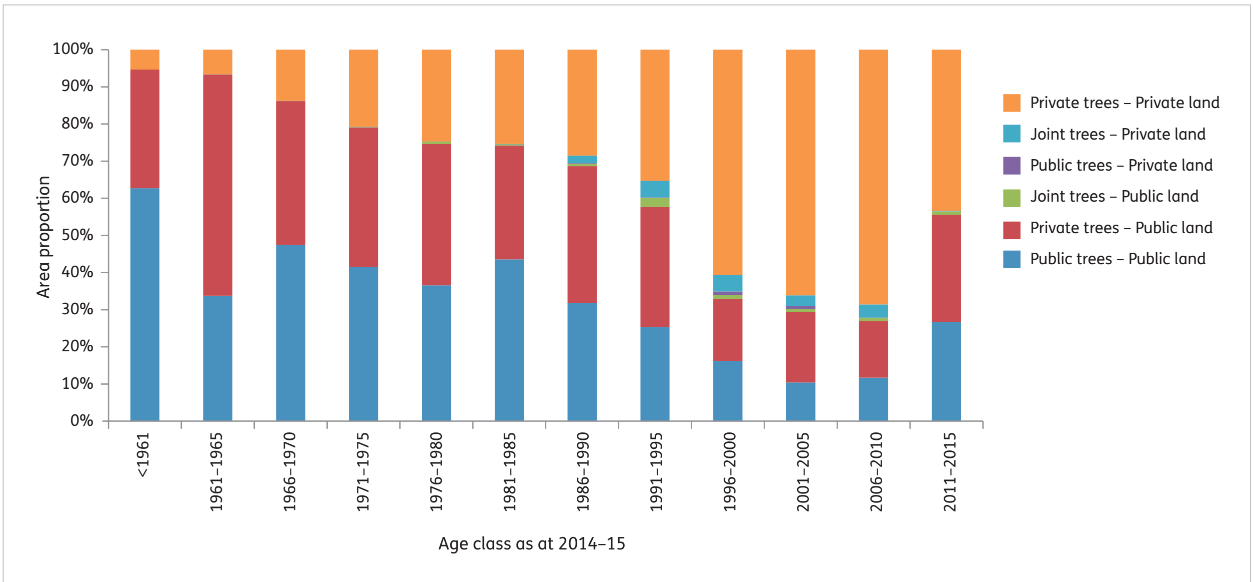
Over this period, farm foresters and other private owners (including small-scale plantation woodlot owners) increased their ownership of the area of commercial plantations from 8% to 21%, due primarily to commercial plantations that were previously owned by managed investment schemes (MISs) under land lease arrangements reverting to the landowner. Ownership by institutional investors (including international superannuation funds) increased from 31% to 50%, due largely to purchase of commercial plantations that were previously owned by MISs. In contrast, private ownership by timber industry companies fell from 13% to 4%, and the proportion of commercial plantations owned by MISs reduced from 24% to 5% (Table 2.9).

Ownership of plantation land

In 2014–15, the majority of commercial plantations that were established or re-established before 1996–2000 were on public land (an average of 79% across these age classes) (Figure 2.7). For plantations with age classes between 1996–2000 and 2006–2010, the majority (an average of 69%) were on private land.

In the period 2011–15, 56% of commercial plantations established or re-established were on public land and 44% were on private land (Figure 2.7). However, the figures for 2011–15 are calculated for a much smaller area of new plantation establishment than are the figures for earlier years (see Figure 2.40, Indicator 2.1e).

Figure 2.7: Area proportion of commercial plantation land and trees in ownership categories, 2014–15, by age-class



Notes: Joint ownership includes government and private ownership arrangements.

Data are area proportions in 2014–15 for each age-class category. Plantations of unknown age, harvested plantations awaiting re-establishment, and new plantations awaiting establishment are not included.

Source: National Plantation Inventory.

The data used to create this figure, together with other data for Indicator 2.1b, are available in Microsoft Excel via www.doi.org/10.25814/5bda8a9ed76d5

Table 2.9: Area proportion of commercial plantations by ownership category, 2010–11 to 2014–15

	2010–11	2011–12	2012–13	2013–14	2014–15
Commercial plantation area ('000 hectares)	**2,017**	**2,013**	**2,013**	**2,000**	**1,973**
Ownership area proportion (%)					
Private owners	76	76	81	81	79
Institutional investors	31	32	40	40	50
Timber industry companies	13	13	13	13	4
Farm foresters and other private owners	8	8	8	8	21
Managed Investment Schemes (MISs)	24	23	20	20	5
Government organisations	24	24	19	19	21

Notes: Ownership data refer to ownership of trees. Joint venture arrangements between government agencies and private owners are included under 'Governments' where government is the manager of the plantation resource. Totals may not tally due to rounding.

Source: Gavran (2013), Gavran (2014), ABARES (2016b).

This table, together with other data for Indicator 2.1b, is available in Microsoft Excel via www.doi.org/10.25814/5bda8a9ed76d5

Plantation species

The main Australian commercial plantation species by climate and rainfall region, and the main uses for the wood they produce, are shown in the SOFR 2018 Introduction, Table I.i.

In 2014–15, the commercial softwood plantation estate was dominated by radiata pine (*Pinus radiata*; 74% by area) and the southern pines (15% by area) (ABARES 2016b). Southern pines comprise Caribbean pine (*P. caribaea*), slash pine (*P. elliottii*) and several varieties of these; a hybrid between southern pine varieties is now the preferred plantation softwood in subtropical and tropical regions of Australia. Both radiata pine and the southern pines are managed primarily for sawlog production. Other regionally important softwood species are maritime pine (*P. pinaster*) in Western Australia, and hoop pine (*Araucaria cunninghamii*) in south-east Queensland, both of which are also managed primarily for sawlog production.

In 2014–15, the commercial hardwood plantation estate was dominated by Tasmanian blue gum (*Eucalyptus globulus*; 53% by area) and shining gum (*E. nitens*; 25% by area), both of which are managed primarily for pulpwood production (ABARES 2016b).

Blackbutt (*E. pilularis*) and flooded gum (*E. grandis*) together comprise 3% of the total hardwood plantation estate area; Dunn's white gum (*E. dunnii*) and various acacia species (such as *Acacia mangium*) each account for 3% by area; and the spotted gums (*Corymbia maculata*, *C. variegata* and related species) comprise 2% by area. A further 7% by area is other eucalypts such as mountain ash (*E. regnans*) and Sydney blue gum (*E. saligna*), and 3% by area is other hardwood species, such as African mahogany (*Khaya senegalensis*) and teak (*Tectona grandis*). All these species are managed primarily for sawlog production.

Hardwood plantation (*Eucalyptus regnans*), Gippsland, Victoria.

Indicator 2.1c

Annual removal of wood products compared to the volume determined to be sustainable for native forests, and future yields for plantations

Rationale

This indicator measures the harvest levels of wood products in relation to future yields. The capacity to implement strategies to deal with changing demand for forest products based on future yields from both native and plantation forests is an integral part of sustainable forest management.

Key points

- An average annual volume of 1.14 million cubic metres of high-quality sawlog was harvested from multiple-use public native forests (including other native forests where timber is owned by the Crown) in the SOFR 2018 reporting period 2011–12 to 2015–16.
  - This is a continued and progressive decline from 1.96 million cubic metres in the SOFR 2008 reporting period 2001–02 to 2005–06, and 1.44 million cubic metres in the SOFR 2013 reporting period 2006–07 to 2010–11.
- The average sustainable sawlog yield from multiple-use public native forests declined nationally by 53% across the five SOFR reporting periods from 1992–93 to 2015–16.
  - This decline was a consequence of several factors. These include transfer of multiple-use public native forests into nature conservation reserves, which reduced the area of native forest available for harvesting; increased restrictions on harvesting in codes of forest practice and other regulatory instruments; revised estimates of forest growth and yield due to improved information and incorporation of climatic effects; and, especially in Victoria, impacts of occasional, intense broad-scale bushfires.
  - Nationally, sustainable yield is forecast to continue to decline to around 38% of the level reported in SOFR 1998 by the period of 2030–34. After that time, it is forecast to increase, given no further reductions in net harvestable area and successful management of risk from wildfire, disease and climate change.
- The volume of sawlogs harvested from multiple-use public native forests in the each of the five reporting periods from 1992–93 to 2015–16 was within sustainable yield levels in New South Wales, Tasmania, Victoria and Western Australia or within allowable tolerances, and within the allowable cut in Queensland.
  - The national sawlog harvest level was below sustainable yield levels by 23% for the reporting period 2011–12 to 2015–16, and below sustainable yield levels by 7–15% for each of the previous four SOFR five-yearly reporting periods.
- The average annual harvest volume of wood from native forest in Tasmania in the SOFR 2018 reporting period 2011–12 to 2015–16 was 2.4 million cubic metres less than that in the SOFR 2013 reporting period 2006–07 to 2010–11. Similarly, the value of wood products harvested annually from native forest in Tasmania declined by $141 million between these two SOFR reporting periods.
  - These changes were due to policy and infrastructure changes in Tasmania in 2013, as well as earlier market changes.
- In 2015–16, Australia harvested a total of 4.1 million cubic metres of native forest logs, 9.8 million cubic metres of plantation hardwood logs, and 16.2 million cubic metres of plantation softwood logs.
- The annual log harvest from plantations, and the contribution of plantations to Australia's total sawlog and pulplog harvest, have both increased steadily since 2000–01. The contribution of plantations to Australia's total sawlog and pulplog harvest reached 86% in 2015–16.
  - Over the period 2000–01 to 2015–16, the annual plantation hardwood pulplog harvest increased from 0.9 million cubic metres to 9.6 million cubic metres.
  - The total sawlog and pulplog harvests from softwood plantations are expected to remain relatively constant over the period from 2015–19 to 2055–59. During the same period, the total sawlog harvests from hardwood plantations are expected to increase, while the total pulplog harvests from hardwood plantations are expected to decrease.

Continued

Continues

Key points

- The national harvest of sawlogs from private native forests has declined progressively since the period 2001–06.
  - Based on ABARES data, the decrease in sawlog harvest from private native forests over the period 2011 to 2016 was 30% in Queensland, 47% in Tasmania, and 71% in New South Wales (the jurisdictions in which the largest volume of sawlogs are harvested from private native forests). The reasons for this decline differ between states, and are not always clear.
- As the supply of high-quality logs from public multiple-use native forests declines, the importance of private native forests for the supply of hardwood logs is predicted to increase.
  - The management intent for private native forests, and their commerciality, will increasingly determine the long-term national supply of high-quality native hardwood logs.
  - There is insufficient information to assess the sustainability of current or predicted future rates of wood harvest from private native forests.

This indicator examines the extent to which a sustainable harvest of wood products is being achieved in native forests, and the availability of future yields of wood products from native forests and plantations. The indicator reports the average annual sustainable yield in multiple-use public native forests, actual annual harvests in multiple-use public[103] and private native forests, projections of sustainable yields from public native forests to 2054, forecast availability of wood products from public and private native forests, and projected future yields from commercial plantations to 2059.

This indicator reports native forest harvesting only for those states where there is significant ongoing native forest harvesting on public and/or private land, namely New South Wales, Queensland, Tasmania, Victoria and Western Australia. Native forest harvesting does not occur in the Australian Capital Territory or South Australia, and at most only a very small volume of commercial harvesting of native forest occurs on public, private or leasehold land in the Northern Territory. Commercial plantation log availability projections are reported using National Plantation Inventory (NPI) regions in Australia (ABARES 2016a).

This indicator also describes the impact of changes in tenure and forest practices on the area of native forest available for the harvesting of wood products. These impacts directly affect the sustainable yields available from native forests and the volumes of wood products harvested.

The main log products harvested from commercial plantations and native forests are sawlogs, sliced and peeled veneer logs (used for wood-based panel products) and pulplogs (used for paper products). Other wood products harvested from commercial plantations and native forests include round and split posts, poles, piles, girders, bush sawn/hewn timber, fuelwood logs and firewood, specialty timber and sleepers. The data presented in this indicator pertain mainly to sawlogs (with logs for sliced veneer generally included in that category) and pulplogs. Sandalwood harvest in Western Australia and Queensland is also considered in this indicator.

Most of Australia's native forest wood products are from multiple-use public native forests, with the remainder from forest on leasehold land, other Crown land and private land. Harvesting in public native forests is subject to regulatory frameworks designed to balance environmental, social and economic values, while maintaining the productive capacity of forests (see Indicators 7.1a and 7.1b). Harvesting on other tenures is subject to state regulatory requirements. Tasmania is the only jurisdiction to publish periodic estimates of wood production from private forests (e.g. PFT 2005).

Sustainable yield from public native forests

The concept of a sustainable level of forest production is that environmental values and the productive capacity of forests are not compromised while providing for society's needs (SOFR 2003); this applies to both wood and non-wood products. Sustainable yield[104] is thus defined as "The yield of products (e.g. wood, water) from an area of forest that ensures that the functioning of the forest ecosystem as a whole is maintained and the flow of products can continue indefinitely under a given management strategy and suite of sustainable-use objectives".

A sustainable timber yield is calculated as the volume of wood (specifically, higher-grade sawlogs) that can be removed each year from an area of forest while ensuring maintenance of the functioning of the native forest system as a whole and the supply of wood products in perpetuity. States in which native forest harvesting on public land occurs have formal processes, backed by a regulatory framework (including legislation, management plans, codes of practice and non-legislative

103 Harvest data for multiple-use public native forests includes harvest data for native forests on other tenures where timber rights are owned by the Crown.

104 Western Australian legislation (*Conservation and Land Management Act 1984*) requires that harvest levels for timber production from State forest and timber reserves in Western Australia are on a 'sustained yield basis'. The Western Australian Regional Forest Agreement (Western Australia and Commonwealth of Australia 1999) defines 'Sustained Yield' as the yield that a forest can produce continuously at a given intensity of management. Sustained yield management implies continuous production planned so as to achieve, at the earliest practical time, a balance between growth increment and cutting within a suite of sustainable use objectives. CCWA (2013) states that sustained yield or sustained timber yield, for the purpose of the *Western Australia Forest Management Plan 2014–2023*, means the first-grade and second-grade sawlog yield (see Table 2.11 for definitions) that the forest can produce for an extended period (to at least the year 2070) at a given intensity of management. Sustained yield as applied in Western Australia, for the purpose of SOFR reporting, is taken to be synonymous with sustainable yield.

policies: see indicators in Criterion 7), that allow calculation of sustainable sawlog yields for publicly managed native forests (primarily multiple-use public forests).

State agencies in New South Wales, Queensland, Tasmania, Victoria and Western Australia that harvest wood from multiple-use public forests have been forecasting sustainable yields and reporting actual harvest levels since the reporting of sustainable yield in SOFR 1998. In the case of Queensland, harvest forecasts and yields include harvest from 'Other Crown land'. The harvesting of wood products from native forests is not permitted in the Australian Capital Territory and South Australia. The Northern Territory has no multiple-use public forests.

The sustainable yield of native forest wood products is thus currently calculated based on the production of high-quality products (generally higher-grade hardwood eucalypt sawlogs, but in New South Wales and Queensland including softwood sawlogs from cypress pine), with the quantity of wood harvested constrained so that future harvesting can occur on a non-declining yield basis. In Western Australia, sandalwood harvesting from forests on Crown and alienated lands[105] is regulated on an 'allowable harvest'[106] basis (DEC 2012b; DPaW 2015b). The harvest of small amounts of sandalwood in Queensland from leasehold land is regulated by a code of practice for native forest timber production (DNPRSR 2014).

High-quality hardwood sawlogs are logs graded to utilisation standards developed and used by state agencies. Native softwood sawlogs are cypress pine sawlogs, and are classed as high-quality or low-quality in New South Wales, and as sawlog-grade in Queensland. High-quality sawlogs in New South Wales were previously known as 'quota' sawlogs. Low-quality sawlogs (or 'non-quota' sawlogs) are sawlogs not included in the high-quality category because they do not meet quality or size specifications. Other hardwood log products include poles, piles, girders and other solid logs. Low-quality sawlogs, pulplogs and other wood products are harvested from native forests, usually as a residual product arising from harvesting for high-quality sawlogs; sustainable yields are generally not determined for these other wood products. Miscellaneous wood products such as firewood, industrial fuelwood, sleeper logs and fencing material form another category of wood product, and can be harvested with or following harvest of high-quality, low-quality and other hardwood products.

Sustainable sawlog harvest volumes are calculated using data on forest type and age-class, standing wood volumes, terrain, accessibility, tree (forest stand) growth and yield, as well as recreational use, water supply, and conservation requirements. The volume of wood available for harvesting is calculated based on the net harvestable area (see Indicator 2.1a), which is the net area of forest available for high-quality sawlog production after areas unavailable for economic, environmental and other reasons have been excluded. Calculations also take into account restrictions on harvesting imposed by codes of practice and other regulations, and risks associated with disease, fire, storm damage and aspects of climate change. Once calculated, sustainable volumes are used to produce harvesting schedules and forecasts of the future spatial and temporal characteristics of forest production.

The substantial transfer of multiple-use public forest to the national reserve system, and specifically to nature conservation reserve tenure, at and after the RFA processes between 1995 and 2005 (Davey 2018a), and subsequently, resulted in many states implementing transitional long-term sustainable wood supply strategies aimed at reducing disruption to the forest industry. These strategies included supplementing the public native forest wood supply with high-quality wood resources from public hardwood plantations, and from the purchase of private forests or logs from private forests. The harvest from public native forests under these long-term supply strategies is considered sustainable because the strategies are designed to maintain the capacity of native forests to produce wood in perpetuity on a non-declining yield basis after a specified transition period.

As sustainable harvest volumes vary over time (due, for example, to changing forest management strategies and utilisation standards, improved resource data, and changes in the net harvestable area of public native forest), calculations are reviewed periodically, usually every 5 to 10 years. Annual harvesting levels will fluctuate around the sustainable volume, with overcuts in some years being balanced by undercuts in other years over a defined period.

National perspective

Table 2.10 reports the proportional change in state and national sustainable yields across the five SOFR reporting periods, compared with the baseline of the first SOFR period (SOFR 1998: 1992–93 to 1995–96).

For the SOFR 2018 reporting period of 2011–12 to 2015–16, the average sustainable yield from multiple-use public native forests declined nationally by 53% from that in the SOFR 1998 reporting period of 1992–93 to 1996–97, with declines between 30% and 75% across the five States (Table 2.10). This decline was due to: transfer of multiple-use public native forests into nature conservation reserves, which reduced the area of native forest available for wood harvesting (see Davidson et al. 2008; the Tasmanian Forest Agreement in 2013 is a further example); increased restrictions on wood harvesting in codes of forest practice; revised estimates of forest growth and yield due to improved information and incorporation of climatic effects; and, especially in Victoria, impacts of occasional, intense broad-scale bushfires (Forests NSW 2010; VicForests 2011b; SOFR 2013). During the reporting periods between SOFR 1998 (1992–93 to 1995–96) and SOFR 2013 (2006–07 to 2010–11), the calculated Tasmanian average sustainable yield increased as a consequence of transitional arrangements involving supplementation with high-quality sawlogs

105 Alienated land is freehold land in Western Australia subject to an agreement relating to the use of that land entered into under the *Land Administration Act 1997* (WA) between the Minister and person who is the holder of the freehold land.

106 'Allowable harvest' equates to the term 'allowable cut', which is the amount of forest product that can be cut in a period. The allowable harvest is specified in the *Sandalwood (Limitation of Removal of Sandalwood) Order (No. 2) 2015*.

Table 2.10: Proportional change in sustainable yields from multiple-use public native forests across SOFR reporting periods, by jurisdiction

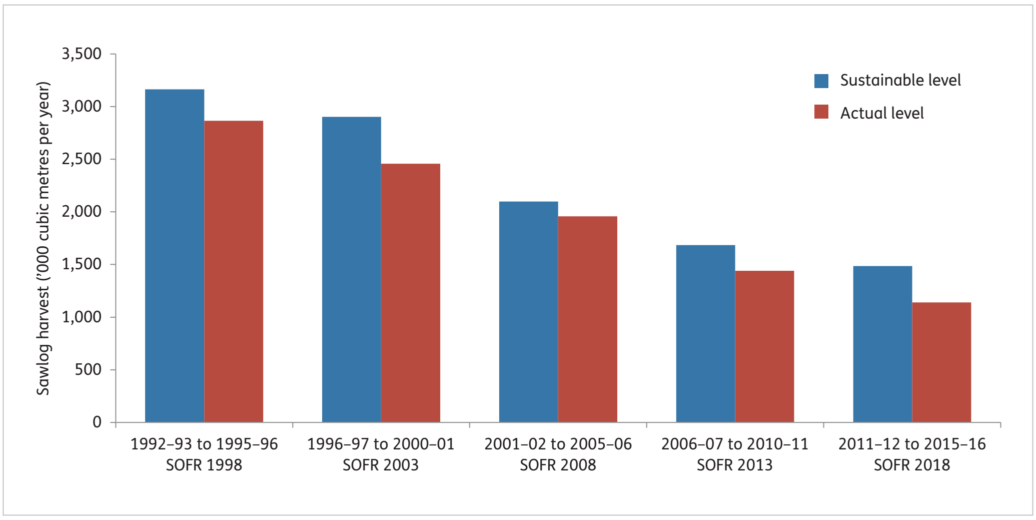
Jurisdiction	Change in sustainable yields from multiple-use public native forests from SOFR 1998 (1992–93 to 1995–96) (%)			
	SOFR 2003 (1996–97 to 2000–01)	SOFR 2008 (2001–02 to 2005–06)	SOFR 2013 (2006–07 to 2010–11)	SOFR 2018 (2011–12 to 2015–16)
NSW	-16	-37	-42	-45
Qld[a]	-11	-14	-37	-45
Tas.	20	17	7	-30
Vic.	-3	-33	-48	-52
WA	-17	-60	-76	-75
Australia	**-8**	**-34**	**-47**	**-53**

[a] Following the 1999 decision by the Queensland government, harvesting of state-owned timber resources changed from a sustainable yield volume basis applied to multiple-use forest, to an allowable cut from Queensland's area available for wood production.

Note: Product groups and standards used in determining sustainable yield are consistent across reporting periods in all jurisdictions.

This table, together with other data for Indicator 2.1c, is available in Microsoft Excel via www.doi.org/10.25814/5bda8a9ed76d5

Figure 2.8: Average annual harvest and sustainable yield for multiple-use public native forests (including other native forests where timber rights are owned by the Crown) in Australia, by SOFR reporting period



Notes:

Sawlog includes only high-quality and sliced veneer hardwood and cypress pine logs.

In all states other than Queensland, yield data apply only to multiple-use public native forests.

The most recent SOFR reporting period includes Queensland's allowable cut estimates as the 'Sustainable level', while the 'Actual level' reports logs harvested from Queensland's 'Defined Forest Area' that includes harvests from leasehold land and freehold land where trees are owned by the State through a forest consent ('profit a prendre') agreement.

SOFR 1998 data includes an updated adjustment applied to Victorian data as a D+ sawlog equivalent. Data for Victoria in all SOFR reporting periods are D+ sawlog equivalent. SOFR 2008 and SOFR 2013 periods contain updated data from CCWA (2012).

Source: ABARES database, state agencies, updated data used in SOFR 2013.

The data used to create this figure, together with other data for Indicator 2.1c, are available in Microsoft Excel via www.doi.org/10.25814/5bda8a9ed76d5

from public hardwood plantations, before reducing in the SOFR 2018 reporting period (2011–12 to 2015–16) due to implementation of the 2013 Tasmanian Forest Agreement.

Figures 2.8–2.13 show the reported harvested volume from multiple-use public native forests, nationally and by jurisdiction, averaged across the periods covered by the five SOFR reports (see Table 2.10). For all states except New South Wales and Queensland, average harvest volumes were lower than the sustainable yields for each of the reporting periods, and in those jurisdictions were within allowable tolerances.

In the SOFR 2018 period 2011–12 to 2015–16, the national average annual volume of high-quality sawlogs harvested from multiple-use public native forests (including other native forests where timber rights are owned by the Crown) was 1.14 million cubic metres. This is a continued and progressive decline from 1.96 million cubic metres in the SOFR 2008 reporting period 2001–02 to 2005–06, and 1.44 million cubic metres in the SOFR 2013 reporting period 2006–07 to 2010–11 (Figure 2.8). The level of actual harvest for 2011–12 to 2015–16 was 23% below the calculated sustainable sawlog yield. The national actual harvest volume from multiple-use public native forests for the four previous SOFR reporting periods was 7–15% lower than the sustainable sawlog yield. The actual harvest volume has decreased over the past five reporting periods in line with the decrease in sustainable yields (Figure 2.8).

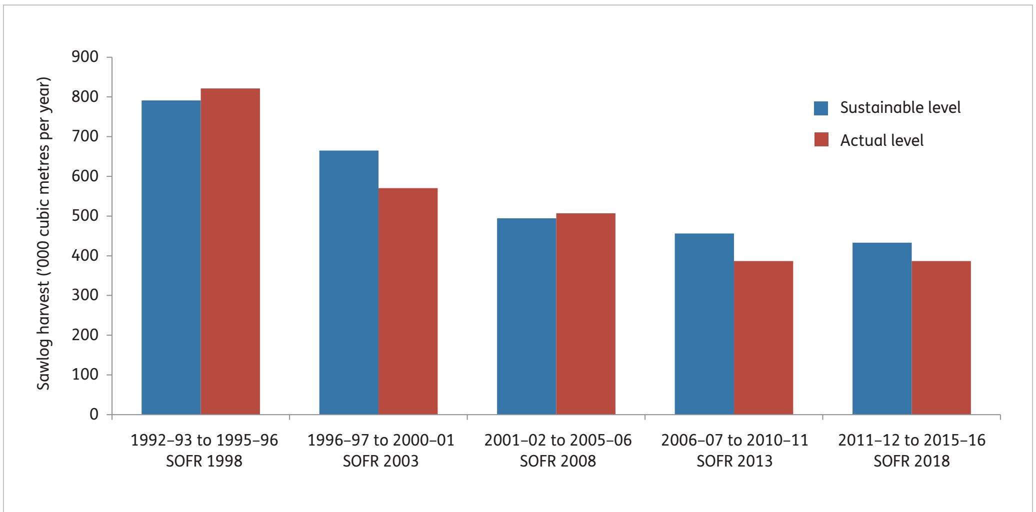
New South Wales

In New South Wales, the actual harvest was slightly higher than the sustainable yield in two of the five SOFR reporting periods (Figure 2.9), but was within allowable limits. Under state wood supply agreements applicable to multiple-use public native forests (Integrated Forestry Operations Approvals, IFOAs), the forest management agency in New South Wales is permitted to vary its actual cut over time: for example, in the Upper North East IFOA, overcuts of up to 5% above the annual allocation of high-quality large sawlogs and large veneer logs can occur in a 4 or 5 year period provided this is balanced by subsequent undercuts so that there is no overall overcut within the approval period.

The sustainable yield from New South Wales public forests for the period 1992–98 was 791 thousand cubic metres of hardwood 'quota' sawlogs and cypress pine sawlogs combined. The figures previously reported in SOFR 2003 and SOFR 2008 from New South Wales for actual logs harvested for the SOFR periods up to 1997–98 included 'non-quota' sawlogs; these figures have now been adjusted to represent only the 'high-quality sawlogs' and cypress pine logs reported after this period, so that log quality is comparable across the five SOFR periods (Figure 2.9)[107].

Forests NSW (2010) forecasted the yields of native forest wood product flows for the state and its regions from 2010 to 2110, and further reductions to sustainable yield were made across 2012–14 for the North East region. An average annual yield of 323 thousand cubic metres of high-quality sawlogs is forecast for multiple-use public forests between 2020 and 2054, but the yield over time is forecast to be uneven. Supplementation from private forests and hardwood plantations is expected to lead to a wood flow that is more even over time. NSW Government (2014) reviewed the wood resources on public forests in north-eastern New South Wales and provided a forecast of high-quality log supply from these forests to 2108.

Figure 2.9: Average annual harvest and sustainable yield for multiple-use public native forests in New South Wales, by SOFR reporting period



Notes:

Sustainable yields are for harvests from multiple-use public native forests, including supplementation from hardwood plantations on multiple-use public forest. Actual harvest levels do not include high-quality logs harvested from hardwood public plantations (see Figure 2.16).

Component figures for hardwood, brushwood (rainforest species), cypress pine and veneer logs from multiple-use public native forests are in 'quota sawlog equivalents' up to 1998–99, and figures for hardwood high-quality large and small sawlog, veneer sawlog and cypress pine from multiple-use public native forests are in 'high-quality equivalents' from 1999–2000. Poles, piles and girders from multiple-use public native forests are included in high-quality equivalents for calculating sustainable yield and reporting actual harvested level from 2006–07.

Source: Data used for SOFR 2013 as amended; Forests NSW, Forestry Corporation NSW and ABARES databases.

The data used to create this figure, together with other data for Indicator 2.1c, are available in Microsoft Excel via www.doi.org/10.25814/5bda8a9ed76d5

107 'Quota' sawlogs are sawlogs of a specified quality and dimension that contribute to the committed volumes outlined in New South Wales Forest Agreements and Integrated Forest Operation Approvals (IFOAs) applying to multiple-use public native forests. 'Non-quota' sawlogs are inferior quality sawlogs that do not contribute to the committed volumes outlined in Forest Agreements and IFOAs. Further explanation of the grade categories used in New South Wales and reported in Figure 2.9 can be found in NSW Government and Office of Environment and Heritage (2011).

Tasmania

A legislated annual minimum yield of 300 thousand cubic metres of 'category 1 and 3' sawlogs from Tasmania's multiple-use public native forest was in place from the first reporting of sustainable yield in 1992, until 2013. The calculated sustainable sawlog yield from Tasmania's multiple-use public native forests was greater than this legislated yield (Figure 2.10; Table 2.10) in line with short-term forest management strategies (Forestry Tasmania 2007) up until 2010–11 (SOFR 2013).

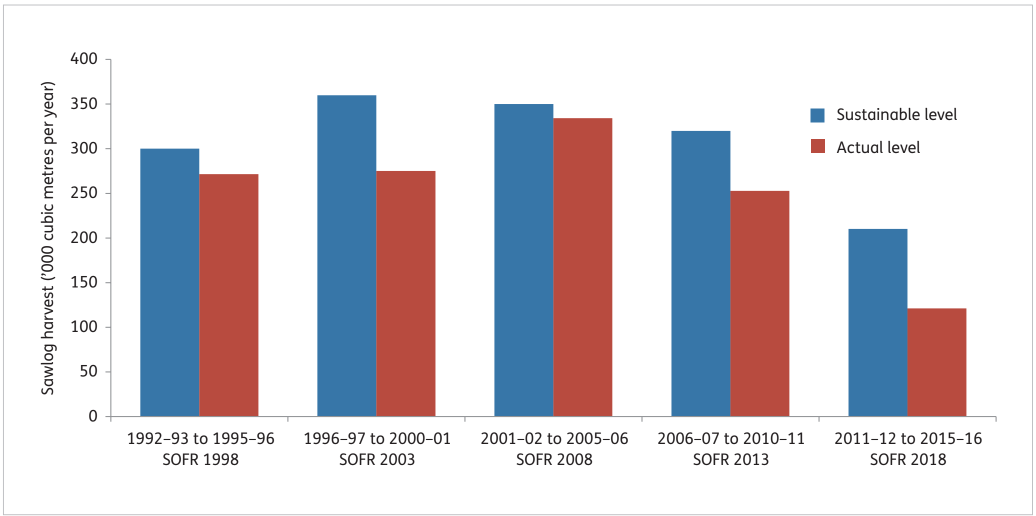
Since the Tasmanian Regional Forest Agreement was signed in 1997, supplementation with high-quality sawlogs from hardwood plantations has formed part of the sustainable wood supply strategy to meet the legislated requirements. In 2002, a non-declining yield for native forest sawlogs of 225 thousand cubic metres was forecast to be maintained after 2020. Following the 2005 Tasmanian Community Forest Agreement, this sustainable yield of native forest sawlogs was reduced to 145 thousand cubic metres after 2023 (Forestry Tasmania 2007). Subsequently, following the 2012–13 Tasmanian Forest Agreement process, a further substantial reduction in net harvestable area available for wood production (Indicator 2.1a) led to the legislated yield of native forest sawlogs being reduced to 137 thousand cubic metres after 2013, and to significant areas of multiple-use public native forest being reclassified as World Heritage Area, reserves and other Crown land (the latter named 'Future Potential Production Forest'; see Indicators 1.1a, 1.1c and 7.1a). As part of modelling for the Tasmanian Forest Agreement process, Burgman and Robertson (2012, p. 72) forecast a 100-year non-declining yield of 97 thousand cubic metres of high-quality sawlogs from native forests alone, for the land-use option adopted under the process.

Forestry Tasmania[108] (2014b) used the outcomes of the Tasmanian Forest Agreement process (including the 2013 World Heritage Area extension) to model the consequences of producing the legislated annual supply of 137 thousand cubic metres of native forest sawlog. The level of supply forecast was 137 thousand cubic metres to 2026, reducing to 100 thousand cubic metres until 2050, then reducing to a non-declining yield of 93 thousand cubic metres before increasing from 2063; high-quality sawlogs from public hardwood plantations were included in the schedule to compensate for the decrease of native forest sawlog after 2026.

As a result of these processes, the average annual sustainable yield of high-quality native sawlog reported in SOFR 2013 was 34% lower than that reported in SOFR 2018 (Figure 2.10). A further reduction would be apparent were the long-term figures for unsupplemented native forest supply to be used for this comparison.

The outcomes of the Tasmanian Forest Agreement process also significantly reduced the access to and supply of Tasmanian special-species timbers (see 'Special-species Timbers' below).

Figure 2.10: Average annual harvest and sustainable yield for multiple-use public native forests in Tasmania, by SOFR reporting period



Notes:
Sustainable yield and actual harvest levels are of category 1 and category 3 sawlogs and veneer logs. Actual harvest levels are from multiple-use public native forest only. Any supplementation from hardwood plantation or other Crown forests is not included in the actual harvest levels.
Source: FPA (2017a), data used in SOFR 2013, Forestry Tasmania annual and sustainability reports.

The data used to create this figure, together with other data for Indicator 2.1c, are available in Microsoft Excel via www.doi.org/10.25814/5bda8a9ed76d5

[108] From July 2017, Sustainable Timber Tasmania.

Victoria

Since the period reported in SOFR 1998, sustainable yields and harvest volumes in Victoria have declined, with harvest volumes remaining less than calculated sustainable yields (Figure 2.11). The major change was that regional forecasts of sustainable yields were reduced following the review by Vanclay and Turner (2001). The Victorian Auditor-General (2013) in reviewing the management of Victoria's native forest resources found that VicForests was harvesting at or within the estimated sustainable harvest level.

During the SOFR 2018 reporting period, management of multiple-use public native forests in eastern and western Victoria was divided between VicForests and the then Department of Environment and Primary Industries until November 2014, when management of western Victorian multiple-use public native forests was transferred to VicForests. Periodic resource outlooks for eastern Victoria have been published by VicForests (2011b, 2013, 2014, 2017), and Bassett et al. (2013) reviewed the expected wood yields from multiple-use public native forests in western Victoria.

Three periods of intense, broad-scale bushfire in eastern Victoria (2002–03, 2006–07, 2009; refer SOFR 2013, Figure 3.9) contributed to the significant decrease in sustainable yield during the SOFR 2013 reporting period 2006–07 to 2010–11. Restrictions on harvesting in mountain ash (*Eucalyptus regnans*) forests imposed following concerns for Leadbeater's possum (*Gymnobelidus leadbeateri*) have resulted in further decreases in sustainable yield during the five-year period to 2015–16. VicForests (2017) forecasts an immediate significant reduction in future sustainable yield (a 29% reduction compared to the resource outlook in VicForests 2011b) from 2017–18 onwards as a consequence of these restrictions associated with Leadbeater's possum.

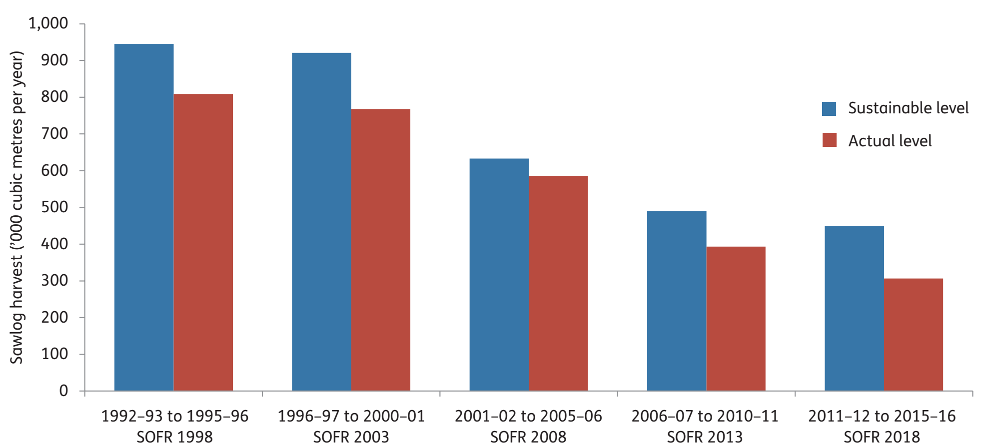
Western Australia

Independent reviews of sustainable yield (Ferguson et al. 2003, 2013) have supported the development of the two 10-year forest management plans in south-west Western Australia (CCWA 2004, 2013) which operated in the SOFR reporting period 2011–2016. These forest management plans require forecasts of the sustainable yield for high-quality jarrah (*Eucalyptus marginata*) and karri (*E. diversicolor*) sawlogs, and incorporate the allowable harvest of these species. The sustainable yield is forecast to increase over the next 50 years (CCWA 2013), subject to management of risk from bushfire, disease and climate impacts.

The current *Forest Management Plan 2014–2023* also specifies upper and lower limits for the allowable cut of both sawlogs and other bole volume for jarrah, karri and marri (*Corymbia calophylla*) (Table 2.11). The lower limit assumes that current industry technologies, practices and constrained markets for lower-grade logs apply throughout the plan, whereas the upper limit provides for potential expansion of silvicultural thinning programs and the development of markets for all lower-grade (non-sawlog) products. The capacity to remove commercially all lower-grade logs made available during the production of high-quality sawlogs, and to promote future sawlog growth (through thinning of regrowth forests), would contribute to forest health, fire management, and climate adaptation outcomes under the plan. Western Australia is the only state that applies principles of sustainable yield to lower grades of logs, including pulplogs, harvested from native forests.

The *Forest Management Plan 2014–2023* specifies an allowable cut for the plan period of first-grade and second-grade jarrah and karri sawlogs of a combined total of 191 thousand cubic metres per annum; this is 12% below

Figure 2.11: Average annual harvest and sustainable yield for multiple-use public native forests in Victoria, by SOFR reporting period



Notes:

Actual harvest levels are from multiple-use public native forest only. Category D+ or equivalent sawlogs are used for the all reporting periods. SOFR 1998 data includes an adjustment applied to Victorian data as a D+ sawlog equivalent (see SOFR 2013).

Source: SOFR 2003, SOFR 2008, SOFR 2013 and Victorian Department of Sustainability and Environment.

The data used to create this figure, together with other data for Indicator 2.1c, are available in Microsoft Excel via www.doi.org/10.25814/5bda8a9ed76d5

Table 2.11: Western Australian average annual allowable cut derived from the sustainable yield for sawlogs (cubic metres per year) for Forest Management Plans 2004–13 and 2014–23

Species/log grade	WA FMP 2004–2013	WA FMP 2014–2023	
		Lower limit	Upper limit[a]
Sustained yield of sawlog			
Jarrah first-grade and second-grade sawlog[b]	131,000	132,000[d]	160,000
Karri first-grade and second-grade sawlog[c]	54,000	59,000[d]	59,000
Total sawlog	**185,000**	**191,000[d]**	**219,000**
Other (non-sawlog) volumes arising[e]			
Jarrah other bole volume	534,000	292,000[f]	521,000[f]
Karri other bole volume	160,000[g]	164,000[f]	164,000[f]
Marri other bole logs	196,000	140,000[f]	254,000[f]

FMP – Forest Management Plan

[a] Upper limit is only accessible through the development of new markets for lower-grade wood products and must be approved by the Western Australian Minister for Environment (CCWA 2013).

[b] First-grade and second-grade jarrah sawlogs are logs cut from the bole of a jarrah (*Eucalyptus marginata*) tree that are a minimum of 2.1 metres in length, have a minimum under-bark diameter of 200 millimetres (first-grade) or 250 millimetres (second-grade), and have a minimum of 50% (first grade) or 30% (second grade) millable timber on the worst end-face. See www.dpaw.wa.gov.au/images/documents/conservation-management/forests/FMP/preparing_FMP_2014-23/timberharvman99.pdf.

[c] First-grade and second-grade karri sawlogs are logs cut from the bole of a karri (*Eucalyptus diversicolor*) tree that are a minimum of 2.4 metres in length, have a minimum under-bark diameter of 300 millimetres, and have a minimum of 50% (first grade) or 30% (second grade) millable timber on the worst end-face. See www.dpaw.wa.gov.au/images/documents/conservation-management/forests/FMP/preparing_FMP_2014-23/timberharvman99.pdf.

[d] Annual sustainable yields (sustained yield) of 146 thousand cubic metres for jarrah and 70 thousand cubic metres for karri (combined total 216 thousand cubic metres) based on standard silvicultural outcomes, sawlog utilisation and current markets were computed as the yields able to continue indefinitely. The average 'allowable' sustainable yield (allowable cut) is the sustained yield adjusted applying a 'safety margin' for first-grade and second-grade sawlog volume of 10% for jarrah and 15% for karri as recommended in Ferguson et al. (2013). The combined total allowable cut of 191 thousand cubic metres is 12% below the calculated sustainable yield of 216 thousand cubic metres.

[e] Bole log is a log extracted from the tree trunk between the ground and the crown break. Bole volume is the volume of a bole log. Other bole volume is the volume of bole log products not meeting first-grade or second-grade sawlog standards (CCWA 2013).

[f] The supply of lower-grade wood products arising as a consequence of sawlog sustained yields after application of a 'safety margin' for non-first-grade and non-second-grade sawlog volume of 10% for jarrah and 15% for karri as recommended in Ferguson et al. (2013). The figure for marri includes marri sawlogs resulting from jarrah and karri harvesting

[g] The Western Australian *Forest Management Plan 2004–13* (CCWA 2004) was amended on 1 November 2011, backdated to the commencement of the Plan, to allow the other bole yield of karri to increase from 117 thousand to 160 thousand cubic metres per year.

Source: CCWA (2004, 2013)

This table, together with other data for Indicator 2.1c, is available in Microsoft Excel via www.doi.org/10.25814/5bda8a9ed76d5

the combined forecast sustainable sawlog yield for karri and jarrah (CCWA 2013; Table 2.11 footnotes). The setting of an allowable cut lower than the projected sustainable yield made provision for possible future impacts of unforeseen bushfire, drought or disease events that could not be readily modelled in the sustained yield calculations.

The calculated sustainable yield and actual harvest yield of sawlogs from multiple-use public forests in Western Australia (Figure 2.12) declined significantly after the 1999 Western Australian Regional Forest Agreement and again after adoption of the *Forest Management Plan 2004–2013* (CCWA 2004). Sustainable yield calculated in the *Forest Management Plan 2004–2013* for first-grade and second-grade jarrah and karri sawlogs was 185 thousand cubic metres per annum (Table 2.11) reported in SOFR 2008. Sustainable yields have stabilised over the subsequent two SOFR reporting periods (2006–07 to 2010–11, and 2011–12 to 2015–16).

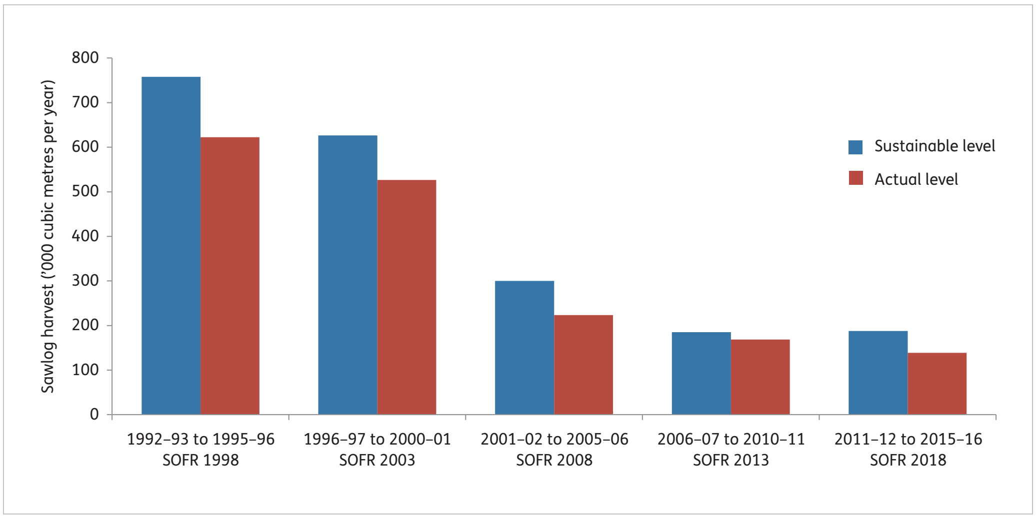
Queensland

In 1999, the Queensland government concluded an agreement with environmental and industry stakeholders to a 25-year transition period during which wood harvesting would be phased out from public native forests in the state's south-east, its major wood-producing area, with these forests to subsequently be gazetted as protected area tenures. The policy implemented in the agreement envisaged that future wood resource would be derived from newly established hardwood plantations and improved management of private native forests in south-east Queensland.

The Queensland government has also made a series of successive decisions on future harvesting levels and on nature conservation reserve areas in other areas of the State. These decisions resulted in the exclusion of harvesting from further areas of public native forests, although many areas were returned to the available harvest area in 2012 with a change in the Queensland government. These decisions are reflected in Figure 2.13, which shows a sustainable yield volume to 1999 and an allowable cut after this date. Queensland Government (1998) described the systems used to forecast sustainable yield before 1999. Wood harvest volumes have declined over all SOFR reporting periods, and remained close to the sustainable yield and allowable cut levels.

Native forest resource in Queensland continues to be made available under long-term wood supply agreements. The area available for wood production by the Crown comprises all State Forest and Timber Reserves, large areas of other Crown land (including leasehold land, Forest Entitlement Areas and unallocated state-owned land) and some freehold land over which the state retains ownership of forest products.

Figure 2.12: Average annual harvest and sustainable yield for multiple-use public native forests in south-west Western Australia, by SOFR reporting period



Notes:

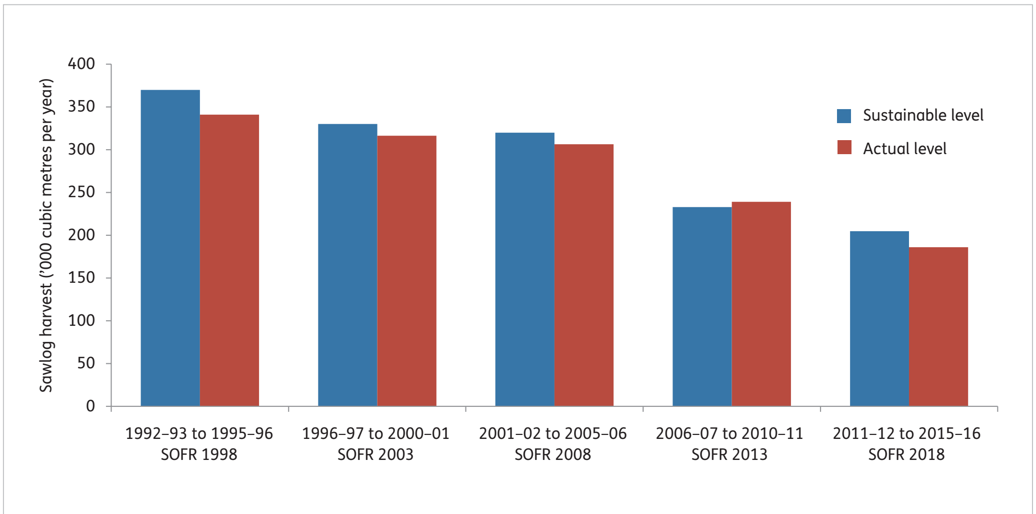
Sustainable yield and actual harvest levels are of first-grade and second-grade karri and jarrah sawlogs (see Table 2.11 for definitions) from forests regulated under the relevant Forest Management Plan (CALM 1994; CCWA 2004, 2013). SOFR 2008 and SOFR 2013 periods contain updated data from CCWA (2012).

Under each Forest Management Plan the annual harvest can exceed the average annual allowable cut in some years but must not, over the ten-year period of the plan, exceed the cumulative total allowable cut. Key performance indicators associated with the plans set the maximum amount by which the annual cut can exceed the average allowable cut: for the *Forest Management Plan 2004–2013* it was 10%; for the *Forest Management Plan 2014–2023* a progressive scaling down was introduced of 10% at year 3, 5% at year 6, and 3% at year 9.

Source: DEC 2012b, SOFR 2003, SOFR 2008, CCWA (2012), Department of Parks and Wildlife, and Department of Biodiversity, Conservation and Attractions.

The data used to create this figure, together with other data for Indicator 2.1c, are available in Microsoft Excel via www.doi.org/10.25814/5bda8a9ed76d5

Figure 2.13: Average annual harvest and allowable cut for state-owned native forests in Queensland, by SOFR reporting period



Notes:

Sustainable yield figures apply to 1999. After that date, figures are 'Allowable cut'.

Data are for hardwood and cypress pine sawlogs; other log categories (e.g. poles, fencing, sleeper and mining timber) are excluded.

Data for the SOFR 2018 period include an adjustment in 2012–13 to an allowable cut applying to Queensland's area for wood production, and actual levels include timber harvested from leasehold land and freehold land where trees are owned by the State through a forest consent agreement (a 'profit a prendre' agreement).

Sources: Queensland Department of Agriculture and Fisheries, SOFR 2003, SOFR 2008, SOFR 2013.

The data used to create this figure, together with other data for Indicator 2.1c, are available in Microsoft Excel via www.doi.org/10.25814/5bda8a9ed76d5

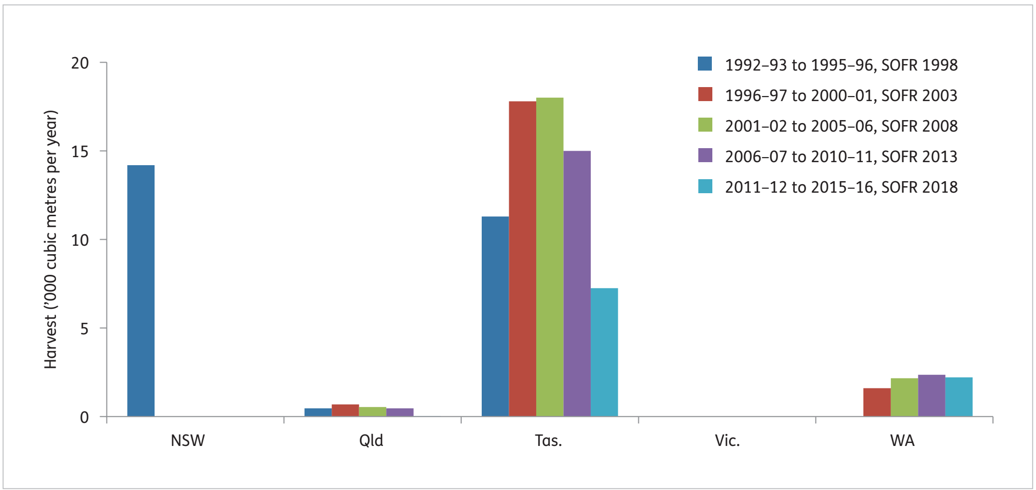
Special-species timbers and sandalwood

Figure 2.14 reports the average annual volumes of special-species timbers harvested from public native forests, by jurisdiction, for the five SOFR reporting periods. These volumes include sandalwood reported from Queensland and Western Australia. Harvesting of logs designated as cabinet rainforest timbers in New South Wales ceased after 1992–93 and no special-species sawlogs have been harvested in that state since that date. Tasmania has been the main source of special-species timbers nationally; a list of special-species timbers in Tasmania is presented in Table 2.12.

Tasmanian special-species timbers make an important contribution to the Tasmanian economy (DSG 2017). A strategy to sustain long-term production of Tasmanian special-species timbers (myrtle, blackwood, sassafras and various native pines) from public native forests was implemented in 2010 (Forestry Tasmania 2010). This was based on sustainable yield estimates, and included supply targets for the 10-year period to 2019 of 10,000 cubic metres per annum of blackwood and 500 cubic metres per annum of other special-species timbers (Table 2.12).

The 2013 Tasmanian Forest Agreement process led to a reduction in the public native forest production estate, and a reduction in the annual harvest of special-species timber sawlogs (Figure 2.14). Forestry Tasmania (2013b) reviewed the sustainable supply of Tasmanian special-species timbers from public native forest. Forestry Tasmania (2015b) then presented recalculated supply levels for category 4/utility sawlogs of special species timber from the Permanent Timber

Figure 2.14: Average annual harvest volumes of special-species timbers from multiple-use public native forests, by SOFR reporting period



Notes:

Special-species timbers include cabinet rainforest timbers (New South Wales) until 1992–93, Tasmanian special-species timbers, and sandalwood (Queensland and Western Australia: cubic metre equivalent converted from tonnes).

Figures for Tasmanian special-species timbers only include millable sawlogs (category 4/utility sawlogs) and exclude non-specification logs and craftwood.

Source: ABARES databases, state agencies.

The data used to create this figure, together with other data for Indicator 2.1c, are available in Microsoft Excel via www.doi.org/10.25814/5bda8a9ed76d5

Table 2.12: Annual log supply, Tasmanian special-species timbers, 2009–2019

Special-species timbers	Supply (cubic metres)
Blackwood (*Acacia melanoxylon*)	10,000
Silver wattle (*A. dealbata*)	500
Myrtle (*Nothofagus cunninghamii*)	500
Sassafras (*Atherosperma moschatum*)	500
Celery-top pine (*Phyllocladus aspleniifolius*)	500
Huon pine (*Lagarostrobos franklinii*)	500
King Billy pine (*Athrotaxis selaginoides*) and other species, including figured eucalypt (*Eucalyptus* spp.)	No volume target – arisings only[a]

Includes 'category 4' sawlogs and 'utility' logs.

[a] Arisings refer to logs produced as a result of planned harvest of other species or log grades.

Source: Forestry Tasmania (2010).

This table, together with other data for Indicator 2.1c, is available in Microsoft Excel via www.doi.org/10.25814/5bda8a9ed76d5

Production Zone managed by Forestry Tasmania, based on resource estimates of special-species timber found in areas for which preliminary harvest plans had been prepared and on application of sustainable yield principles. Updated supply levels were presented for blackwood (4,275 cubic metres per annum for the period 2015–2016 to 2026–2027, and 3,095 cubic metres per annum after 2027) and for other special-species timbers (a total across all other species of 560 cubic metres per annum for the period 2015–2016 to 2026–2027, and 285 cubic metres per annum after 2027). Forestry Tasmania (2017) and *The Tasmanian Special Species Management Plan* (DSG 2017) covered access to the Permanent Timber Production Zone as well as other land management categories and tenures.

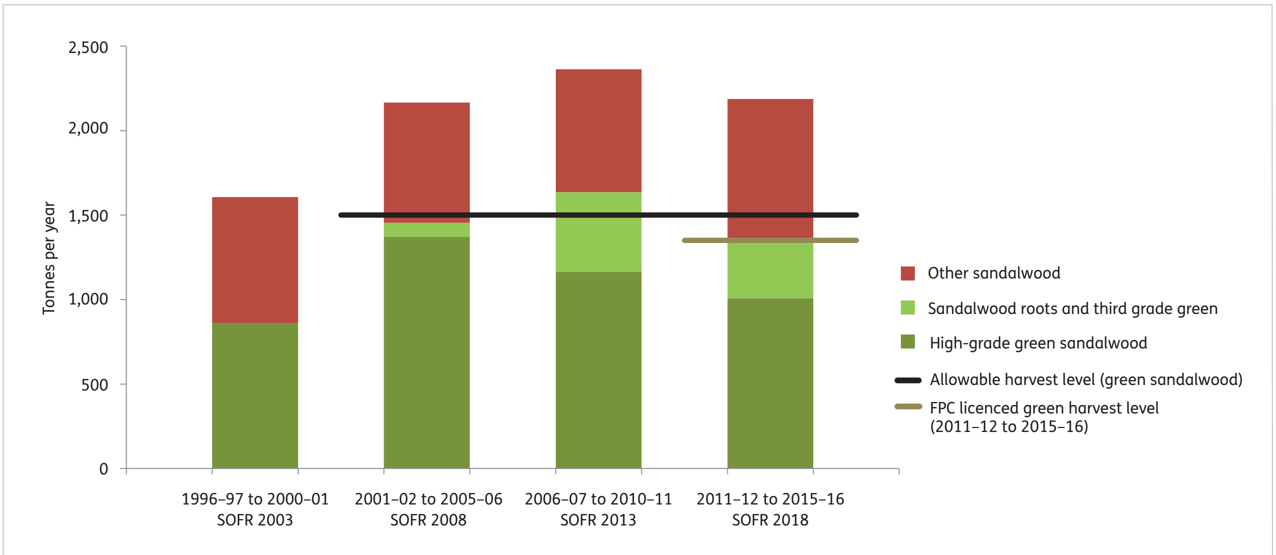
In Western Australia, harvests of wild-collected Australian sandalwood (*Santalum spicatum*) comprise high-grade and low-grade green[109] sandalwood, root, bark and dead sandalwood under licence from public and private lands. The total annual allowable harvest level of green sandalwood to 2016 was 1,500 tonnes per annum, of which the Forest Products Commission (FPC) was licenced to remove 1,350 tonnes per annum. Figure 2.15 reports the harvest of sandalwood by the FPC from Western Australian public native forest by SOFR reporting period. The allowable harvest level applies to high-grade green sandalwood, third-grade green sandalwood and sandalwood root, and does not include 'Other sandalwood'. Bark and dead material are included in the 'Other sandalwood' figures. Green (live) sandalwood trees produce more oil than dead trees and consequently have a higher commercial value.

Since 2006, improved harvesting techniques have resulted in greater utilisation of third-grade and sandalwood root products. These products were previously not able to be processed efficiently and were not included in total production. From 1 July 2016, a reduced annual harvest quota of 1,250 tonnes of green sandalwood and 1,250 tonnes of dead sandalwood has been set, of which 1,125 tonnes of green sandalwood is licenced to the FPC. This revised quota applies until 2026, when sandalwood plantations (including almost 6,000 hectares of public plantations and 20,000 hectares of private plantations) is expected to begin to contribute to the supply of sandalwood (DPaW 2015b; FPC 2016).

Supplementation from hardwood plantations

Sustainable yield estimates of high-quality sawlogs from multiple-use public native forests in New South Wales and Tasmania include supplementation with sawlogs of similar quality from public hardwood plantations. The supplementary component of sustainable yield estimates is based on projected yields of high-quality sawlogs from these plantations. The extent of supplementation is currently very small for Tasmania, but supplementary quantities of high-quality hardwood sawlogs are forecast to increase in New South Wales and Tasmania after 2025 (Forests NSW 2010, Forestry Tasmania 2014b).

Figure 2.15: Average annual harvest by the Forest Products Commission of Western Australian sandalwood from public native forests, by SOFR reporting period



Notes:
No data are available for SOFR 1998 reporting period 1992–93 to 1995–96.
Bark and dead material are included in 'Other sandalwood'.
Source: Western Australian Forest Products Commission annual reports.

The data used to create this figure, together with other data for Indicator 2.1c, are available in Microsoft Excel via www.doi.org/10.25814/5bda8a9ed76d5

109 Green sandalwood is live sandalwood that meets minimum specified size and quality specifications and includes all grades including live root material.

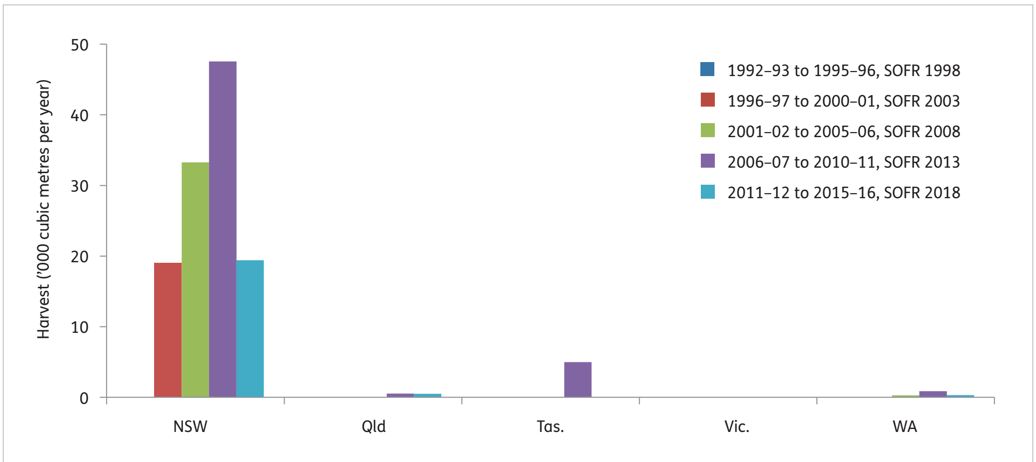
Figure 2.16 shows the average annual yield of high-quality hardwood sawlogs harvested from public plantations, by jurisdiction, for the five SOFR reporting periods. To date, the plantation sawlog yield in every state except for New South Wales has been small compared with the multiple-use public forest sawlog yield from the same jurisdiction. In New South Wales, high-quality hardwood sawlogs have been harvested from public plantations since 1997–98, and the north-eastern region of the state, in particular, contains older plantations available for harvest. Small amounts of high-quality sawlogs from plantations are becoming available in Tasmania and Western Australia.

Sawlog yields from private native forests

There is no calculated sustainable yield for wood production from native forests on private land across Australia, and there is insufficient information nationally to assess whether the current or future rate of wood harvest from private native forests is sustainable. However, increasing regulatory restrictions on harvesting operations on private land in all states have led to a reduction in wood harvest volumes from private forests. In practice, most private forest managers make limited use of their native forests for wood production, and respond only to immediate needs and opportunities in the market (Commonwealth of Australia 2016b). Thompson and Connell (2009) and Jay et al. (2009) provide a review of the issues confronting sustainable private native forests in Australia and particular regions.

For all SOFR periods, the supply of sawlogs from private native forests has been significant in New South Wales, Queensland and Tasmania, and comparatively small in Victoria and Western Australia, with the Northern Territory reporting sawlog production in only one period (Figure 2.17). The harvesting of sawlogs from private native forests has not been permitted in the Australian Capital Territory or South Australia since SOFR reporting begun. Based on ABARES data, the harvest of sawlogs from private native forests has decreased steadily in Queensland and Tasmania since the SOFR 1998 reporting period 1992–93 to 1995–96, and since the SOFR 2013 reporting period has declined by 30% in Queensland, by 47% in Tasmania, by 71% in New South Wales and by 80% in Western Australia (Figure 2.17). The decline in sawlog production in Tasmania was associated with the decline in pulplog production, as sawlog production is not profitable without the grower also being able to access pulplog markets; the decline in pulplog production resulted from overseas market changes and from reduced access to pulplog export facilities. A possible driver for the decline in New South Wales and Queensland has been increased regulatory requirements applying to private landowners, although it is also possible that a proportion of the private native sawlog harvest in New South Wales is not captured in these data. The decline in Western Australia reflects the episodic nature of the harvest of private native forests in the south-west of the state. The sawlog harvest from private native forest in Victoria increased during the SOFR 2018 reporting period but is a relatively small volume.

Figure 2.16: Average annual harvest of high-quality hardwood sawlogs from public plantations, by SOFR reporting period



Notes:

Plantation high-quality sawlogs are assessed against jurisdictional quality and size specifications for similar products from native forest. These specifications are similar between states.

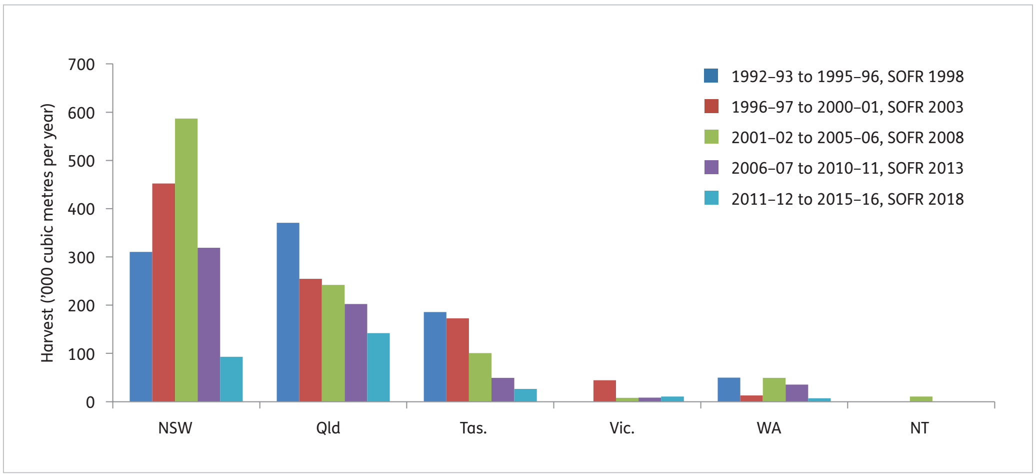
No high-quality sawlogs were produced from plantations in the first reporting period (SOFR 1998).

Victoria has reported no production of high-quality sawlogs from public plantations in all SOFR periods.

Source: ABARES databases, state agencies.

The data used to create this figure, together with other data for Indicator 2.1c, are available in Microsoft Excel via www.doi.org/10.25814/5bda8a9ed76d5

Figure 2.17: Average annual sawlog harvest from private native forests, by SOFR reporting period



Notes:

Sawlogs harvested from private forests include high-quality and low-quality hardwood sawlog, hardwood 'veneer sawlog' and cypress pine sawlog.

Data are unavailable for the 1992–93 to 1995–96 reporting period for Northern Territory and Victoria.

Data for Tasmania and Western Australia are incomplete for this period.

No sawlogs are harvested from private native forests in the Australian Capital Territory or South Australia.

Source: ABARES databases, state agencies.

The data used to create this figure, together with other data for Indicator 2.1c, are available in Microsoft Excel via www.doi.org/10.25814/5bda8a9ed76d5

PFT (2005) previously estimated wood supply from private native forest in Tasmania, but that estimate is no longer current. Dare and Eversole (2013) report the future harvesting intent of Tasmanian non-industrial private forest owners, while Wilson (2012) provides some updated forest inventory data for private forests in Tasmania.

A 2009 national assessment of the role, value and potential of private native forests (Parsons and Pritchard 2009) estimated the contribution of private native forests to regional wood supply at a state level. There has been no similar national assessment of private native forests since 2009. The assessment by Parsons and Pritchard (2009) found that, despite adequate information on the area of private native forests, little information is available on their quality, condition, value, current management regime and future management intent. It also found that, although a proportion of landowners (varying by region) want to manage their forests to provide wood and other products and services in the long term, there is insufficient information nationally and regionally to assess whether the rate of wood harvest from private native forests is sustainable. These limitations on information continue to remain an impediment regionally and nationally for regional forest industry planning (Burns et al. 2015). However, the contribution to regional economies, communities and industry that can be made by harvesting wood products from private native forest was recognised in Commonwealth of Australia (2015, 2016a).

Jay et al. (2009) and Thompson and Connell (2009) discuss the sustainability of forestry on private native forests in northern New South Wales, and more broadly in Australia. An assessment of the sustainability of wood supply from private forests in north-east New South Wales (EPA 2013a) found that, over time, the quality of the wood resource from private native forests in the region would decline due to selective harvesting of high-quality trees and the failure to apply silvicultural practices to maintain and promote future high-quality sawlog resources.

Pulplogs from public and private native forests

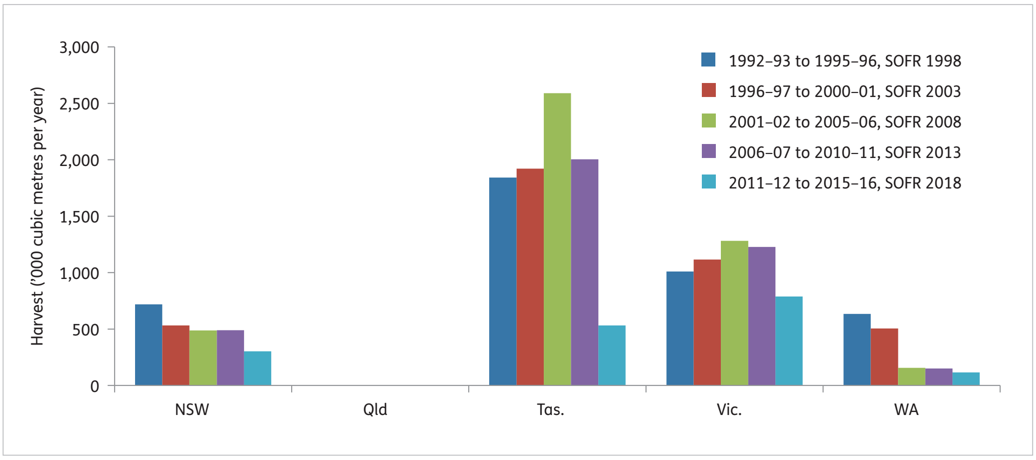
Sustainable wood yields on public land are calculated based on the production of high-quality sawlogs and veneer logs (logs for production of sliced veneer). Pulplogs, together with low-quality sawlogs and other wood products, are usually a residual product of sawlog and sliced veneer log harvesting, and sustainable yields are not determined specifically for pulplogs, peeler logs (logs for production of peeled veneer) or other wood products (an exception is the treatment of bole logs in Western Australia, see above).

During the SOFR 2018 reporting period 2011–12 to 2015–16, the volume of pulplogs harvested from multiple-use public native forests decreased substantially in Tasmania (73%) and significantly, but to a lesser extent, in New South Wales (38%), Victoria (36%) and Western Australia (24%), compared to the SOFR 2013 reporting period 2006–07 to 2010–11 (Figure 2.18). No pulplogs have been harvested from public native forests in Queensland since the SOFR 2003 reporting period of 1996–97 to 2000–01, and Queensland export of native forest woodchips ceased from Queensland forests in 1997–98.

While Tasmania has historically been Australia's major provider of pulplogs from private native forests, harvest volumes from this source decreased by 90% in the SOFR 2018 reporting period (Figure 2.19). The decreases in pulplogs harvested from both multiple-use public native forest (Figure 2.18) and private native forest (Figure 2.19) in Tasmania during the SOFR 2018 reporting period were due to changes in overseas markets, policies associated with the 2013 Tasmanian Forest Agreement process, reduced access to pulp wood export facilities, and cessation of harvesting on some large private forest estates.

Pulplogs harvested from private forests decreased in New South Wales (74%) and Victoria (41%) in the SOFR 2018 reporting period; and increased slightly in Western Australia. No pulplogs have been harvested from private native forests in Queensland or the Northern Territory in any of the SOFR reporting periods.

Figure 2.18: Average annual pulplog harvest from multiple-use public native forests, by SOFR reporting period



Notes:

Pulplog includes logs sold for pulp or equivalent, and for woodchip.

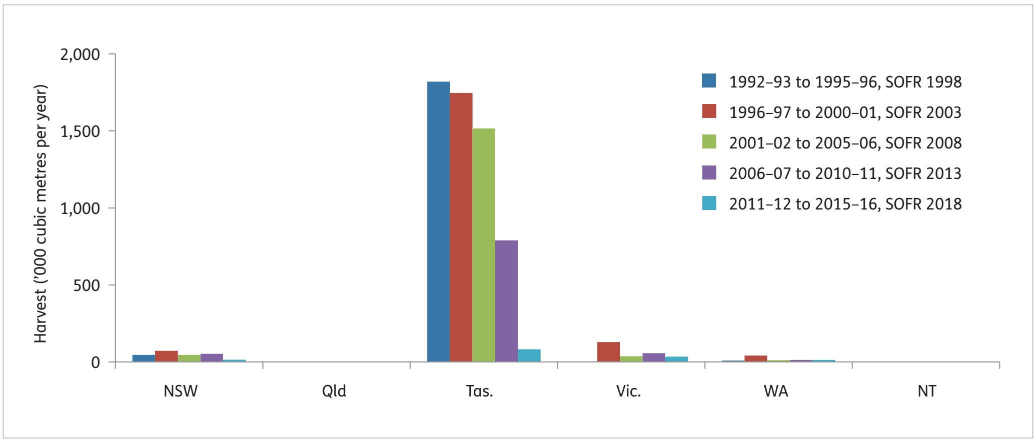
Data have been converted from tonnes to cubic metres. There was a very small amount of pulplog harvest reported for the 1992–93 to 1995–96 reporting period for Queensland, but none for subsequent reporting periods.

Data previously unavailable for the 1992–93 to 1995–96 reporting period for Tasmania are now included.

Source: ABARES databases, state agencies.

The data used to create this figure, together with other data for Indicator 2.1c, are available in Microsoft Excel via www.doi.org/10.25814/5bda8a9ed76d5

Figure 2.19: Average annual pulplog harvest from private native forests, by SOFR reporting period



Notes:

Data are unavailable for the 1992–93 to 1995–96 reporting period for all states and territories other than New South Wales and Tasmania, and limited data are available for Western Australia for this period.

Data have been converted from tonnes to cubic metres. Pulplog includes logs sold for pulp or equivalent, and for woodchip.

Source: ABARES databases, state agencies.

The data used to create this figure, together with other data for Indicator 2.1c, are available in Microsoft Excel via www.doi.org/10.25814/5bda8a9ed76d5

Other wood products

The supply of other wood products, such as low-quality sawlogs, girders, poles, piles, other logs that are not sawlogs or pulplogs, as well as wood used in mines, split and round posts, bush sawn/hewn timber and sleepers (but excluding fuelwood logs and firewood), varies by jurisdiction. In multiple-use public native forests, harvesting is often opportunistic and can occur in association with harvesting of high-quality sawlogs and pulplogs, as a follow-up to high-quality wood product harvesting, or be confined to low-volume or non-sawlog areas suiting the production of these other wood products. These products are a major resource in New South Wales, Tasmania and Victoria. Figure 2.20 shows average annual harvest volumes for these products from multiple-use public native forests, by jurisdiction. Limited data are available on harvest rates for these products from private forests. Fuelwood and firewood are treated separately from these products, and are discussed separately below[110].

National overview of wood and wood products from native forests

This section presents information at the national level and discusses trends on the volume and value[111] of wood and wood products from native forests.

The quality of SOFR 1998 data on the harvesting of wood products was limited in terms of data accuracy, consistency and completeness, and was only adequate for the harvest of sawlogs. The *Australian Forest and Wood Product Statistics* (AFWPS) series, published by ABARES and its precursors, and available from 1996–97 and thus covering the last four SOFR reporting periods, provides data of better quality on the types, volume and value of wood products harvested from native forests. The AFWPS series provides data on four wood and wood product categories: total wood products, sawlogs and peeler logs, pulplogs, and other log products (which includes fuelwood logs and firewood).

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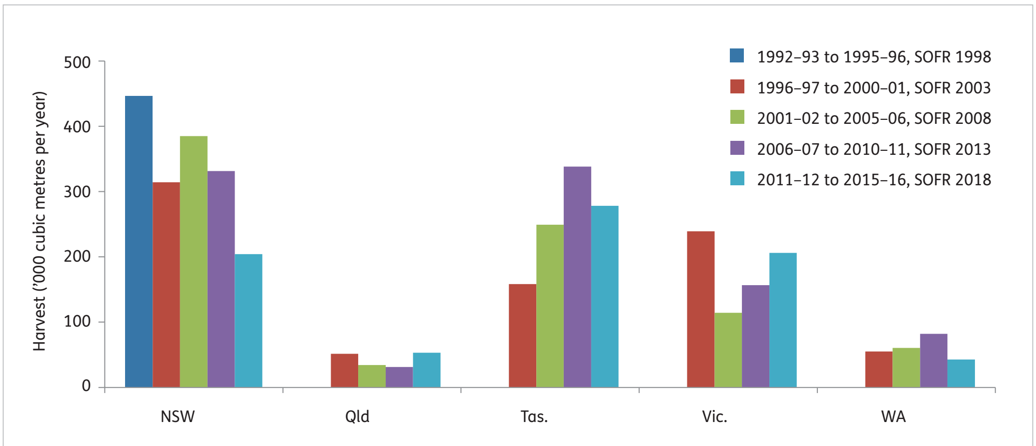
Figure 2.20: Average annual harvest of 'other wood products' from public native forests, by SOFR reporting period



Notes:

Data are unavailable for the SOFR 1998 reporting period 1992–93 to 1995–96 for all states other than New South Wales. Figures for all periods are from native multiple-use public forests for all states, except for Queensland in the SOFR 2018 period, which relate to Queensland's Defined Forest Area and include timber harvested from leasehold land and freehold land where trees are owned by the State through a forest consent ('profit a prendre') agreement.

'Other wood products' are products that are not included under high-quality sawlogs and veneer logs, special-species timbers or pulplogs; they include lower grades of sawlog and peeler logs but not firewood and fuelwood.

Poles, piles and girders are included other than in New South Wales where these products are reported as high-quality sawlogs (Figure 2.9).

Source: ABARES databases, state agencies.

The data used to create this figure, together with other data for Indicator 2.1c, are available in Microsoft Excel via www.doi.org/10.25814/5bda8a9ed76d5

110 "Other wood products" excludes fuelwood logs and firewood, whereas "Other log products" includes fuelwood logs and firewood.

111 Data for log value represent the value as received at the mill door.

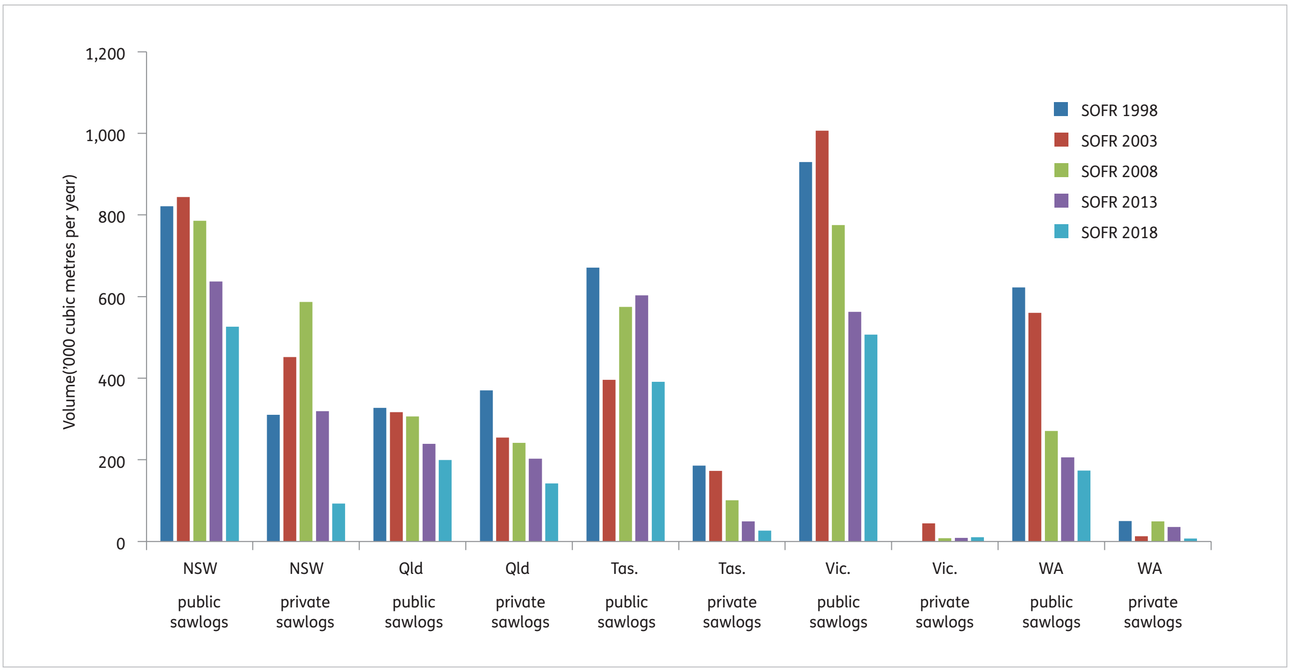
Figure 2.21 presents the average annual volume of sawlogs harvested from public and private native forests by jurisdiction across the five SOFR reporting periods. Sawlog harvest occurred in public and private native forests in New South Wales, Queensland, Tasmania, Victoria and Western Australia during these reporting periods. In addition to the significant supply from multiple-use public forests, private native forests have been an important source of sawlog supply in New South Wales, Queensland and Tasmania, but a relatively minor source in Victoria and Western Australia.

In the Northern Territory, small volumes of wood products were harvested from private native forests (primarily from Indigenous owned private land) during the SOFR 2008 reporting period 2001–02 to 2005–06. Sales of commercial sawlogs were recorded in the Northern Territory for this period at an annual average of 11 thousand cubic metres (Figure 2.17), with a high of 25 thousand cubic metres in 2005–06, but no commercial sales have been recorded in other SOFR reporting periods. There is no harvesting of wood and wood products on public forest tenures in the Northern Territory.

Commercial harvesting of wood products from native forests is not permitted in the Australian Capital Territory and South Australia.

Figure 2.22A–D and Figure 2.23A–D show the average annual volume and value, respectively, of wood and wood products from native forests for the SOFR 2003, SOFR 2008, SOFR 2013 and SOFR 2018 reporting periods, separately for five states. The four panels in each figure show respectively total native forest production, production of sawlog and peeler logs, production of pulplogs, and production of other log products.

Figure 2.21: Average annual volume of sawlogs harvested from public and private native forests, by SOFR reporting period



Notes:

Public and private sawlogs are reported based on public or private ownership of the extracted wood, noting that ownership of wood on leasehold land can vary within and across jurisdictions.

Public sawlogs include sawlogs extracted from multiple-use forests, other Crown land, Commonwealth land and leasehold forest where the Crown owns the timber rights. All sawlogs harvested from private land are treated as private sawlogs, including those harvested to supplement public forest harvest.

Sawlogs harvested from public and private native forests include high-quality and low-quality hardwood sawlog, hardwood 'sliced veneer sawlog' and cypress pine sawlog.

Peeler logs, poles, girders and piles are not included in the figures.

Data are unavailable for the SOFR 1998 reporting period 1992–93 to 1995–96 for private forest sawlogs in Victoria, and data for Tasmanian and Western Australia private forests in the SOFR 1998 reporting period was incomplete.

No sawlogs are harvested from public and private native forests in the Australian Capital Territory or South Australia. Sawlog production from private forests in the Northern Territory is minimal (see Figure 2.17).

Source: ABARES databases, state agencies.

The data used to create this figure, together with other data for Indicator 2.1c, are available in Microsoft Excel via www.doi.org/10.25814/5bda8a9ed76d5

Nationally, the annual average volume of wood products harvested from native forests fell from 10.4 million cubic metres during the SOFR 2003 reporting period to 4.4 million cubic metres during the SOFR 2018 reporting period (a 58% decrease). This fall was due primarily to a decrease in the national average annual pulplog harvest, from 6.1 million cubic metres in the SOFR 2003 reporting period, to 1.9 million cubic metres in the SOFR 2018 reporting period (a 69% decrease). The national average annual sawlog harvest (including peeler logs) fell from 4.1 million cubic metres in the SOFR 2003 reporting period, to 2.1 million cubic metres in the SOFR 2018 reporting period (a 48% decrease).

During the SOFR 2003, SOFR 2008 and SOFR 2013 reporting periods, the state with the highest national average total volume and value of wood products from native forests was Tasmania, with 41–47% of total national volume, and 35–39% of total national value (Figures 2.22a, 2.23a). These high levels were due primarily to the production of high pulplog volumes associated with the harvesting of sawlogs in Tasmania.

Outcomes of both the Tasmanian Forest Agreement process in 2013, and the consequent 2013 World Heritage Area extension, as well as disruption in the markets for exports of pulpwood (pulplogs and woodchips) from Tasmania, and changes in the management of major private forest estates, resulted in significant declines in the volume and value of wood products from native forests in Tasmania during the SOFR 2018 reporting period 2011–12 to 2015–16. The total average annual volume of wood products harvested in Tasmania was 3.5 million cubic metres during the SOFR 2013 reporting period 2006–07 to 2010–11, and decreased to 1.1 million cubic metres in the SOFR 2018 reporting period. The average annual value of wood products harvested in Tasmania was $213 million during the SOFR 2013 reporting period, and decreased to $72 million in the SOFR 2018 reporting period. Policy, market and management intent changes in Tasmania during 2013 therefore contributed to an average annual volume reduction of 2.4 million cubic metres and an annual average value reduction of $141 million in harvested wood products from native forest, between the SOFR 2013 and SOFR 2018 reporting periods.

Nationally, over the four SOFR reporting periods, the highest sawlog harvest volume was in New South Wales, followed by Victoria. Together, these jurisdictions accounted for more than half of the total sawlog volume harvested from native forests in all four SOFR reporting periods.

Except for Tasmania, sawlog harvests generally decreased across consecutive SOFR periods (Figure 2.21). In Tasmania, the sawlog and peeler harvest increased from the SOFR 2003 reporting period across the two subsequent SOFR reporting periods (SOFR 2008 and SOFR 2013), then decreased to below the SOFR 2003 level.

Tasmania and Victoria harvest the majority of native forest pulplogs in Australia. Taken together, these two states accounted for more than 80% of the national average annual pulplog harvest in the SOFR 2003, SOFR 2008 and SOFR 2013 reporting periods, and 77% of the national average annual pulplog harvest during the SOFR 2018 reporting period.

Tasmania exported most of its pulplogs (generally more than 90%) during the four SOFR reporting periods, as there was little local processing capacity. By contrast, Victoria's pulplog harvest has been used in the domestic production of paper and hardboard[112] (50%, 35%, 38% and 67% during the SOFR 2003, SOFR 2008, SOFR 2013 and SOFR 2018 reporting periods, respectively), with the remainder being exported as woodchips. During the four SOFR reporting periods, the pulplog harvest from native forests in Western Australia was all exported as woodchips. All of the pulplog harvest from native forests in New South Wales was exported, except for a small volume used to manufacture hardboard. Queensland did not produce pulplogs from native forests as the tree species harvested were generally not suitable.

The annual Tasmanian pulplog harvest during the SOFR 2018 reporting period (0.61 million cubic metres) was 17% of the annual pulplog harvest reported for Tasmania during the SOFR 2003 reporting period (3.7 million cubic metres). This volume decrease led to an 81% decrease in annual pulplog harvest value, from $157 million to $29 million annually[113].

During the SOFR 2018 reporting period, Tasmania's contribution to the total national production of wood products from native forests was 24% by volume, below the contributions of New South Wales (25%) and Victoria (32%). In value terms, Tasmania's contribution to total national production was 18%, also below the contributions of New South Wales (30%) and Victoria (29%).

All the above five states produce other log products from native forest, such as fuelwood, poles and piles[114]. Between the 2013 and 2018 SOFR reporting periods, the joint contribution of New South Wales and Western Australia increased from 61% to 74% of total national production of other log products. Wood for domestic firewood and industrial fuelwood represent a high proportion of other log products produced in both states.

In New South Wales, poles and piles represent a high proportion of other log products from that state (27%, 18%, 25% and 32% in the SOFR 2003, SOFR 2008, SOFR 2013 and SOFR 2018 reporting periods, respectively); these are reported as high-quality products for sustainable yield calculations (see Figure 2.9). New South Wales also generally produces more than half of Australia's poles and piles (49%, 53%, 58% and 69% in the SOFR 2003, SOFR 2008, SOFR 2013 and SOFR 2018 reporting periods, respectively).

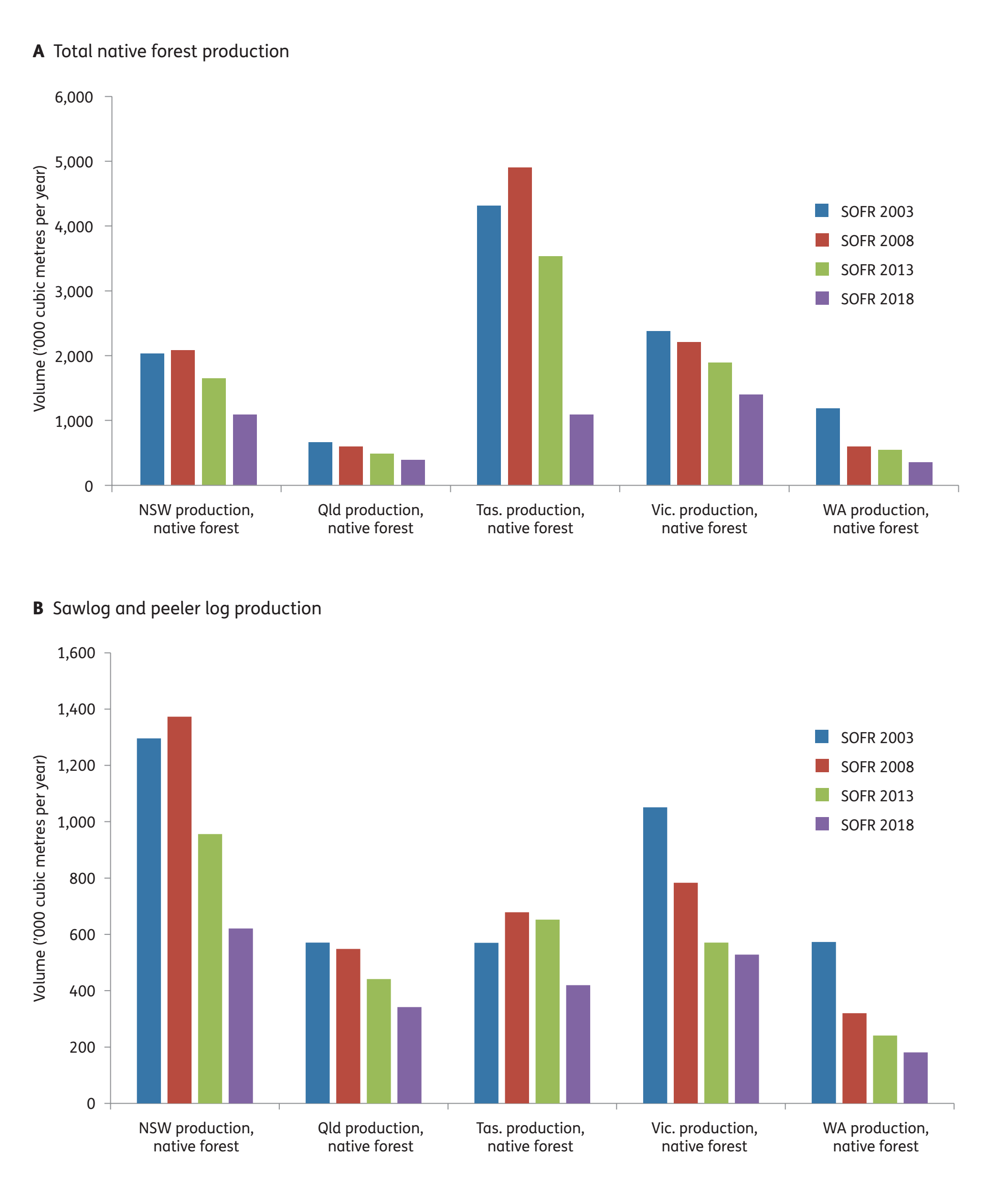
Poles and piles are high-value products, and so the value of other log products has increased significantly in New South Wales over the four SOFR reporting periods compared to other states (Figure 2.23). Queensland also produces poles and piles, and the value of these products has also contributed to the increasing value of other log products over the four SOFR reporting periods for that state.

112 Hardboard manufacturing in Victoria stopped in 1998.

113 Dollar figures are actual figures, not corrected or indexed.

114 'Other log products' includes fuelwood logs and firewood, whereas 'Other wood products' excludes fuelwood logs and firewood. Girders may be included in the statistics for poles and piles.

Figure 2.22: Average annual volume of wood and wood products from native forests, by SOFR reporting period



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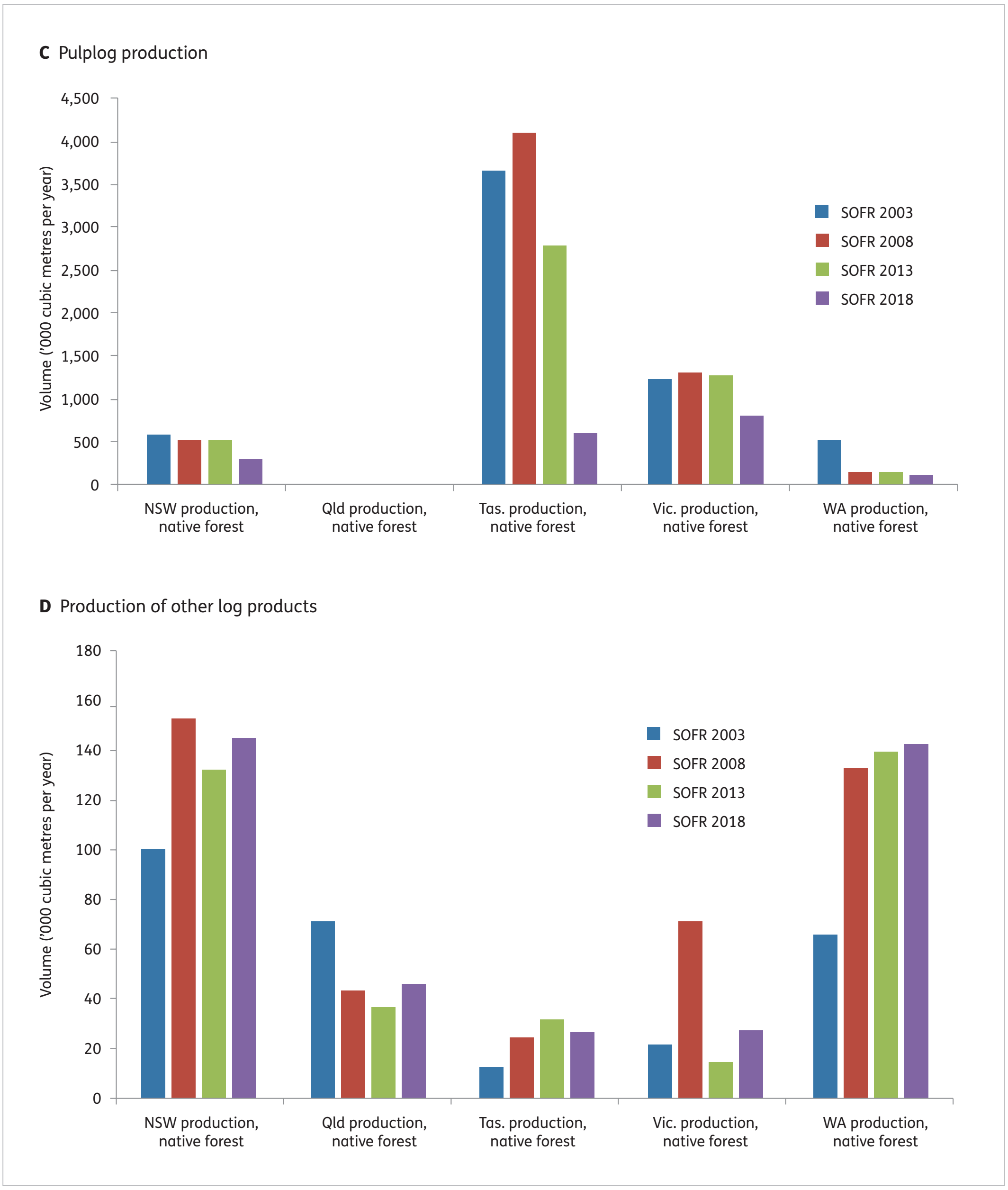

Notes:

Total native forest production is the sum of the production of sawlog and peeler log, pulplog, and other log products.

Sawlog includes all categories of domestically used or exported sawlogs and veneer logs.

Sliced peeler logs for the domestic market are grouped with sawlogs even though they can be a mix of sawlog or pulplog quality; this log category is only recorded as a separate product category in Tasmania.

Exported peeler logs are split into exported sawlog or exported pulplog based on quality, and these logs are reported as sawlog and peeler log, and pulplog, respectively.

Pulplogs are logs used in domestic hardboard or paper production, or exported as pulplogs or woodchips.

Other log products includes sleeper logs, poles, piles, fencing, mining timber, other log types not included elsewhere, and fuel logs for industrial and domestic use (firewood).

Data from Northern Territory are not shown because the quantities harvested are small.

Source: ABARES databases.

The data used to create this figure, together with other data for Indicator 2.1c, are available in Microsoft Excel via www.doi.org/10.25814/5bda8a9ed76d5

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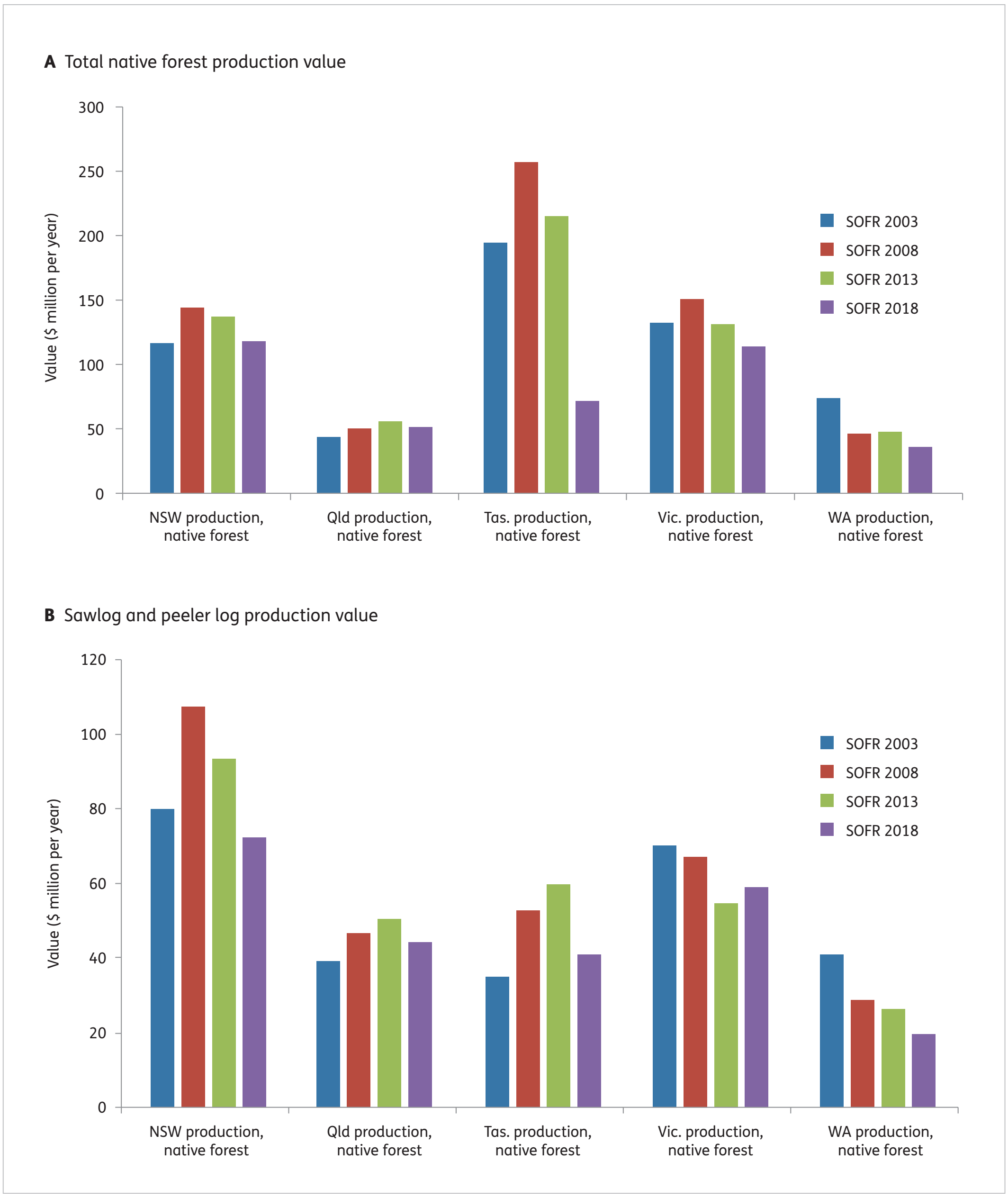
Figure 2.23: Average annual value of wood and wood products from native forests, by SOFR reporting period



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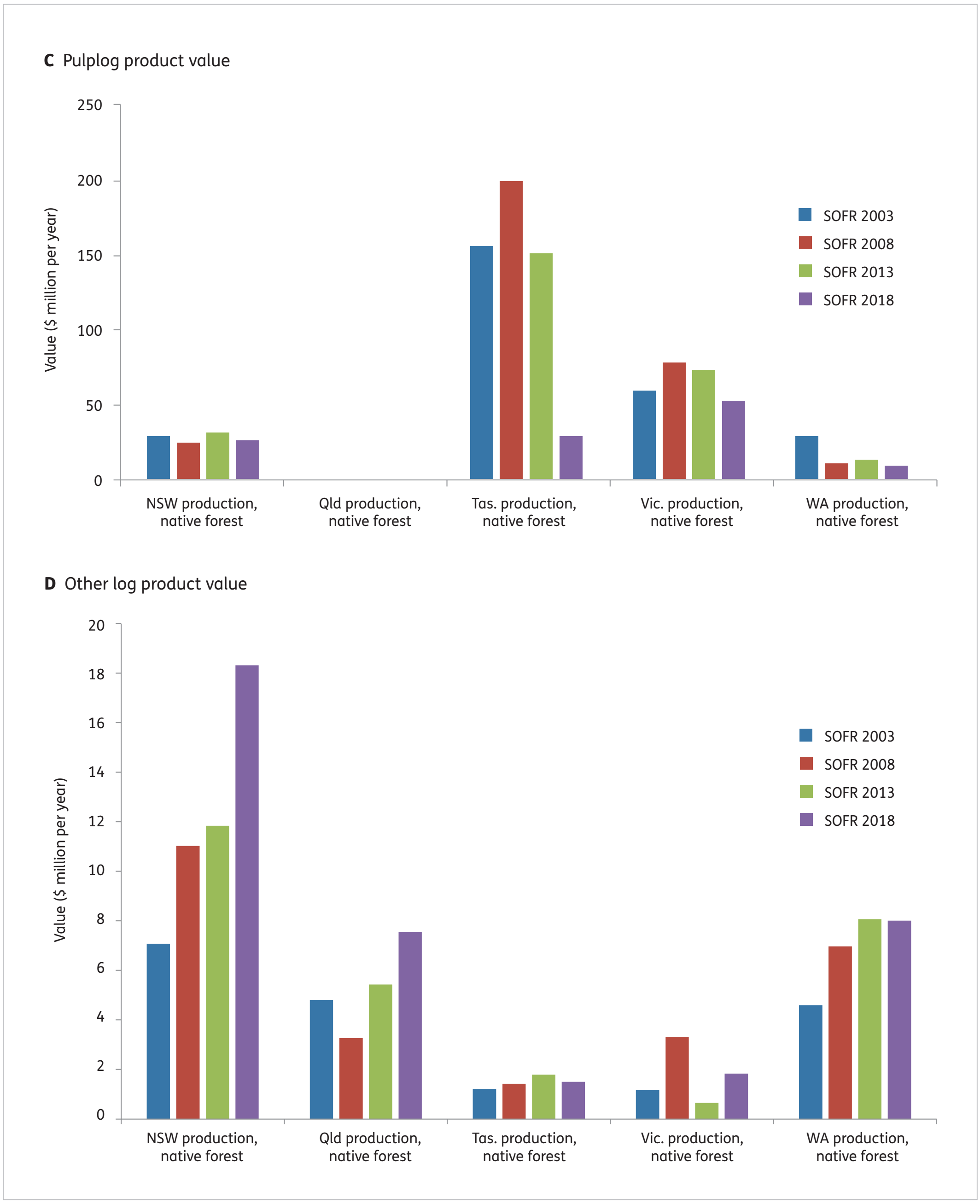


See notes under Figure 2.22A–D.

Source: ABARES databases.

The data used to create this figure, together with other data for Indicator 2.1c, are available in Microsoft Excel via www.doi.org/10.25814/5bda8a9ed76d5

Logs harvested from plantations and native forests

Figure 2.24 shows the annual harvest volumes of different log types from Australia's native forests and plantations from 2000–01 to 2015–16. A total of 4.1 million cubic metres of native forest logs (sawlogs, pulplogs and other logs, including native forest softwood logs), 9.8 million cubic metres of plantation hardwood logs (sawlogs, pulplogs and other logs), and 16.2 million cubic metres of plantation softwood logs (sawlogs, pulplogs and other logs) were harvested in 2015–16.

Of the logs harvested from native forest, 52% by volume were sawlogs and 44% by volume were pulplogs.

Approximately 60% by volume of the total plantation log harvest was used for sawn timber, and 39% by volume was used for pulp, in the period 2011–16. However, of the total plantation hardwood log volume harvested, only 2% was sawlogs and 98% was pulplogs.

A very small amount of other logs (poles, piles, fencing and other logs not elsewhere included) account for the remaining total log harvest in native forests and plantations.

Over the period 2000–01 to 2015–16, the sawlog and pulplog harvest from native forests declined due to changes in land use and land tenure, and market decisions, while the harvest from plantations increased as plantations matured (Figure 2.24). The most substantial change in Australia's log harvest during this period was an increase in plantation hardwood pulplog harvest from 0.9 to 9.6 million cubic metres per annum. This increase was offset by a decrease in the harvest of native forest pulplogs over the same period, from 7.0 to 1.8 million cubic metres per annum. The plantation softwood sawlog harvest increased from a low of 7.2 million cubic metres in 2000–01 to a peak of 10.0 million cubic metres in 2015–16. The plantation softwood pulplog harvest increased from 4.7 million cubic metres to a peak of 5.9 million cubic metres over the same period.

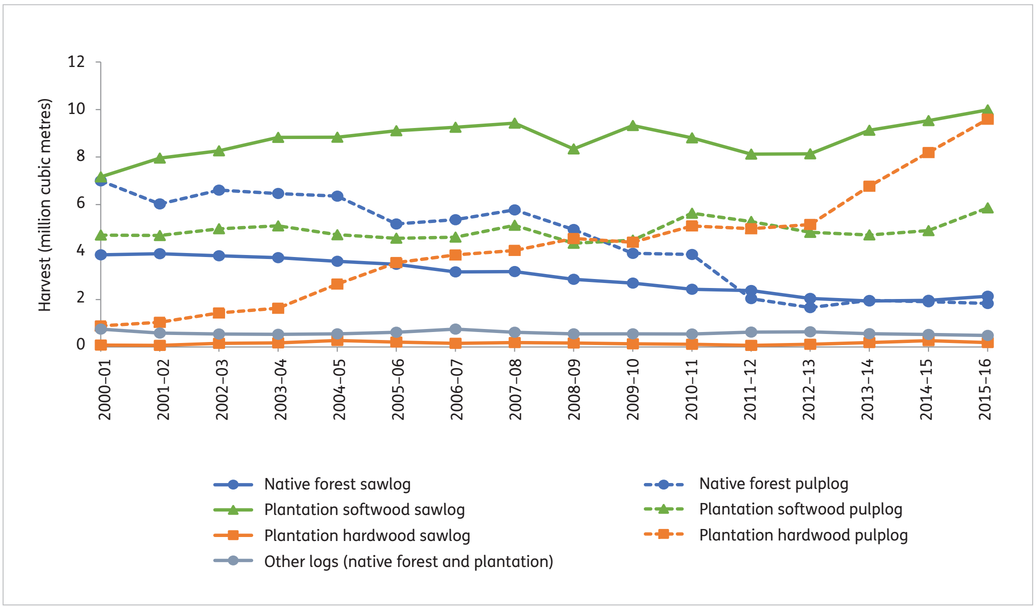
The contribution of plantations to Australia's total log harvest has increased steadily from 55% in 2000–01 to 86% in 2015–16, and averaged 84% across the SOFR 2018 reporting period of 2011–12 to 2015–16 (Table 2.13). Native forests remain the main source of hardwood sawlogs, producing 92% of Australia's total harvest in the SOFR 2018 reporting period of 2011–12 to 2015–16 despite the native forest sawlog harvest volume decreasing over this period from 3.9 to 2.1 million cubic metres; this is because most hardwood plantations are not managed to produce sawlogs, or are not able to produce sawlogs. Plantation-grown hardwood sawlogs generally cannot be used to make the same feature-grade sawn timber products as can be made from native forest hardwood sawlogs.

The reduction in total native forest log harvest between 2000–01 and 2015–16 occurred in both the public and private native forest production estates (Figure 2.25). Over this period, the total log harvest from multiple-use public native forests decreased from 8.1 to 3.7 million cubic metres; and from private native forests from 3.0 to 0.5 million cubic metres, predominantly caused by a drop in the harvest of sawlogs in New South Wales, Queensland and Tasmania (Figure 2.17) and in the harvest of pulpwood in Tasmania (Figure 2.19).

Native forests accounted for 16% of Australia's total log supply by volume over the SOFR 2018 reporting period (Table 2.13). This continues a declining trend since the SOFR 2008 reporting period, as plantations continued to increase their proportional contribution to total sawlog production (81% by volume in 2011–12 to 2015–16) and total pulplog production (86% in 2011–12 to 2015–16). Softwood sawlogs

Unloading hardwood pulplogs, Eden, NSW.

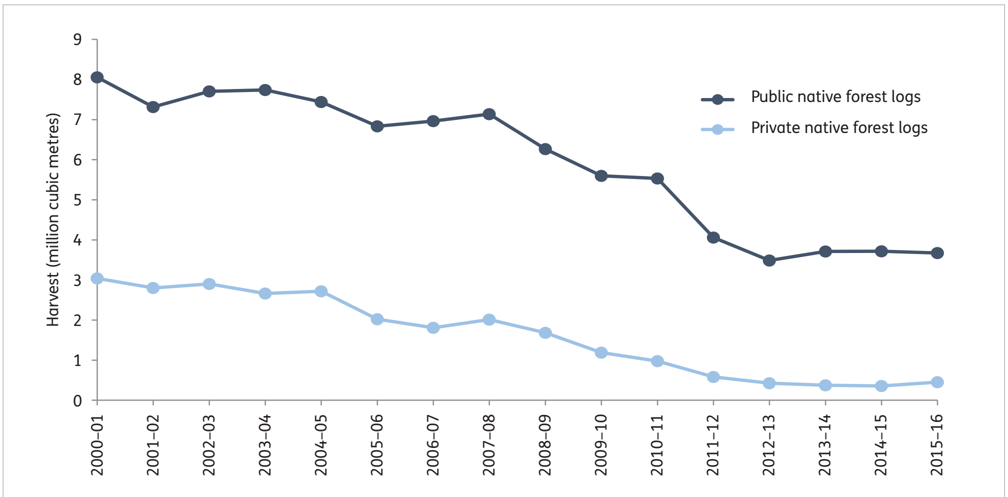
Figure 2.24: Annual harvest of sawlogs and pulplogs from Australia's native forests and plantations, 2000–01 to 2015–16



Note: Native forest sawlog includes native cypress pine sawlogs.
Source: ABARES (2017c).

The data used to create this figure, together with other data for Indicator 2.1c, are available in Microsoft Excel via www.doi.org/10.25814/5bda8a9ed76d5

Figure 2.25: Annual log harvest from Australia's native forests, 2000–01 to 2015–16



Notes: Public native forest logs are predominately sourced from multiple-use public native forest. Logs are also sourced from tenures where the Crown (state and territory governments) owns and/ or manages the tree resource (e.g. leasehold land).
Private native forest logs are logs sourced from private and leasehold land where the owner is not the Crown.
Source: ABARES (2017c).

The data used to create this figure, together with other data for Indicator 2.1c, are available in Microsoft Excel via www.doi.org/10.25814/5bda8a9ed76d5

Table 2.13: Proportions of log harvest volumes derived from various sources, 2001–02 to 2015–16

Wood harvest type	Source	2001–02 to 2005–06 (SOFR 2008) %	2006–07 to 2010–11 (SOFR 2013) %	2011–12 to 2015–16 (SOFR 2018) %
Total	Native forest	39	29	16
	Plantation	61	71	84
Total	Sawlog	48	45	44
	Pulplog	50	53	54
Total native forest	Sawlog	37	37	50
	Pulplog	61	61	45
Total plantation	Sawlog	57	51	44
	Pulplog	43	49	56
Total sawlog[a]	Native forest	30	24	19
	Hardwood	28	22	17
	Softwood	2	2	1
Total sawlog[a]	Plantation	70	76	81
	Hardwood	1	1	1
	Softwood	69	75	80
Total hardwood sawlog	Native forest	95	95	92
	Plantation	5	5	8
Total softwood sawlog	Native forest	3	2	2
	Plantation	97	98	98
Total pulplog	Native forest	47	34	14
	Hardwood	47	34	14
Total pulplog	Plantation	53	66	86
	Hardwood	16	31	49
	Softwood	37	35	37
Total hardwood pulplog	Native forest	75	52	22
	Plantation	25	48	78

[a] Total sawlog includes native hardwood, native softwood (cypress pine), and plantation hardwood and softwood sawlog.
Totals may not tally due to rounding. Values are annual averages for the period.
Source: ABARES (2017c).

This table, together with other data for Indicator 2.1c, is available in Microsoft Excel via www.doi.org/10.25814/5bda8a9ed76d5

continue to be predominantly produced from plantations (98% in 2011–12 to 2015–16), whereas hardwood sawlogs continue to be predominantly supplied from native forests (92% in 2011–12 to 2015–16).

Forecast national native forest log availability

The five states that harvest high-quality sawlogs from public native forests provide forecasts of the sustainable yields of high-quality sawlogs from public native forests. Figure 2.26 shows the national forecasts calculated from these state data and other data (see Burns et al. 2015 and notes to Figure 2.26), compared with the forecast of this parameter published in SOFR 2013. Table 2.14 shows the same data expressed as the proportion of the 1992–96 sustainable yield. In the SOFR 2018 reporting period, the sustainable yield of high-quality sawlogs was reduced to 47% of the sustainable yield reported in the SOFR 1998 reporting period (1992–93 to 1996–96), and is forecast to reduce to 37% of this value in later SOFR reporting periods (Table 2.14).

Nationally, sustainable yield is forecast to continue to decline to around 38% of the level reported in SOFR 1998 by the period of 2030–34. After that time, sustainable yield is forecast to increase (Figure 2.26; Table 2.14). These forecasts assume the ongoing satisfactory management of risks from bushfire, disease and climate impacts, and no further reductions in net harvestable area (see Indicator 2.1a) as would result from further reservation or from application of stricter code prescriptions.

The New South Wales and Western Australia sustainable yield forecasts contributed similarly to the SOFR 2013 and SOFR 2018 national forecast totals. In contrast, the forecasts from Tasmania and Victoria were lower for the SOFR 2018 national forecast than for SOFR 2013 national forecast, as a consequence of the Tasmanian Forest Agreement 2013 outcomes (FPA 2017a) and increased code prescriptions applying to Leadbeater's possum and old-growth forests in Victoria (VicForests 2017); these decreases were offset by an increase in the allowable harvest in Queensland arising from a Queensland government policy change in 2012, with these changes extending past 2025.

Table 2.14: Average annual sustainable yield of sawlogs from native public production forests across 5-year SOFR reporting periods to 2016, then 5-year forecast periods to 2054

Period	1992–96	1996–01	2001–06	2006–11	2011–16	2015–19	2020–24	2025–29	2030–34	2035–39	2040–44	2045–49	2050–54
Data type	**Actual**					**Forecast**							
Average annual sustainable yield ('000 cubic metres)	3,164	2,902	2,098	1,684	1,486	1,224	1,145	1,123	1,113	1,126	1,142	1,176	1,168
Average annual sustainable yield as proportion of average annual sustainable yield for period 1992–96 (%)	100	92	66	53	47	39	36	35	35	36	36	37	37

Notes:
'Actual' data from Figure 2.8 ('Average annual harvest and sustainable yield for multiple-use public native forests in Australia, by SOFR reporting period').
'Forecast' data are the SOFR 2018 forecast shown in Figure 2.26 (refer to notes in that Figure).
Data or forecasts do not include any supplementation with high-quality sawlogs from public hardwood plantations.
The 1992–96 reporting period for Victoria includes an adjustment to C+ sawlogs to express these as a D+ equivalent.
This table, together with other data for Indicator 2.1c, is available in Microsoft Excel via www.doi.org/10.25814/5bda8a9ed76d5

Figure 2.27 shows forecasts of potential future log availability from the sum of multiple-use public, leasehold and private native forest from 2015–19 to 2050–54, separately by log type. Native forest hardwood pulplog availability is forecast to average 2.7 million cubic metres annually during 2015–19, increasing gradually over the remaining periods, and average approximately 3.0 million cubic metres per year in 2050–54 (Figure 2.27). The forecast shown on Figure 2.27 combines both the decrease in sustainable yield of native forest sawlogs from multiple-use public forests over the forecast period (Figure 2.26, Table 2.14) with a forecast increase in availability of high-quality native sawlogs from private and leasehold forests. However, the actual supply of sawlogs from private and leasehold forests will also depend on market forces and the objectives and goals of private and public owners.

Forecast national plantation log availability

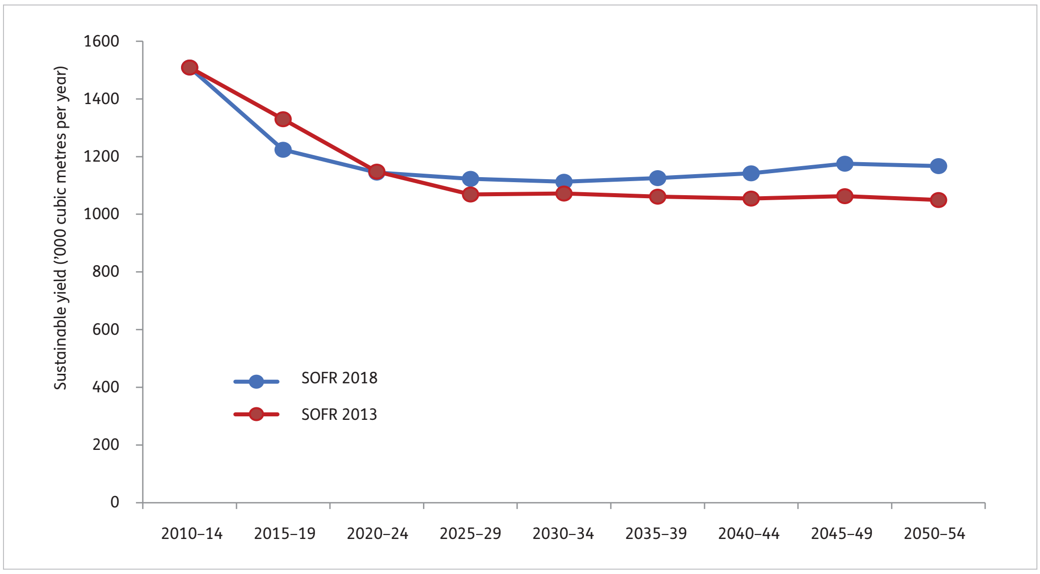
Commercial plantations are primarily located in 15 National Plantation Inventory (NPI) regions in Australia (Figure 2.28), and have been established mainly to produce timber and other wood-based products. Commercial plantation estates are managed as businesses, so the timing and volume of log harvests is determined mainly by market forces, rotation length and thinning regimes. The Western Australia, Green Triangle and Tasmania NPI regions each contain plantation estates of more than 200 thousand hectares.

ABARES (2016a) forecast potential future log availability from existing plantations to 2055–59 (Table 2.15), based on data collected from the 15 NPI regions in 2014–15. The forecasts are based on the assumption that most harvested areas will be replanted with the same type of plantation species. For each given type of plantation, log availability forecasts take into account the area of existing plantations by year of establishment and the assumed production period (rotation), silvicultural regimes (including thinning), and growth rate. Market demand and supply will influence the actual volumes that are harvested at a particular time, and plantation managers will adjust silvicultural regimes, scheduling and operational management accordingly to meet market demand.

The potential annual average plantation log availability is forecast to peak at 29.7 million cubic metres in both the 2015–19 and the 2040–44 periods, with lower availability between these periods (Table 2.15). Plantation log availability is forecast to decline towards the end of the forecast period, and reach an annual average of 26.3 million cubic metres in 2055–59.

Total plantation hardwood log availability is forecast to trend downwards over the period 2015–19 to 2055–59, from an annual average of 12.9 million cubic metres in 2015–19 to an annual average of 9.1 million cubic metres in 2055–59 (Table 2.15). The actual plantation hardwood log harvest in 2015–16 was 24% lower than the 2015–19 forecast hardwood log availability, which suggests a potential short-term increase in hardwood log availability before the long-term downward trend.

Figure 2.26: Forecast sustainable yield of high-quality native forest sawlogs from public production forest in Australia, 2010–14 to 2050–54



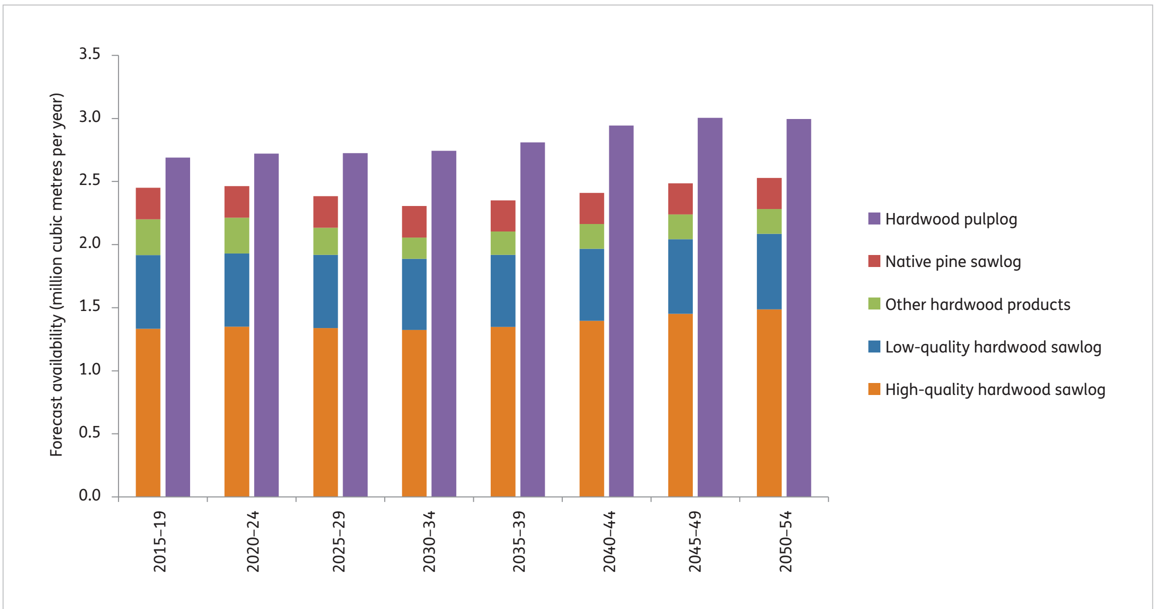
Notes: Forecasts of sustainable yield from public native forests are based on state agency data or information, and do not include any supplementation with high-quality sawlogs from public hardwood plantations. Forecasts include yields of both hardwood and cypress pine from public native forests.

The forecast undertaken for SOFR 2013 included data from Forests NSW (2010) and VicForests (2011b), and for Queensland included allowable cut estimates to 2025 but no harvesting after that date, and did not include changes resulting from the Tasmanian Forest Agreement 2013. The SOFR 2013 forecast for 2045–49 was extended to 2050–54 using these inclusions and exclusions for comparison with the updated forecast presented in SOFR 2018.

The updated forecast (SOFR 2018) is based on Burns et al. (2015) and ABARES (in preparation); it includes data from the Conservation Commission of Western Australia (CCWA 2013, applying the allowable cut level), Forests NSW (2010), Forestry Tasmania (2014b), adjustments reported in VicForests (2017), and an allowable cut forecast from Queensland's 'Defined Forest Area' estate (described in the Queensland section associated with Figure 2.13) that extends past 2025 (Burns et al. 2015). Source: ABARES database. Data used in Burns et al. (2015) and ABARES (in preparation).

The data used to create this figure, together with other data for Indicator 2.1c, are available in Microsoft Excel via www.doi.org/10.25814/5bda8a9ed76d5

Figure 2.27: Forecast log availability from native forest on public, leasehold and private land in Australia, 2015–19 to 2050–54



Notes:

Native pine sawlog is cypress pine sawlog.

Other hardwood product includes poles, piles, girders and other logs. Miscellaneous wood products such as firewood, industrial fuelwood, sleeper logs and fencing material are not included in the forecast projections.

Low-quality hardwood sawlogs are sawlogs not included in the high-quality category

High-quality hardwood sawlogs are hardwood logs graded to standards used by state agencies.

Source: ABARES (in preparation).

The data used to create this figure, together with other data for Indicator 2.1c, are available in Microsoft Excel via www.doi.org/10.25814/5bda8a9ed76d5

Harvesting softwood sawlogs, Bombala, NSW.

Plantation hardwood pulplog availability is forecast to follow a similar trend to total plantation hardwood availability, peaking at an annual average of 12.5 million cubic metres in 2015–19, and trending downwards to an annual average of 8.1 million cubic metres in 2055–59 (Table 2.15). In 2015–19, the Western Australia, Green Triangle and Tasmania NPI regions are forecast to be the main hardwood pulplog-producing regions, accounting for 31%, 28% and 21%, respectively, of the national total availability of plantation hardwood pulplogs (Figure 2.29). Despite minor changes in their relative contributions to plantation hardwood pulplog availability, these three NPI regions are forecast to remain as the major producing NPI regions across the entire forecast period.

To date, increases in plantation hardwood area have not led to substantial increases in harvested sawlog volume, because hardwood plantations are primarily managed for pulplog production. However, plantation hardwood sawlog availability is forecast to follow an increasing trend over the period 2015–19 to 2055–59 (Table 2.15, Figure 2.30), contrary to the decreasing trend of forecast total hardwood log availability. Annual average plantation hardwood sawlog availability in 2015–19 is forecast to be 0.408 million cubic metres, and increase to a peak annual average of 0.994 million cubic metres in 2055–59 (Table 2.15, Figure 2.30).

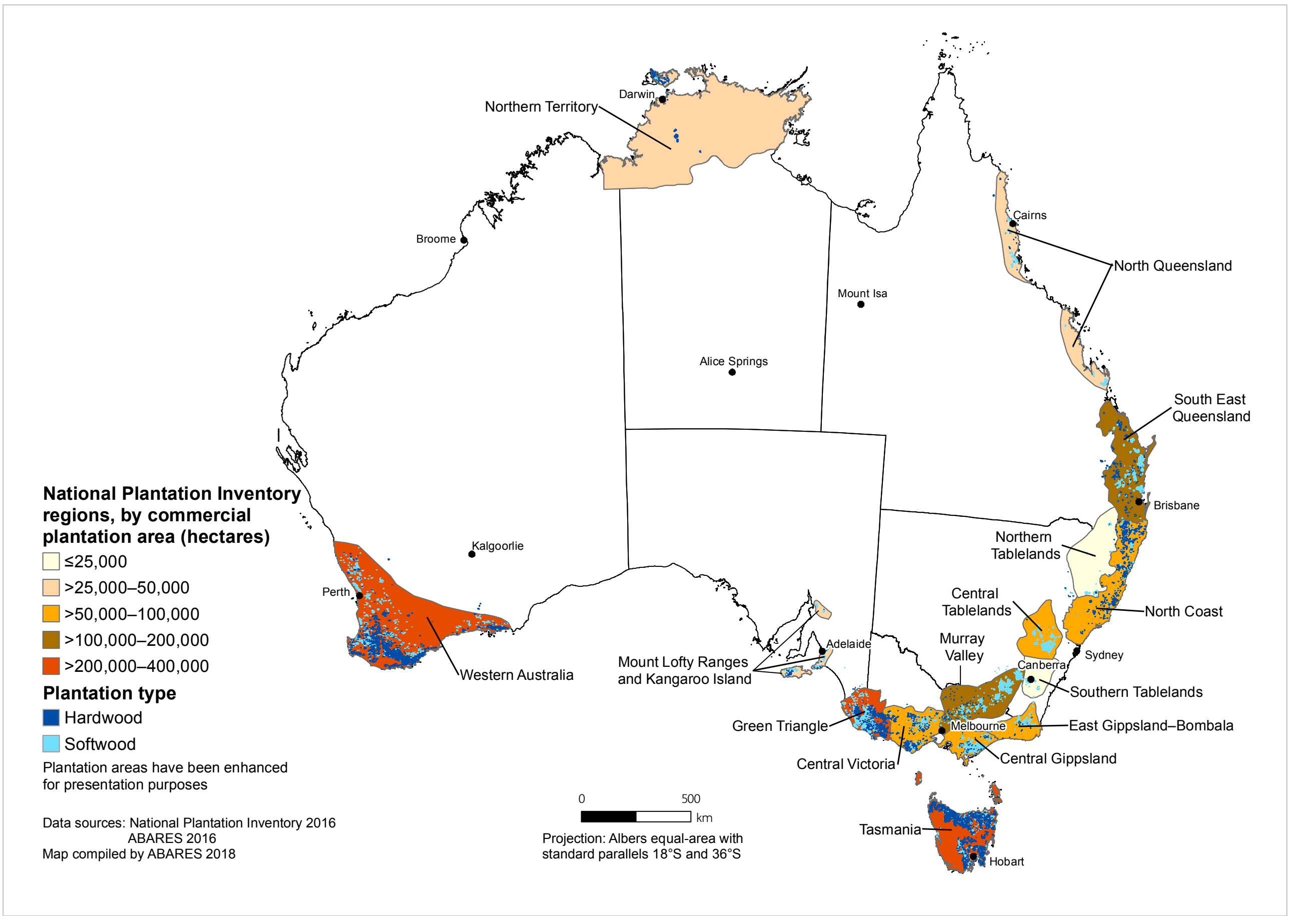
In 2015–19, the Tasmania and North Coast NPI regions are forecast to be the main sources of plantation hardwood sawlog availability, accounting for 27% and 14%, respectively, of the national total availability (Figure 2.30). After 2015–19, Tasmania's contribution to plantation hardwood sawlog availability is forecast to increase substantially, and peak at 62% of the national total availability in 2045–49. Sawlog estimates include peeler logs, high-grade and low-grade sawlogs and posts and poles.

Plantation softwood log availability is forecast to remain relatively stable over the forecast period, with an annual average 16.8 million cubic metres in 2015–19, peaking at an annual average of 18.9 million cubic metres in 2035–39, and averaging 17.2 million cubic metres annually in 2055–59 (Table 2.15). The upturn in 2035–39 is driven mostly by an increase in the forecast availability of plantation softwood sawlogs.

Most of the sawn timber used for housing and general construction in Australia is derived from plantation softwood sawlogs. The availability of plantation softwood sawlogs is forecast to average 12.1 million cubic metres per year in 2015–19, and increase to a peak annual average of 14.3 million cubic metres in 2035–39 (Table 2.15). The Green Triangle, Murray Valley and South East Queensland NPI regions are forecast to produce the majority of the plantation softwood sawlogs available over the entire forecast period, contributing an average of 26%, 18% and 16%, respectively, of the national total availability (Figure 2.31).

Plantation softwood pulplog availability is forecast to average 4.7 million cubic metres annually in 2015–19, and to vary around an annual average of 4.4 million cubic metres per year

Figure 2.28: Commercial plantations and National Plantation Inventory regions



Source: ABARES, National Plantation Inventory.

A higher resolution version of this map is available via www.doi.org/10.25814/5be3bc4321162

Table 2.15: Forecast potential annual average plantation log availability, Australia, 2015–19 to 2055–59

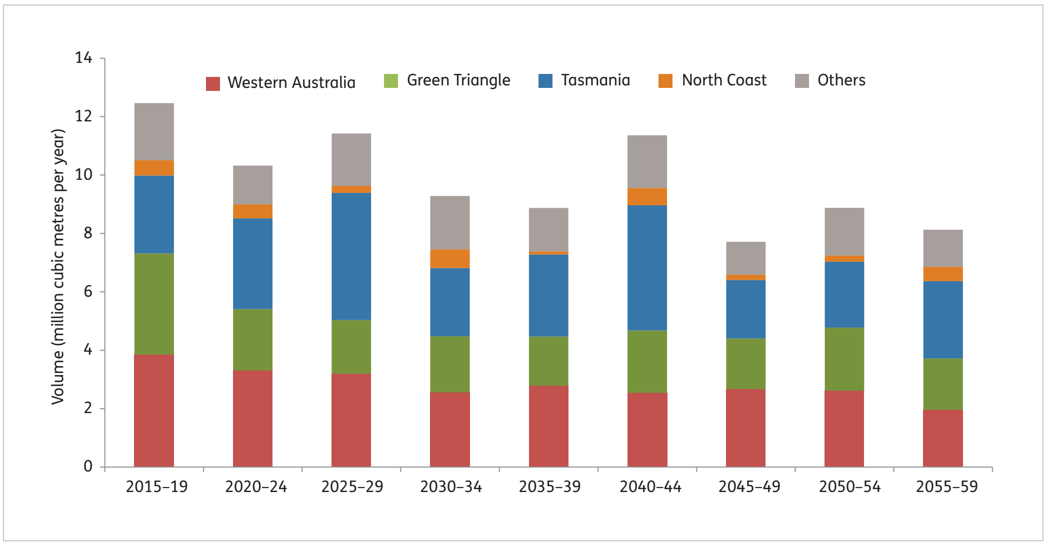
	Volume ('000 cubic metres)								
Log type	**2015–19**	**2020–24**	**2025–29**	**2030–34**	**2035–39**	**2040–44**	**2045–49**	**2050–54**	**2055–59**
Hardwood									
Pulplog	12,466	10,326	11,424	9,283	8,875	11,361	7,715	8,880	8,129
Sawlog	408	293	715	904	785	866	780	863	994
Subtotal	**12,874**	**10,619**	**12,139**	**10,186**	**9,659**	**12,227**	**8,496**	**9,743**	**9,123**
Softwood									
Pulplog	4,726	4,759	4,215	4,228	4,540	4,224	4,520	4,563	4,509
Sawlog	12,099	11,662	11,731	12,278	14,316	13,249	13,491	12,877	12,709
Subtotal	**16,825**	**16,421**	**15,946**	**16,506**	**18,856**	**17,473**	**18,011**	**17,440**	**17,218**
Total	**29,699**	**27,040**	**28,085**	**26,692**	**28,515**	**29,699**	**26,507**	**27,183**	**26,342**

Notes: Sawlogs include all quality classes of plantation sawlogs.
Totals may not tally due to rounding.
Source: ABARES (2016a).

This table, together with other data for Indicator 2.1c, is available in Microsoft Excel via www.doi.org/10.25814/5bda8a9ed76d5 over the remaining periods to 2055–59 (Table 2.15). The Green Triangle, Murray Valley and Tasmania NPI regions are forecast to be the main softwood pulplog-producing regions over the entire forecast period, contributing an average of 25%, 24% and 14%, respectively, of the national total availability (Figure 2.32).

Compared to forecasts in *Australia's plantation log supply 2010–2054* (Gavran et al. 2012), the 2015–19 to 2055–59 average total plantation log availability forecast published in ABARES (2016a) is 10% lower. The overall plantation hardwood log availability forecast is 21% lower for the period 2015–19 to 2055–59; decreases in forecast availability of hardwood pulplogs and sawlogs are due to plantation growers and managers revising downwards their yield estimates since 2012, and to the removal of plantation area now deemed unproductive or where leases for plantation land were not renewed with landowners. The overall plantation softwood log availability forecast is 2% lower for the period 2015–19 to 2055–59; the forecast plantation softwood sawlog availability is 7% higher, and the forecast plantation softwood pulplog availability is 21% lower, partly resulting from some companies entering new markets for lower-grade softwood logs since 2012.

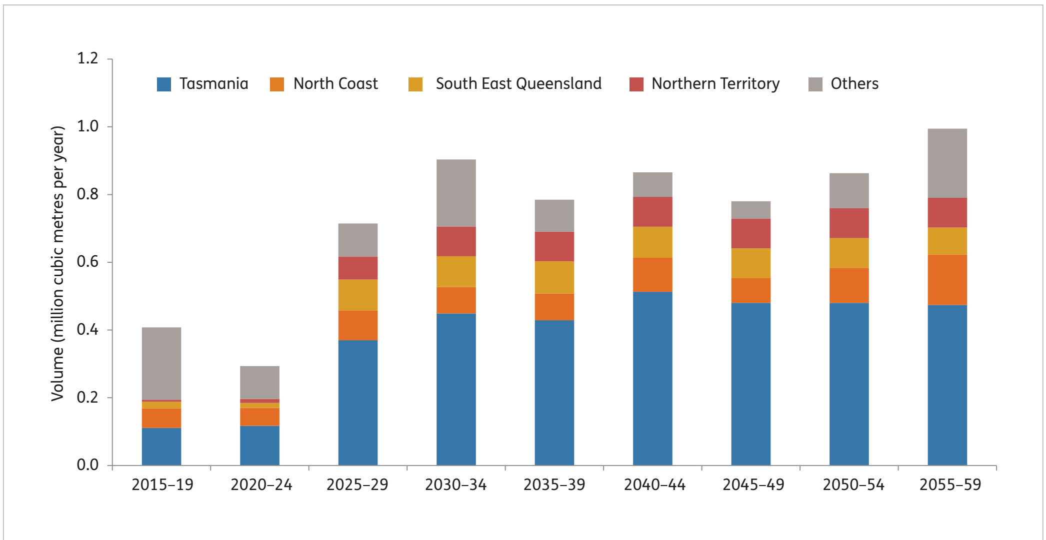
Figure 2.29: Forecast availability of plantation hardwood pulplogs, by National Plantation Inventory region



Source: ABARES (2016a).

The data used to create this figure, together with other data for Indicator 2.1c, are available in Microsoft Excel via www.doi.org/10.25814/5bda8a9ed76d5

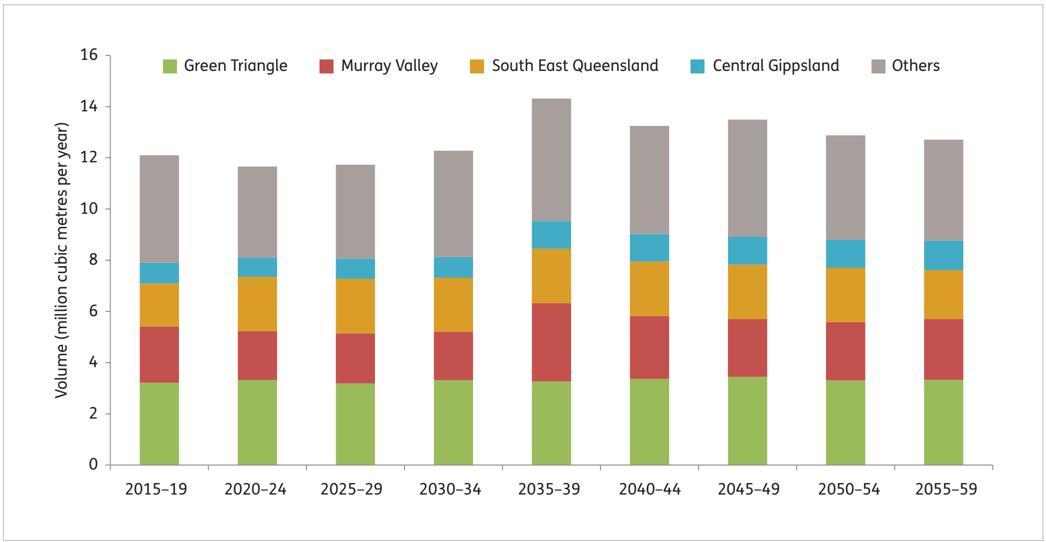
Figure 2.30: Forecast availability of plantation hardwood sawlogs, by National Plantation Inventory region



Source: ABARES (2016a).

The data used to create this figure, together with other data for Indicator 2.1c, are available in Microsoft Excel via www.doi.org/10.25814/5bda8a9ed76d5

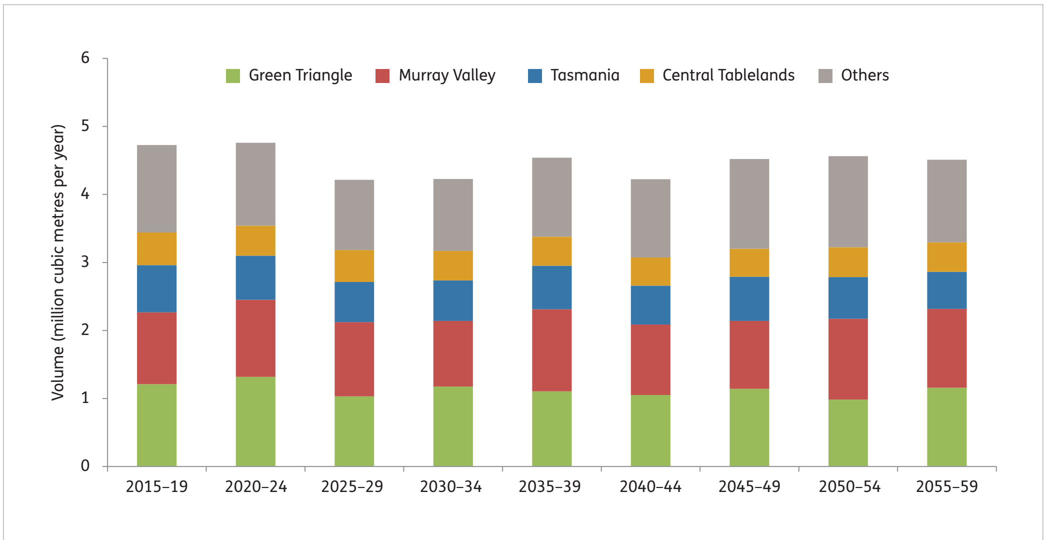
Figure 2.31: Forecast availability of plantation softwood sawlogs, by National Plantation Inventory region



Source: ABARES (2016a).

The data used to create this figure, together with other data for Indicator 2.1c, are available in Microsoft Excel via www.doi.org/10.25814/5bda8a9ed76d5

Figure 2.32: Forecast availability of plantation softwood pulplogs, by National Plantation Inventory region



Source: ABARES (2016a).

The data used to create this figure, together with other data for Indicator 2.1c, are available in Microsoft Excel via www.doi.org/10.25814/5bda8a9ed76d5

Indicator 2.1d

Annual removal of non-wood forest products compared to the level determined to be sustainable

Rationale

This indicator assesses the sustainability of the harvest of non-wood forest products. These products can represent a significant asset base supporting the livelihoods of regional and remote communities.

Key points

- Australia produces a wide range of non-wood forest products (NWFPs) derived from forest fauna, flora and fungi. High-value NWFPs include wildflowers, seed, honey, and aromatic products derived from sandalwood.
- State and territory governments regulate the removal of NWFPs in their respective jurisdictions, including through the issue of permits and licences. Commonwealth legislation, such as the *Environment Protection and Biodiversity Conservation Act 1999*, also regulates the removal of certain NWFPs.
- Data on annual removals and sustainable yields are limited for many NWFPs, but are available for some of the more commercially significant NWFPs. Data are presented on the harvest or production of tree ferns in Tasmania, eastern grey kangaroo and wallaroo in Queensland, Bennett's wallaby and brushtail possum in Tasmania, and honey nationally.
- Indigenous Australians rely to varying degrees on the use of NWFPs for customary purposes (e.g. food and medicine) and commercial purposes (e.g. art and craft).

Non-wood forest products (NWFPs) are products of biological origin, other than wood, that are derived from forests. Examples include wildflowers, tree ferns, seeds, bark, animal meat and skins, honey and mushrooms. A more comprehensive list is provided in Table 2.15 of SOFR 2013.

For convenience, certain wood products, such as wood carvings and aromatic items produced from sandalwood (*Santalum* spp.), are included in this indicator. Sandalwood is also discussed in Indicator 2.1c. Water and carbon values derived from forests are discussed under Criteria 4 and 5, respectively, and the economic value and use of NWFPs are reported in Indicator 6.1b.

The Australian, state and territory governments have regulations to limit and control the removal of plant and animal products from forests. Most commonly, these involve the issue of permits or licences for harvesting and hunting activities (Box 2.1). The species and allowable rates of extraction vary by jurisdiction. For example, in the Northern Territory magpie geese (*Anseranas semipalmata*, a forest-dwelling species) are abundant[115] and were harvested under permit in 2015 and 2016 for commercial purposes[116], but they are not harvested in southern states where they are less common (Nye et al. 2007) and listed as threatened or endangered[117].

The Australian Government has legislated measures to protect threatened species nationally through the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), which also regulates, among other things, the ecologically sustainable use of wild native plants and animals that are exported.

Limited quantitative data are available to report the harvest of NWFPs and the sustainability of this harvest. The following text is an overview, with examples of some higher-value products for which data exist. Data on volumes and values of products are covered in Indicator 6.1b.

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115 denr.nt.gov.au/land-resource-management/magpie-goose-management

116 Unpublished permit data provided by the Northern Territory Department of Land Resource Management (from September 2017, the Department of Environment and Natural Resources).

117 Magpie geese are protected in all jurisdictions of Australia, including the Northern Territory where the species is protected under the Territory Parks and Wildlife Conservation Act (PWSNT 2009). Magpie geese are listed as vulnerable in NSW, threatened in Victoria and endangered in South Australia. The species is listed as a marine protected species under the *Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth) (www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=978).

Box 2.1: State and territory legislation relevant to the harvesting of non-wood forest products

Australian Capital Territory

The *Nature Conservation Act 2014* requires that licences be obtained to take protected fauna or flora.

New South Wales

The *National Parks and Wildlife Act 1974* protects all native fauna (mammals, birds, reptiles and amphibians) and flora. A licence is required to take protected fauna or flora. Regulation of non-native fauna is under the control of the *Non-Indigenous Animals Act 1987*. The *Threatened Species Conservation Act 1995* and the *Environmental Planning and Assessment Act 1979* also have provisions relevant to the harvesting of non-wood forest products. The *Threatened Species Conservation Act 1995* was replaced by the *Biodiversity Conservation Act 2016* on 03 December 2016.

Northern Territory

The *Territory Parks and Wildlife Conservation Act* requires that a permit is obtained to take protected fauna or flora, unless the activity is exempt. The Territory Parks and Wildlife Conservation Regulations manage the use of native flora and fauna, and the Department of Land Resource Management[118] regulates this permit system. If the integrity of a species is beginning to be compromised by commercial use, a management plan is required. Such management plans are in place for cycads, crocodiles and the magpie goose[119].

The Northern Territory's 'Balanced Environment Strategy'[120] covers the development of management plans for sustainable use of wildlife and other environmental assets, aiming to ensure the protection of natural resources while supporting economic outcomes.

Queensland

The *Forestry Act 1959* provides for forest reservations, and the management, silvicultural treatment and protections of State forests, including the sale of state owned forest products and quarry material. Forest products includes timber and non-wood products such as honey, seeds and flowers. The *Forestry Act 1959* applies to state forests, timber reserves, leasehold lands, reserves, public lands and certain freehold lands.

The *Nature Conservation Act 1992* is the principal legislation that provides for the protection of native flora and fauna. Appropriate authorisations or permits under the Act are required prior to any taking or interfering with protected flora and fauna, unless the activity is exempt.

South Australia

The *National Parks and Wildlife Act 1972* provides the state's legislative framework for the conservation of wildlife and flora in their natural environment. Protected animals include indigenous and migratory birds, mammals and reptiles. A permit is needed to take any protected species, except where the relevant minister declares otherwise based on a threat to crops or property, or declares an open hunting season for protected animals of specified species. A permit is needed to take native plants on any public land, as well as certain native plants on private land.

Tasmania

Wildlife in Tasmania (defined as all living creatures except stock, dogs, cats, farmed animals and fish) is protected by the *Wildlife Regulations Act 1999*. Open season may be declared by the Minister for Environment, Parks and Heritage for particular species of wildlife, including wallabies, possums, deer, wild ducks and mutton-birds.

A permit is required to take native plant species listed as endangered, vulnerable or rare under the *Threatened Species Protection Act 1995*. Harvesting of tree ferns is regulated by a management plan implemented under *Tasmania's Forest Practices Act 1985* (FPA 2017b).

Victoria

In Victoria, wildlife (defined as vertebrate species Indigenous to Australia, some non-native game species, and terrestrial invertebrate animals that are listed under the *Flora and Fauna Guarantee Act 1988*) is protected under the *Wildlife Act 1975*. A licence or authorisation is needed to take, destroy or disturb wildlife or flora listed as protected under the *Flora and Fauna Guarantee Act 1988*.

Continued

118 From 12 September 2016, the Department of Environment and Natural Resources.

119 See www.environment.gov.au/biodiversity/wildlife-trade/publications/mgt-program-saltwater-crocodile-nt-2014-2015, www.environment.gov.au/biodiversity/wildlife-trade/publications/management-program-cycads-nt-2009-2014 and denr.nt.gov.au/land-resource-management/magpie-goose-management

120 nt.gov.au/__data/assets/pdf_file/0010/363772/balanced-environment-strategy.pdf; but see denr.nt.gov.au/environment-information/environmental-regulatory-reform/environmental-regulatory-reform-program

Continues

Western Australia

The *Conservation and Land Management Act 1984* and the *Wildlife Conservation Act 1950*[121] provide for the conservation and protection of all native flora and fauna in Western Australia through a system of licensing for commercial use, area-specific and species-specific management, and monitoring. The taking of kangaroos for commercial purposes requires the issue of a licence under the Wildlife Conservation Regulations 1970. A management plan governs the commercial harvesting of protected flora in Western Australia (DEC 2013b).

Harvesting sandalwood, Kalgoorlie, Western Australia.

Plant products

In general, factors that influence the sustainability of the harvest of native plant products include the plant part that is harvested; the plant's reproductive strategy, habitat specificity and growth rates; other uses for the land on which the plant grows (such as wood production or grazing); harvest methods; remoteness from human settlement; and land-use context or environmental factors (such as climate change). It is feasible to undertake sustainability assessments based on quantitative data for some products, such as sandalwood and tree ferns. For other products, quantitative assessments are not feasible, and sustainability of harvest is addressed through the application of regulatory systems (summarised in Box 2.1), backed up by population monitoring.

In Tasmania, the only trunked tree fern that may be harvested is soft tree fern (also known as manfern, *Dicksonia antarctica*) (FPA 2017b). Harvesting of tree ferns in Tasmania for the past five years averaged 13 thousand stems per year (Figure 2.33), which is a small proportion of the estimated total of 130 million *D. antarctica* individuals in Tasmania. Tree ferns are supplied to domestic and export markets. Each tree fern taken must be tagged so that buyers can verify that it has been taken legally. The number of tree fern tags issued has declined substantially since 2002–03 (Figure 2.33), due to loss of export markets, a reduction in forestry operations, and fewer operating tree fern harvesters (FPA 2017b).

Seed and wildflowers are important NWFPs, particularly in Western Australia. Wildflower and seed industries in Western Australia are based on a combination of horticulture and native resources from forest and non-forest vegetation on public and private lands. A substantial proportion of the wildflowers harvested in Western Australia is exported (DEC 2013b).

In Western Australia, the Department of Parks and Wildlife[122] manages wildflower and seed harvesting in accordance with a management plan for commercial harvesting of protected flora on public and private land (DEC 2013b). The Australian Government has approved the management plan for the purpose of the EPBC Act (DPaW 2016c).

Collecting seed of forest species is also important in other states and territories, for use in native forest regeneration, plantation establishment, propagating nursery stock, revegetation and environmental plantings. Collection is regulated and reported by relevant public authorities.

Forestry Tasmania[123] reported collection of an average of 787 kg per year of native tree seed from 2011–12 to 2015–16, which is 87% less than in the previous five-year period (FPA 2017a). The decrease was due to a reduction in the area of forest harvesting for which seed to undertake regeneration was required.

Sandalwood has been harvested from native forests in Australia since the early 19th century[124]. The wood is used in a range of products, such as incense, and for carving, and sandalwood oil is distilled from the heartwood. Almost all sandalwood products produced in Australia are derived from the native forest resource of Australian sandalwood (*Santalum spicatum*) in Western Australia (the largest producer), or northern sandalwood (*S. lanceolatum*) in northern

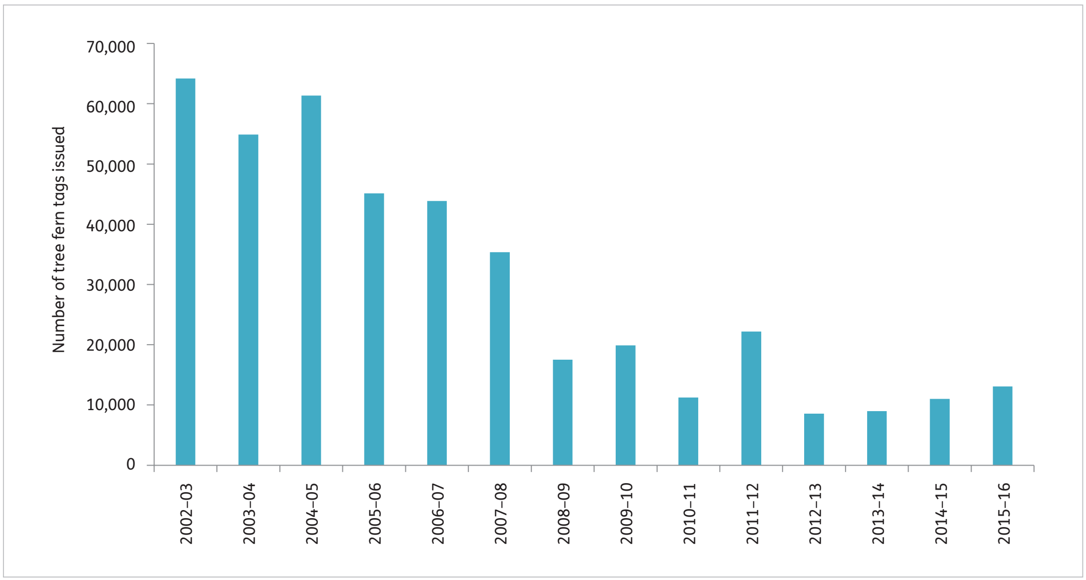
121 This Act was replaced by the *Biodiversity Conservation Act 2016* in December 2016.

122 From July 2017, Parks and Wildlife Service within the Western Australian Department of Biodiversity, Conservation and Attractions.

123 From July 2017, Sustainable Timber Tasmania.

124 More recently, Australian sandalwood (*Santalum spicatum*) plantations have been established in Western Australia, mainly in the wheat belt, as part of measures to control groundwater salinity, while Indian sandalwood (*S. album*) has been planted in Australia by private investment schemes since 2006. Some harvest of plantation sandalwood has occurred in Western Australia. This indicator covers products from native forests.

Figure 2.33: Tree fern harvesting in Tasmania



Source: FPA (2012, 2016a).

The data used to create this figure, together with other data for Indicator 2.1d, are available in Microsoft Excel via www.doi.org/10.25814/5bda8a9ed76d5

Queensland. Indicator 6.1b reports value, export amounts and domestic consumption of sandalwood.

In Western Australia, the allowable harvest level of sandalwood from native forests is governed by the *Sandalwood (Limitation of Removal of Sandalwood) Order 1996* which provides for the harvest of up to 1,500 tonnes per year each of green and dead sandalwood. This was reviewed in 2015 and the allowable harvest volumes of green and dead sandalwood were reduced to 1,350 tonnes each (DPaW 2015b). In comparison, the actual volumes harvested in 2013–14 were 1,117 tonnes of green wood and 983 tonnes of dead wood (DPaW 2015b). Indicator 2.1c provides further details.

In Queensland, sandalwood is a protected plant under the *Nature Conservation Act 1992* so licences are required for its harvest. In the absence of data on growth rates and the extent of the species, the permitted level of harvest is restricted to levels harvested historically, which averages 200 to 300 tonnes per year. Harvesting from state forests and timber reserves must follow environmental management standards specified in a code of practice (DNPRSR 2014).

Animal products

Mammals, reptiles, amphibians, birds, and insects and other invertebrates provide a range of NWFPs, such as meat, eggs, skins, fibres, honey and other bee products. In addition, many animal species provide important ecosystem services; for example, bees and other insects pollinate flowering plants.

Taking native animals from Australian forests is either prohibited or is subject to regulations enforced by government agencies in all jurisdictions. Harvesting for meat and skin products is largely restricted to species that are considered to be common, and in most cases requires a permit. Permits are usually only issued after a detailed sustainability analysis based on population monitoring. These analyses take into account factors such as local population levels (including trends in population numbers), reproduction rates, and population pressures such as disease or habitat loss. Harvesting of feral pest species does not require such sustainability analyses, since there are management targets for controlling their populations.

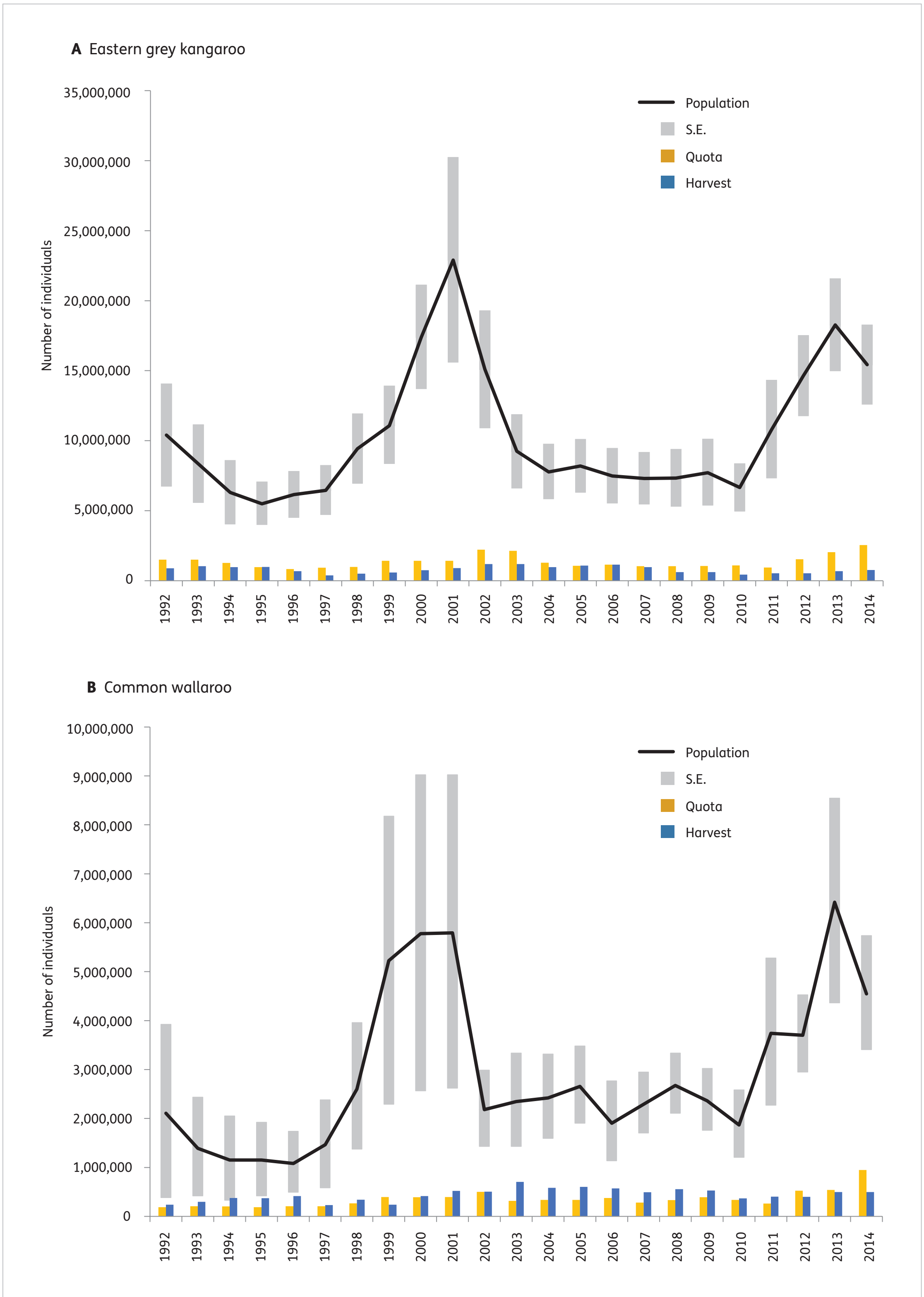
Kangaroos (common wallaroo or euro, *Macropus robustus*; eastern grey kangaroo, *M. giganteus*; red kangaroo, *M. rufus*; and western grey kangaroo, *M. fuliginosus*) are harvested commercially for meat and skins in New South Wales, Queensland, South Australia and Western Australia. Bennett's wallaby (*M. rufogriseus*) and Tasmanian pademelon (*Thylogale billardierii*) may be harvested commercially in Tasmania. These species dwell both in forests and in non-forested areas. They are common and not considered threatened or endangered. Commercial harvesting of other kangaroo and wallaby species is not permitted.

The commercial kangaroo industry has management goals based on principles of sustainability (DSEWPaC 2011b). Annual quotas are set for each species by the relevant state agencies and endorsed by the Australian Government under delegated authority provided by approved species management plans. The annual harvest quotas vary from year to year, based on consideration of population trends, previous harvests and seasonal conditions[125]. In some states, subquotas are set regionally and allocated to individual property holders on a permit basis. In all states, commercial harvesting is done under a strict code of practice (NRMMC 2008)[126] and a tag must be attached to each carcass before it can be processed.

125 www.qld.gov.au/environment/plants-animals/wildlife-permits/macropods-quotas

126 www.environment.gov.au/biodiversity/wildlife-trade/publications/national-codes-practice-humane-shooting-kangaroos-and-wallabies

Figure 2.34: Long-term population, quota and harvest data for eastern grey kangaroo and common wallaroo in Queensland, 1992–2014



S.E., standard error

Notes:

Harvest data is combined commercial harvest and take from damage mitigation permits. Commercial harvest quotas are based on survey estimates from the previous year.

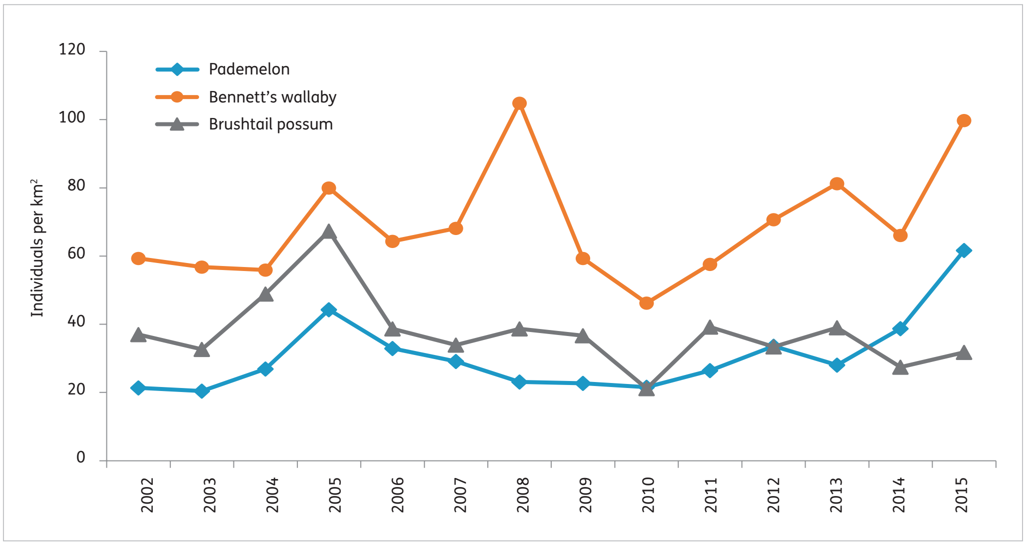
Source: Replotted from data in Queensland Department of Environment and Heritage (2015).

The abundance of Tasmanian pademelon and Bennett's wallaby is monitored annually in Tasmania (Figure 2.35) . Recreational or commercial hunter's licences must be obtained to take these species. The number of commercial game licences issued has changed little over the past decade, but has declined substantially in the longer term (Figure 2.36) . The number of commercial licences is a small proportion of the number of licences issued for non-commercial shooting of wallabies (shooting to reduce populations that are damaging agricultural and forestry crops). The number of non-commercial licences has increased marginally over the past five years, and significantly in the longer term (Figure 2.37).

The abundance of red kangaroos, eastern grey kangaroos and common wallaroos is monitored in Queensland by aerial survey. Harvest quotas are set at 10–20% of the population per region. Figure 2.34 shows data from long-term monitoring of macropod populations, and quotas and harvest levels, for eastern grey kangaroo and common wallaroo in Queensland to 2014. The majority of harvesting occurs in the central harvest zone in Queensland, with smaller harvests in the eastern and western zones (Queensland Department of Environment and Heritage 2015); the eastern zone includes relatively more forest.

The abundance of Tasmanian pademelon and Bennett's wallaby is monitored annually in Tasmania (Figure 2.35)[127]. Recreational or commercial hunter's licences must be obtained to take these species. The number of commercial game licences issued has changed little over the past decade, but has declined substantially in the longer term (Figure 2.36)[128]. The number of commercial licences is a small proportion of the number of licences issued for non-commercial shooting of wallabies (shooting to reduce populations that are damaging agricultural and forestry crops). The number of non-commercial licences

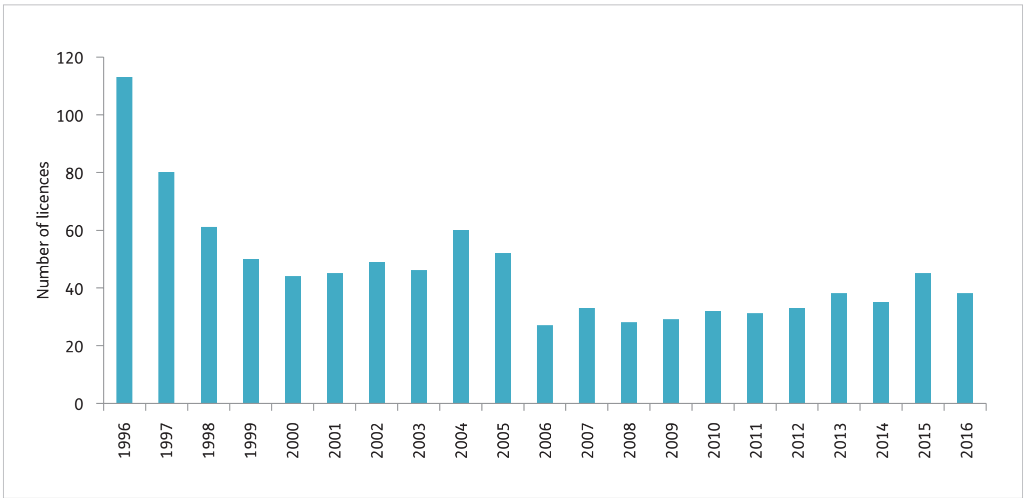
Figure 2.35: Population density of macropods in Tasmania from annual spotlight surveys, 2002–15



Source: DPIPWE (2015a).

The data used to create this figure, together with other data for Indicator 2.1d, are available in Microsoft Excel via www.doi.org/10.25814/5bda8a9ed76d5

Figure 2.36: Wallaby hunting commercial game licences sold, Tasmania, 1996–2016



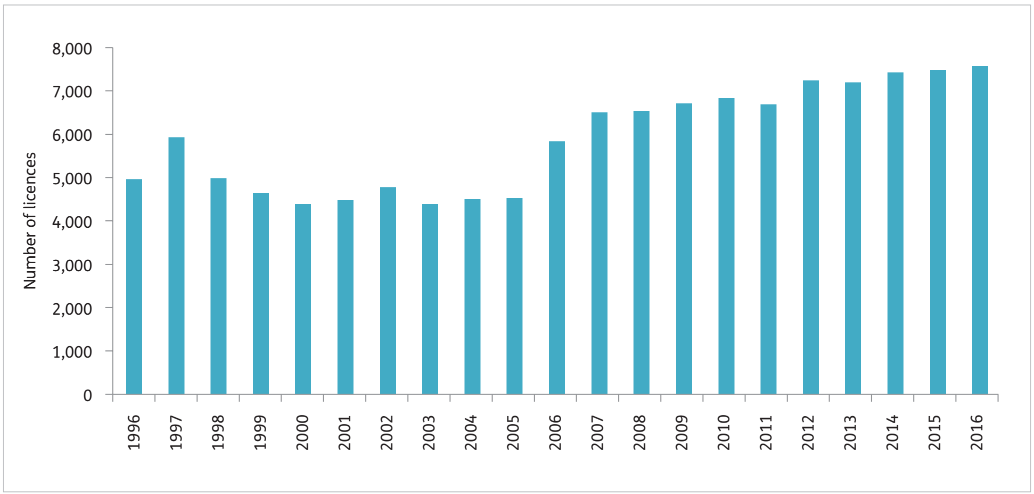
Source: FPA (2012, 2017a).

The data used to create this figure, together with other data for Indicator 2.1d, are available in Microsoft Excel via www.doi.org/10.25814/5bda8a9ed76d5

127 www.environment.gov.au/biodiversity/wildlife-trade/natives/wild-harvest/kangaroo-wallaby-statistics/wallaby; www.environment.gov.au/biodiversity/wildlife-trade/natives/wild-harvest/kangaroo-wallaby-statistics/kangaroo-tas

128 The number of licences issued is not a direct indicator of the number of animals taken, because a wallaby hunting licence does not specify the number of animals a licence holder may take. Instead, the Tasmanian wallaby harvest is monitored using property-specific take figures from wallaby crop protection permit holders (dpipwe.tas.gov.au/wildlife-management/management-of-wildlife/game-management/game-hunting-requirements).

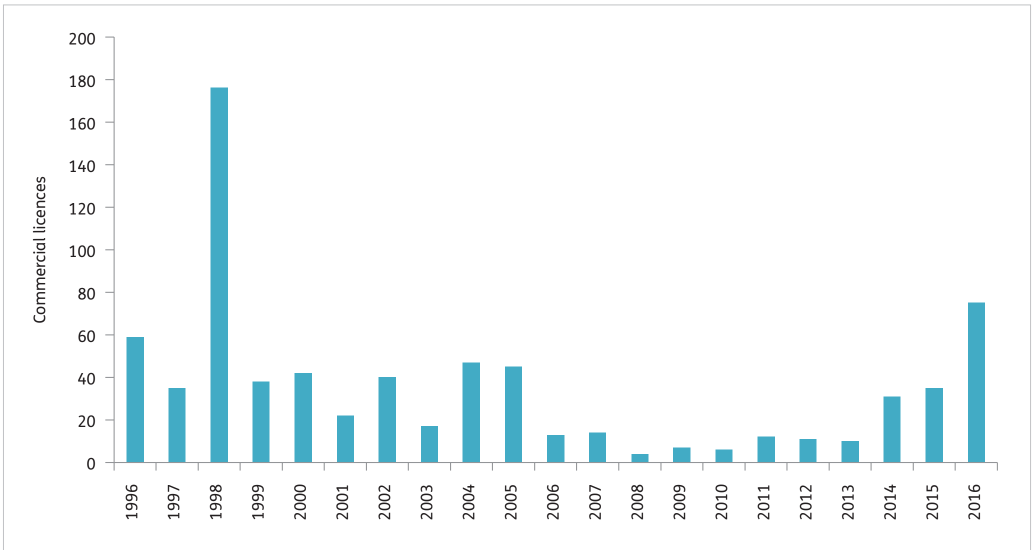
Figure 2.37: Wallaby hunting non-commercial game licences sold, Tasmania, 1996–2016



Source: FPA (2012, 2017a).

The data used to create this figure, together with other data for Indicator 2.1d, are available in Microsoft Excel via www.doi.org/10.25814/5bda8a9ed76d5

Figure 2.38: Licences for commercial harvest of common brushtail possums in Tasmania



Source: FPA (2012, 2017a).

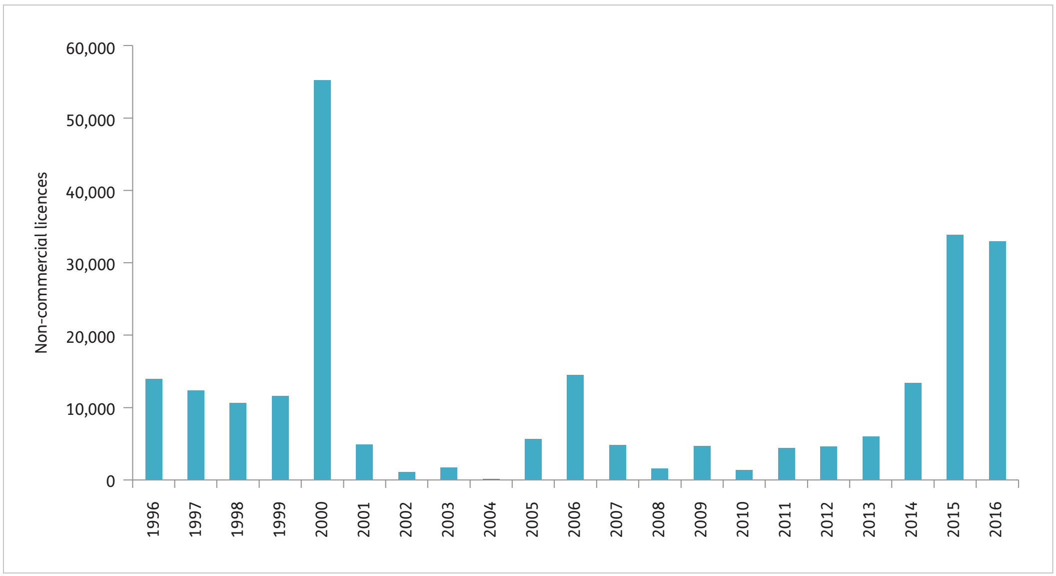
The data used to create this figure, together with other data for Indicator 2.1d, are available in Microsoft Excel via www.doi.org/10.25814/5bda8a9ed76d5

has increased marginally over the past five years, and significantly in the longer term (Figure 2.37).

Common brushtail possums (*Trichosurus vulpecula*) are harvested in Tasmania for skin and meat (Figure 2.38) in accordance with a management plan approved under the EPBC Act (DPIPWE 2015b). Considerably more possums are killed without commercial harvest, to protect agricultural and forestry crops from damage (Figure 2.39). Commercial hunters must be licenced, are limited to a quota and must comply with a code of practice when shooting the possums (DPIPWE 2012). Commercial hunting is not permitted in forests reserved for conservation. The species population is monitored annually (Figure 2.35). At no time has any level of harvest been shown to endanger regional possum populations (DPIPWE 2015a).

Forest-dwelling exotic fauna species are also harvested in Australia for meat and skins. Many of these, such as pigs, goats and water buffalo, are officially declared pests that damage forests. In these cases, the harvesting rate is usually determined by forest management considerations rather than ecological sustainability criteria. Deer are harvested for venison and antlers from forests in New South Wales, Tasmania and Victoria. In Tasmania, annual harvest of male deer during 1996–2015 varied from a low of 544 animals in 1999 to a peak of 1,996 animals in 2015 (FPA 2017a).

Figure 2.39: Licences for non-commercial harvest of common brushtail possums in Tasmania



Source: FPA (2012, 2017a).

The data used to create this figure, together with other data for Indicator 2.1d, are available in Microsoft Excel via www.doi.org/10.25814/5bda8a9ed76d5

Table 2.16: Proportions of honey production from public and private land, 2014–15

	Proportion of honey production, 2014–15 (%)						
Land tenure	**NSW**	**Vic.**	**Qld.**	**SA**	**Tas.**	**WA**	**Australia**
State forests	26	40	22	0	51	37	25
National parks	14	11	5	7	30	26	12
Other public land	1	8	1	0	0	0	2
Total public land	41	58	28	7	82	63	39
Private land	59	42	72	93	18	37	61
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Totals may not tally due to rounding.

Source: ABARES Australian Honey Bee Industry Survey 2014–15 (van Dijk et al. 2016). This survey sampled registered beekeeping businesses from New South Wales, Victoria, Queensland, South Australia, Western Australia and Tasmania that operated 50 or more hives in 2014–15.

This table, together with other data for Indicator 2.1d, is available in Microsoft Excel via www.doi.org/10.25814/5bda8a9ed76d5

Apiary products are another important animal NWFP. Commercial beekeeping occurs in all states and territories of Australia, although honey production occurs mainly along the east coast of Australia[129]. Hives are placed in forests based on the availability of flowering tree and understorey resources, as well as in agricultural areas where the bees forage in crops, and in other introduced vegetation and in remnant native vegetation.

Table 2.16 shows that, in all states except South Australia, a proportion of honey production derives from public land; this is generally forest land[130]. A further proportion of honey production comes from non-agricultural private land (van Dijk et al. 2016), much of which will also be forest or woodland.

State and territory governments regulate apiarists by issuing permits and licences for apiary sites and hives. The numbers of permits and licences are based on on-ground constraints such as road access requirements, necessary distances between sites, and flowering intensity, rather than on an assessment of the potential effects on native flora or fauna.

Potential threats to the sustainability of the honey industry include restrictions on access to native flora due to land clearing for agriculture, rural dieback[131] of forest, bushfires and the conversion of State forest land to reserves or national parks where apiaries may be excluded (RIRDC 2007a), as well as external threats such as colony collapse disorder and varroa mite. Changing climate conditions also affect flowering patterns of forest species. Tree plantations, including of eucalypt species, are unlikely to increase substantially the floral resources available to the beekeeping industry (Somerville 2010).

Other important animal NWFPs are wild-collected crocodile eggs and juveniles that are harvested for use in the farmed crocodile industry in northern Australia (see Indicator 6.1b).

129 www.agrifutures.com.au/farm-diversity/beekeeping-honey-bees/

130 Other data on honey production are provided in Indicator 6.1b.

131 Rural dieback is a collective term used to describe the degradation and loss of vigour of trees and native forest ecosystems as a result of changes in hydrology, salinity and nutrient balances; deterioration in soil attributes; increased pest and pathogen impacts; and changed fire regimes.

Textiles hand-dyed by Anindilyakwa Art Centre artists, Groote Eylandt, Northern Territory, using forest plants.

Indigenous harvest, including traditional use

Indigenous peoples harvest forest products for both traditional and commercial purposes. Indigenous NWFPs include bark for painting, plant parts for weavings, pigments and dyes; small-scale commercial bush foods; and subsistence products such as those used for food and ceremonial purposes. For convenience of classification, Indigenous NWFPs also include wooden carvings and sculptures. The sustainable use of NWFPs is extremely important to Indigenous communities in remote regions of Australia; such products often constitute a significant proportion of local customary and non-welfare cash economies.

Despite the importance of the Indigenous NWFP harvest to the livelihoods of many Indigenous communities, little data and few studies are available to assess its size and impact nationally.

One commercial product is Kakadu plum (*Terminalia ferdinandiana*) which is harvested from the wild under a permit system in the Northern Territory and Western Australia. Assessment of demand, relative to the abundance of the tree and quantity of fruit produced, suggests that currently the risk of widespread, uniform over-harvest is low (Gorman et al. 2016), but there is a risk of localised overharvest at accessible high-density sites (Whitehead et al. 2006). Increased market demand could be met sustainably in the short term, if wild harvest was coordinated across a number of regions (Gorman et al. 2016). Further information on commercial harvest of Kakadu plum is provided in Indicator 6.1b.

Indicator 2.1e

The area of native forest harvested and the proportion of that effectively regenerated, and the area of plantation harvested and the proportion of that effectively re-established

Rationale

This indicator is used to assess the success of the re-establishment of forests after harvesting. Re-establishment is critical to the maintenance of the productive capacity of the forest.

Key points

- Effective regeneration of harvested multiple-use public native forest was reported for New South Wales, Queensland, Tasmania, Victoria and Western Australia for various time periods in the range 1993–94 to 2015–16.
  - Across the period 2011–12 to 2015–16, the annual average proportion of harvested multiple-use public native forest that was effectively regenerated, as assessed against stocking standards, was reported as 79% in New South Wales, 100% for Queensland, 95% for Tasmania and 92% for Victoria. For Western Australia, adequate regeneration was reported, with more detailed reporting to be provided in the mid-term performance review of the *Forest Management Plan 2014–2023*.
  - Factors contributing to low regeneration rates in Victoria and New South Wales included drought, fire, poor seed reserves, and difficulties in carrying out regeneration burns or mechanical disturbance.
- Re-establishment of commercial plantations is also assessed against stocking standards.
  - The average rate of commercial plantation re-establishment between 2011–12 and 2015–16 was 38,500 hectares per year. The average area proportion of re-established commercial plantation that met stocking standards over this period varied between 93% and 99% between jurisdictions. Data are also available separately for public and private plantations.
- Tasmania also reported compliance with regeneration standards for harvesting of private native forests, and compliance with stocking standards for re-establishment of public and private plantations, using performance rating systems developed with the Tasmanian Forest Practices Authority.

The term ‘forest regeneration’ usually refers to new trees that establish in a forest after harvesting, fire, or other disturbance agents (e.g. wind or flood damage) have removed some or all trees from the forest overstorey. Regeneration can occur naturally or through human management intervention (e.g. burning, mechanical disturbance, sowing seed).

Regeneration is a targeted outcome of harvesting under many of the silvicultural systems used in native forests. State jurisdictions apply codes of forest practice and other regulatory instruments to ensure the effective regeneration and/or restocking of harvested multiple-use public native forests to specified stocking standards. Some states also apply codes of practice and regulations to private native forests.

Where specified regeneration and restocking standards are not achieved, remedial action is carried out by the grower or manager, including by state government agencies on multiple-use public native forests. This indicator provides annual information on the area regenerated after harvesting, the proportion of the total area of harvesting that this represents, and the success of the regeneration effort.

For public and private plantations, this indicator reports where possible on the area planted, or re-planted after final harvesting, and the success of the planting or re-planting effort. Codes of practice apply to commercial plantations, and remedial action is carried out by the grower or manager where specified restocking standards are not achieved. National data have been collated to report on plantation establishment and its performance against stocking standards for the SOFR 2018 reporting period 2011–12 to 2015–16. Separate data are also available from restocking or re-planting audits carried out in Tasmania on public and private native forests and plantations.

Native forest regeneration

Ensuring effective regeneration of native forest after timber harvesting is a fundamental requirement of sustainable forest management, since regeneration determines the long-term productivity, growth, dynamics and composition of forest stands. Managers of multiple-use public forests are required by codes of forest practice, silvicultural manuals or guidelines, and other regulatory instruments to assess quantitatively the effective regeneration (by stocking, density, or species composition) of areas harvested for timber production, and to report the results publicly[132].

Depending on the state, effective regeneration is judged by a combination of meeting a regeneration standard that prescribes the required stocking, and meeting specified silvicultural regeneration goals and objectives based on sustainable forest management objectives. For example, some of the silvicultural treatments applied to certain forest types promote the establishment of a cohort of trees for the next harvest. The guidelines, goals, and objectives also consider both sustainable use and conservation requirements.

The states have established standards for the effective regeneration of multiple-use public native forests; some also have standards for private forests. Regeneration is usually assessed 1–3 years after harvesting, although the period is longer in some jurisdictions. Further follow-up treatments to promote regeneration, or supplementary planting with local tree species, are carried out if regeneration standards are not met at the first assessment. The definitions of, and standards for, effective regeneration vary between jurisdictions, but all aspire to stocking the site in a way that accords with silvicultural manuals or guidelines, goals and objectives.

Regional differences in forest type, climatic and biophysical conditions, and management objectives mean that each state has its own method for assessing the success or effectiveness of regeneration, and its own range of silvicultural techniques to ensure regeneration after harvesting (see Indicator 2.1a). Assessment techniques are similar across jurisdictions for even-aged native forests, but for multi-aged forests (in which a single stand may contain trees of markedly different growth stage, age and height) are more variable across jurisdictions.

Retention of seed trees, use of prescribed fire, and mechanical site disturbance are variously employed to encourage regeneration in multiple-use public native forests. These methods are sometimes combined with aerial sowing of seed collected from the harvest site (or from a similar local area termed a 'seed zone') before harvesting of trees. Other silvicultural systems require adequate on-site regeneration to be present in the harvesting area before wood harvesting takes place; shelterwood and native cypress pine silvicultural systems are examples. Promotion of a subsequent regeneration event is not a priority where young regrowth stands are thinned.

In New South Wales, effective regeneration in multiple-use public native forests for the period 2001–02 to 2015–16 (covering the SOFR 2008, SOFR 2013 and SOFR 2018 reporting periods) was generally above 70% (see Table 2.17). In the three years when regeneration rates were below 70% (2001–02, 2006–07 and 2012–13), the impact of drought was a significant factor in the reduced regeneration of some of these forests (successful regeneration requires adequate soil moisture for seedling establishment). Wildfires also affected regeneration on harvested areas in some of these forests. In the SOFR 2018 reporting period 2011–12 to 2015–16, effective annual regeneration in multiple-use public native forests varied from 69% to 91%. Annual averages for the three SOFR reporting periods from 2001–02 varied from 79% to 85% (Table 2.17).

In New South Wales, a sampling process to assess effective regeneration with commercial species is undertaken in areas where regeneration is a targeted outcome from wood harvesting, where the site-based assessment determines a risk of regeneration failing, or where forests are of types harvested with silvicultural systems that require post-harvest regeneration assessments. A regeneration threshold of 65% of assessed plots in any given harvest area is considered adequate stocking. The stocked proportion of areas that do not meet the 65% threshold are not specifically reported, but these areas are listed for further assessment and potential remedial actions. Additional silvicultural treatment is undertaken when regeneration standards are not met, and the outcome of such treatment is not included in the effective regeneration data reported in Table 2.17. The proportion effectively regenerated is the area effectively regenerated compared to the area harvested[133]. The sampling approach for determining the proportion of harvested area effectively regenerated is consistent for all years reported. The Forestry Corporation of New South Wales[134] (FCNSW) is planning to move towards remote assessments using drones in future to allow census recording (rather than sampling) of regeneration success.

In Victoria, the area of multiple-use public native forest treated and regenerated after wood harvesting has been reported since 1993–94, covering all five SOFR reporting periods (Table 2.18). Prior to 2001, there was a 4–5 year lag between reporting regeneration treatment and assessment of effectiveness. Since 2004, results have been reported annually, with effectiveness assessed sooner (from 2007, up to 3 years after treatment). A harvested coupe that does not meet the minimum standard is further treated, followed by a re-survey for the effectiveness of regeneration 18–30 months after the additional treatment, with the goal that over time all the harvested area is effectively restocked

132 There is no native forest harvesting in the Australian Capital Territory or South Australia, and very limited native forest harvesting in the Northern Territory.

133 More precisely, the proportion effectively regenerated is the area effectively regenerated where regeneration is a targeted outcome compared to the area harvested where regeneration is a targeted outcome: see Table 2.17.

134 Until January 2013, Forests NSW.

Table 2.17: Area proportion of harvested multiple-use public native forest effectively regenerated, New South Wales, 2001–02 to 2015–16

Year	Total area planned for harvest (hectares)[a]	Net area harvested (hectares)[b]	Net area harvested where regeneration is a targeted outcome (hectares)[c]	Net area effectively regenerated where regeneration is a targeted outcome (hectares)[d]	Proportion effectively regenerated (%)
2001–02	50,351	n.r.	n.r.	n.r.	68[e]
2002–03	49,062	n.r.	n.r.	n.r.	87[e]
2003–04	45,746	n.r.	n.r.	n.r.	86[e]
2004–05	42,923	29,009	3,990	3,312	83
2005–06	43,709	23,569	5,045	3,733	74
2006–07	44,806	24,422	3,709	2,337	63
2007–08	52,960	26,677	5,418	5,093	94
2008–09	27,952	18,127	3,616	2,929	81
2009–10	38,499	16,603	3,845	3,653	95
2010–11	27,484	14,067	5,382	4,951	92
2011–12	28,054	23,080	7,837	6,034	77
2012–13	31,221	30,941	5,812	4,010	69
2013–14	23,807	18,167	6,365	4,965	78
2014–15	22,235	22,660	6,975	5,650	81
2015–16	17,878	13,837	4,106	3,736	91
Annual average for each SOFR reporting period					
2001–02 to 2005–06	46,358	n.r.	n.r.	n.r.	80
2006–07 to 2010–11	38,340	19,979	4,394	3,792	85
2011–12 to 2015–16	24,639	21,737	6,219	4,879	79

n.r., not reported.

a Total area planned for harvest (see also Table 2.5, Indicator 2.1a).

b Net area harvested is the actual area harvested as reported in the FCNSW Forest Resource Event Database from 2004–05 onwards. Annual reporting prior to this time only reported the area planned for harvest in harvest units operated in during that financial year.

c Regeneration targets are not required when thinning existing growing stock or releasing advanced growth.

d In harvested areas where regeneration is a targeted outcome, FCNSW uses a sampling process to assess regeneration success. A similar sampling process is also used to monitor regeneration where an initial site-based assessment determines there is a risk of regeneration failing.

e Area proportion data supplied by New South Wales.

Source: Forestry Corporation of NSW.

This table, together with other data for Indicator 2.1e, is available in Microsoft Excel via www.doi.org/10.25814/5bda8a9ed76d5

(VicForests 2011a). Harvested coupes are transferred from the commercial harvesting agency (VicForests) back to the custodial managing agency (Department of Environment, Land, Water and Planning, DELWP[135]) once the coupe has been adequately regenerated and meets coupe regeneration handover guidelines.

Table 2.18 shows, for reporting years 1993–94 to 2015–16, the area of harvested multiple-use public native forest in Victoria that received an initial regeneration treatment, the area that met the standard and so was assessed as effectively regenerated (including previously treated areas that were supplementary seeded or further treated), and the ratio between these two areas, which is the proportion effectively regenerated. Effective annual regeneration varies from 44% to 125%, with a long-term average success rate of 84% (the inclusion of re-treated areas explains why this value can exceed 100% in some years: see notes below Table 2.18). Annual averages for the five SOFR reporting periods varied from 72% to 92%. Low regeneration occurred in years affected by drought, bushfire, low availability of viable seed, or an inability to carry out adequate regeneration burns or mechanical disturbance. Higher levels of regeneration occurred in years with favourable conditions for regeneration establishment, or where regeneration of areas from previous years has reached a standard that can be assessed as effectively regenerated. Harvest coupes that have not reached the regeneration standards at the first attempt are increasingly difficult to regenerate.

In Western Australia, the *Forest Management Plan 2014–2023* (CCWA 2013) and previous forest management plans (CALM 1994; CCWA 2004) that cover all the main wood production areas in the state's south-west, together with supporting guidance documents such as the silvicultural guidelines, require that regeneration success and effective stocking rates be monitored in publicly owned native forests and pine plantations. In mixed-age jarrah (*Eucalyptus marginata*) forest, the regeneration stocking target is that no more than 5% of the area regenerated annually will require remedial action because it is understocked. In karri (*E. diversicolor*) forest, the regeneration stocking rates within harvested even-aged forest are also assessed after the first winter, and infill planting is undertaken if the stocking of patches falls below agreed standards. The average annual area

135 Until January 2015, the Department of Environment and Primary Industries.

Table 2.18: Area of multiple-use public native forest treated for regeneration and area effectively regenerated, Victoria, 1993–94 to 2015–16

Reporting year	Total harvested area treated for regeneration (hectares)	Total area effectively regenerated (hectares)	Proportion of total harvested area effectively regenerated (%)
1993–94	9,328	6,987	75
1994–95	6,742	5,902	88
1995–96	8,961	8,046	90
1996–97	6,650	5,050	76
1997–98	5,590	5,140	92
1998–99	6,730	5,820	86
1999–2000	7,714	6,939	90
2000–01	8,119	6,988	86
2001–02	6,964	6,129	88
2002–03	5,810	4,984	86
2003–04	5,817	4,968	85
2004–05	4,556	2,655	58
2005–06	4,749	2,112	44
2006–07	4,545	4,062	89
2007–08	4,997	3,367	67
2008–09	4,466	3,050	68
2009–10	4,263	5,311	125
2010–11	4,804	4,137	86
2011–12	4,298	4,055	94
2012–13	3,327	3,397	102
2013–14	2,981	2,242	75
2014–15	4,331	3,459	80
2015–16	4,820	5,194	108
Annual average for each SOFR reporting period			
1993–94 to 1995–96	8,344	6,978	84
1996–97 to 2000–01	6,961	5,987	86
2001–02 to 2005–06	5,579	4,170	72
2006–07 to 2010–11	4,615	3,985	87
2011–12 to 2015–16	3,951	3,669	92

Notes:

There is a time lag between regeneration treatment and assessment of the success of the regeneration. In addition, areas not effectively regenerated are subject to subsequent remedial action (e.g. by supplementary seeding), but areas of follow-up treatment in a year are not included in the figures for the total harvested area treated for regeneration in that year. Consequently, the total area effectively regenerated in a year may relate both to areas harvested in that year and to areas harvested in previous years, and can be higher than the total area treated for regeneration in that year.

Silvicultural guidelines were amended in 2013, but with no significant changes to guidelines applying to regeneration stocking.

Source: SOFR 2013, Victorian Department of Economic Development, Jobs, Transport and Resources, VicForests.

This table, together with other data for Indicator 2.1e, is available in Microsoft Excel via www.doi.org/10.25814/5bda8a9ed76d5

harvested and regenerated has declined from 11,471 hectares in the period 2001–02 to 2005–06 (SOFR 2008 reporting period) to 6,768 hectares in the period 2011–12 to 2015–16 (SOFR 2018 reporting period) (Table 2.19).

Key performance indicators have been developed for public reporting of the timeliness and effectiveness of regeneration, and are audited and reported by the Conservation Commission of Western Australia (CCWA 2012, Key Performance Indicator 10, *Effectiveness of regeneration of native forest and plantation*). Effectiveness of karri and jarrah regeneration, as well as re-establishment of *Pinus* plantations, is reported in this Key Performance Indicator. Silvicultural guidelines are reviewed and updated in response to outcomes of monitoring regeneration success (Burrows et al. 2011).

Table 2.19 summarises the effectiveness of regeneration after harvesting in multiple-use public native forests in Western Australia covering the last three SOFR reporting periods. Jarrah regeneration was 100% for all the years reported, and karri regeneration varied from 97% to 100% (CCWA 2012). Western Australia has experienced 100% or nearly 100% effective regeneration of harvested multiple-use public native forest for all years reported until 2009–10 (SOFR 2008 and SOFR 2013 reporting periods). Assessments undertaken by Western Australia but not reported here indicate adequate regeneration was achieved in areas sampled for karri and jarrah forest during the period 2010 to 2015 (DBCA, personal communication).

Table 2.19: Area of multiple-use public native forest effectively regenerated, Western Australia, 2001–02 to 2015–16

Reporting year	Total area harvested (hectares)[a]	Proportion of harvested area effectively regenerated (%)[b]
2001–02	16,630	100.00
2002–03	13,950	100.00
2003–04	9,725	100.00
2004–05	9,610	99.94
2005–06	7,440	99.94
2006–07	9,670	99.98
2007–08	8,820	99.90
2008–09	7,640	100.00
2009–10	10,660	99.65
2010–11	6,140	n.r.
2011–12	7,490	n.r.[c]
2012–13	7,780	n.r.[c]
2013–14	6,730	n.r.[c]
2014–15	5,480	n.r.[c]
2015–16	6,360	n.r.[c]
Annual averages for SOFR reporting periods		
2001–02 to 2005–06	11,471	100.0
2006–07 to 2010–11	8,586	99.9
2011–12 to 2015–16	6,768	n.r.[c]

n.r., not reported in this format

a Total forest area harvested is the gross harvested area and includes jarrah forest harvested to a range of silvicultural objectives, but excludes areas cleared for mining.

b Proportion of harvested area effectively regenerated, based on harvested areas where the silvicultural objectives of the silvicultural systems require regeneration establishment in the harvested area and follow-up assessment for effectiveness, and calculated as the weighted average of regeneration success reported for karri and jarrah regeneration for that year. Regeneration success can relate to areas harvested 18–30 months previously.

c Western Australia reported that, across these years, adequate regeneration was achieved in all areas of harvested karri within 18 months, and in most areas of harvested jarrah within 30 months. More detailed reporting will be provided in the mid-term performance review of the Forest Management Plan 2014–2023.

Source: CCWA (2012), Western Australian Department of Environment and Conservation, Western Australian Department of Biodiversity, Conservation and Attractions.

This table, together with other data for Indicator 2.1e, is available in Microsoft Excel via www.doi.org/10.25814/5bda8a9ed76d5

In Tasmania under the Tasmanian Forest Practices Code 2015 (FPA 2015b), which applies to public and private native forests and plantations, sowing and planting mixtures applied to native forests must approximate the natural composition of the canopy trees of the forest before wood harvesting. The code also requires that regeneration surveys in eucalypt forest be conducted one year after clearfelling or two years after partial harvesting. The stocking standard is based on the number and spatial distribution of acceptable seedlings, saplings or trees that occur within the area being assessed, and prescriptions are tailored to each forest type and silvicultural system. Where surveys show that survival is less than the prescribed stocking, additional treatment measures to increase stocking to the prescribed stocking are applied.

Forestry Tasmania reports annually on the level of regeneration achieved in all harvested native forest areas in multiple-use public forests. Each year from 1998–99 to 2015–16, covering four SOFR reporting periods (SOFR 2003 to SOFR 2018), Forestry Tasmania exceeded its regeneration success target of 85% of the regenerated area meeting prescribed stocking standards (Table 2.20). In the majority of reporting years, greater than 90% of the regenerated area met the stocking standard, and Forestry Tasmania averaged 93–96% effective annual regeneration for the four SOFR reporting periods.

Tasmania is the only state or territory to report compliance with regeneration standards for wood harvesting from both public and private native forests. In 2003–04, the Tasmanian Forest Practices Authority (FPA) introduced a performance rating system to measure compliance with regeneration standards for public and private native forest and plantations. The performance rating system had a maximum possible rating of 'four', and a minimal compliance rating of 'three' was considered acceptable. In 2014–15, the rating system was changed to 3.0 as both the acceptable level and maximum rating. Each year, a random sample of Forest Practices Plans were included in annual assessment programs run by the FPA.

Table 2.21 presents the results for regeneration of native forest across management tenures from 2003–04 to 2015–16, separately for private industrial managers, private independent managers and state forest. During the period from 2003–04 to 2013–14, operations in state forests averaged a rating of 3.6, with a minimum of 3.4. A rating of 3.0 was recorded for operations in state forests in 2014–15 under the new rating system, and a rating of 2.3 was recorded in 2015–16.

For the period 2004–05 to 2013–14, operations under private industrial forest managers averaged 3.5, with the rating for one year (2004–05) of 2.6 being below the minimum acceptable compliance level. Operations under private

Table 2.20: Area of regenerated multiple-use public native forest meeting stocking standards, Tasmania, 1998–99 to 2010–11

Reporting year	Regeneration year: Eucalypt clearfelling and partial logging	Regeneration year: Rainforest/ blackwood swamp	Total area harvested and regenerated (hectares)	Total area that achieved standard (hectares)	Proportion of total area that achieved standard (%)
1998–99	1995–96	1993–94	4,006	3,815	95
1999–2000	1996–97	1994–95	5,466	5,184	95
2000–01	1997–98	1995–96	4,145	4,011	97
2001–02	1998–99	1996–97	4,808	4,568	95
2002–03	1999–2000	1997–98	4,148	3,837	93
2003–04	2000–01	1998–99	5,526	5,141	93
2004–05	2001–02	1999–2000	6,569	6,526	99
2005–06	2002–03	2000–01	7,226	6,942	96
2006–07	2003–04	2001–02	9,445	9,244	98
2007–08	2004–05	2002–03	10,207	10,010	98
2008–09	2005–06	2003–04	7,522	7,002	93
2009–10	2006–07	2004–05	6,882	6,220	90
2010–11	2007–08	2005–06	7,820	6,888	88
2011–12	2008–09	2006–07	9,377	9,002	96
2012–13	2009–10	2007–08	9,190	8,639	94
2013–14	2010–11	2008–09	7,414	7,192	97
2014–15	2011–12	2009–10	4,580	3,985	87
2015–16	2012–13	2010–11	2,994	2,994	100
Annual average for each SOFR reporting period					
1996–97 to 2000–01	n.a.	n.a.	4,539	4,337	96
2001–02 to 2005–06	n.a.	n.a.	5,655	5,403	95
2006–07 to 2010–11	n.a.	n.a.	8,375	7,873	93
2011–12 to 2015–16	n.a.	n.a.	6,711	6,362	95

n.a., not applicable
Source: FPA (2017a).

This table, together with other data for Indicator 2.1e, is available in Microsoft Excel via www.doi.org/10.25814/5bda8a9ed76d5

independent forest managers recorded four years that were below minimum acceptable compliance levels over this period, and an average rating reported as 3.0. A rating of 3.0 was recorded in 2015–16 for operations under private independent forest managers under the new rating system, a substantial improvement on the rating of 1.7 recorded for 2014–15.

In Queensland, single-tree selection silvicultural systems that suit the ecology of the eucalypt and cypress pine forest types have been applied since 2000 to the harvest of wood products from multiple-use public native forests. These systems retain a mix of canopy trees and regeneration of various ages. In these forest types, regeneration is generally established continually and naturally from seed, coppice or lignotubers in the gaps produced by harvesting, associated soil disturbance, and/or post-harvest burning. Effective regeneration is monitored on harvested areas of multiple-use public native forests through the post-harvest audit process conducted by the Queensland Parks and Wildlife Service. Effective regeneration has been reported as being 100% since 2000–01 for three SOFR reporting periods (SOFR 2008, SOFR 2013 and SOFR 2018). The areas harvested and effectively regenerated in the five years from 2011–12 to 2015–16 were 34 thousand, 35 thousand, 35 thousand, 40 thousand and 38 thousand hectares respectively (Table 2.6 in Indicator 2.1a reports annual harvest figures in previous years for multiple-use public native forest in Queensland).

Commercial plantation establishment and re-establishment

The size of Australia's commercial plantation estate depends on the establishment of new plantations on land not previously used for plantation forestry, and the extent to which existing plantations are re-established after clearfell harvesting at the end of a rotation. The decision to re-establish plantations, especially short-rotation hardwood plantations, depends on factors such as site suitability, previous yield, grower intent, market demand and alternative land uses.

Establishment of new commercial plantations in Australia has decreased over the last decade (Figure 2.40), and the total plantation estate decreased marginally between 2011–12 and 2015–16. The average annual rate of commercial plantation establishment during the 2018 SOFR reporting period was 2,000 hectares, a substantial decrease from 48,300 hectares

Table 2.21: Annual performance rating for regeneration in native forest operations, Tasmania, 2003–04 to 2010–11

Reporting year	Private industrial	Private independent	State forest	All tenures
Rating system 2003–04 to 2013–14				
2003–04	3.3	4.0	3.5	3.4
2004–05	2.6	2.9	3.4	3.0
2005–06	3.3	3.5	3.8	3.6
2006–07	3.4	2.4	3.7	3.4
2007–08	3.4	3.0	3.8	3.5
2008–09	3.5	3.1	3.7	3.5
2009–10	3.4	3.0	3.5	3.3
2010–11	3.6	3.5	3.6	3.6
2011–12	3.7	3.0	4.0	3.5
2012–13	4.0	2.5	3.8	3.3
2013–14	4.0	2.8	3.4	3.2
Average	**3.5**	**3.0**	**3.6**	**3.4**
New rating system				
2014–15	3.0	1.7	3.0	2.7
2015–16	–	3.0	2.3	2.8

–, no native forest operations of that type were assessed that year.

Notes:

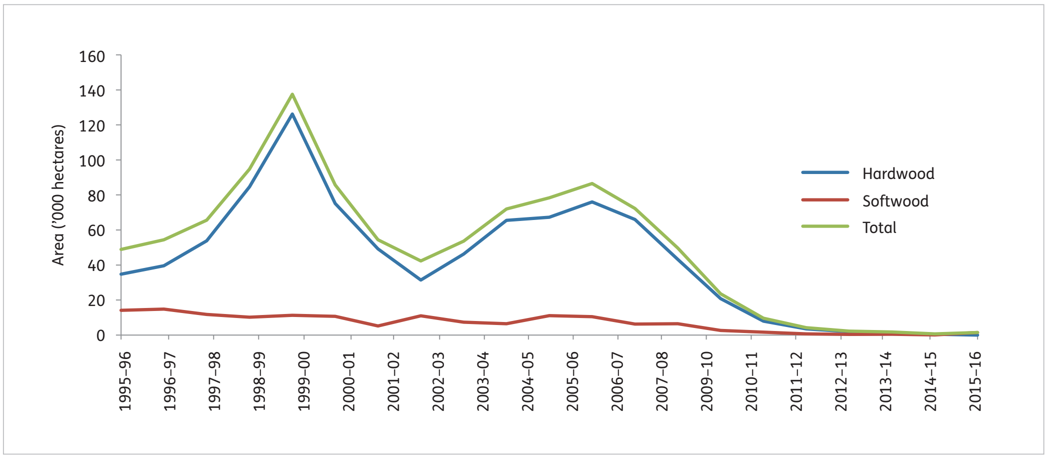
The rating scheme applied from 2003–04 to 2013–14 had a maximum rating of 4.0, with a rating of 3.0 being considered acceptable. A new rating scheme was applied after 2014–15 where the rating of 3.0 was both the acceptable and the maximum rating. The 'all-tenures' (state-wide) performance rating is calculated as the weighted mean of the total sample (FPA 2016a).

Data are for the random sample of Forest Practices Plans that were included in annual assessment program run by the FPA.

Source: FPA (2017a).

This table, together with other data for Indicator 2.1e, is available in Microsoft Excel via www.doi.org/10.25814/5bda8a9ed76d5

Figure 2.40: New commercial plantation establishment, Australia



Source: ABARES (2016b), Downham and Gavran (2017), National Plantation Inventory.

The data used to create this figure, together with other data for Indicator 2.1e, are available in Microsoft Excel via www.doi.org/10.25814/5bda8a9ed76d5 per year in the 2013 SOFR reporting period. In commercial plantations, rates of successful establishment are typically above 90%.

Most public and private plantation growers and managers have internal management systems to assess plantation restocking after establishment or re-establishment, and prescribe remedial treatment if needed. SOFR 2013 provided data on historical establishment stocking success for public softwood plantations in New South Wales, South Australia and Western Australia, and public hardwood plantations in New South Wales. For the SOFR 2018 reporting period, ABARES surveyed plantation growers and managers nationally regarding annual plantation re-establishment and the proportion meeting stocking standards. Responses are summarised by jurisdiction in Table 2.22, for public tree ownership in Table 2.23, and for private tree ownership in Table 2.24.

In 2015–16, there were 48,900 hectares of commercial plantation forest area re established in Australia; the average rate of re-establishment between 2011–12 and 2015–16 was 38,500 hectares per year (Table 2.22). Victoria had the largest contribution to Australia's average yearly commercial plantation re-establishment with 11,000 hectares (29%), followed by New South Wales plus the Australian Capital Territory with 10,500 hectares (27%) and Western Australia plus the Northern Territory with 6,200 hectares (16%). The average area proportion of re-established commercial plantation meeting stocking standards over the SOFR 2018 reporting period varied between 93% and 99% across jurisdictions.

Seedlings of blue gum (*Eucalyptus globulus*) for plantation establishment or re-establishment.

Total public plantation re-establishment in Australia averaged 12,600 hectares per year between 2011–12 and 2015–16, with the majority (94%) occurring in softwood plantations (Table 2.23). New South Wales and the Australian Capital Territory together accounted for 9,400 hectares (75%) of Australia's average yearly re-established public plantation area, and Western Australia accounted for 2,200 hectares (17%). The average area proportion of re-established public plantation meeting stocking standards over the SOFR reporting period ranged from 97% in New South Wales and the Australian Capital Territory to 100% in South Australia, Tasmania and Victoria.

Table 2.22: Commercial plantation re-establishment and proportion meeting stocking standards, 2011–12 to 2015–16

Jurisdiction	Re-establishment	2011–12	2012–13	2013–14	2014–15	2015–16	Annual average
NSW and ACT[a]	Total area (ha)	8,500	9,900	9,900	12,100	12,200	10,500
	Stocking standard (%)	99	99	93	99	93	96
Qld	Total area (ha)	4,600	2,800	4,000	5,800	7,500	5,000
	Stocking standard (%)	100	100	99	97	100	99
SA	Total area (ha)	1,600	700	1,400	1,200	4,400	1,800
	Stocking standard (%)	99	100	99	93	100	98
Tas.	Total area (ha)	4,100	2,900	2,300	3,300	7,100	3,900
	Stocking standard (%)	93	97	93	94	97	95
Vic.	Total area (ha)	11,300	9,200	10,700	11,300	12,400	11,000
	Stocking standard (%)	94	96	90	90	98	93
WA and NT[b]	Total area (ha)	8,900	5,700	3,600	7,600	5,400	6,200
	Stocking standard (%)	98	100	100	100	83	97
Australia	Total area (ha)	38,900	31,200	31,900	41,400	48,900	38,500
	Stocking standard (%)	96	98	94	95	95	96

[a] Combined data for New South Wales and the Australian Capital Territory.

[b] Combined data for Western Australia and the Northern Territory.

Notes: Data are re-establishment data as reported by major growers and managers, representing around 70% of the total plantation estate.
Stocking standard results apply only to that proportion of the area re-established for which stocking data were provided.
Proportions are calculated as weighted averages.
Totals may not tally due to rounding. Figures are rounded to the nearest 100 hectares.
Source: ABARES.

This table, together with other data for Indicator 2.1e, is available in Microsoft Excel via www.doi.org/10.25814/5bda8a9ed76d5

Table 2.23: Public plantation re-establishment and proportion meeting stocking standards, 2011–12 to 2015–16

Jurisdiction	Re-establishment	2011–12	2012–13	2013–14	2014–15	2015–16	Annual average
NSW and ACT[a]	Hardwood (ha)	700	500	400	200	300	400
	Softwood (ha)	7,700	8,500	9,400	9,900	9,200	8,900
	Total area (ha)	8,400	9,000	9,700	10,200	9,500	9,400
	Stocking standard (%)	99	99	91	99	99	97
SA	Hardwood (ha)[b]	0	0	0	0	0	0
	Softwood (ha)	300	200	400	300	300	300
	Total area (ha)	300	200	400	300	300	300
	Stocking standard (%)	100	100	100	100	100	100
Tas.	Hardwood (ha)	600	200	100	100	300	200
	Softwood (ha)	700	600	400	400	0	400
	Total area (ha)	1,200	800	500	500	300	600
	Stocking standard (%)	100	100	100	100	100	100
Vic.	Hardwood (ha)	nd	nd	nd	nd	nd	nd
	Softwood (ha)	17	14	25	22	25	20
	Total area (ha)	17	14	25	22	25	20
	Stocking standard (%)[c]	100	100	100	100	100	100
WA	Hardwood (ha)	0	0	0	0	0	0
	Softwood (ha)	2,300	2,100	2,000	2,100	2,600	2,200
	Total area (ha)	2,300	2,100	2,000	2,100	2,600	2,200
	Stocking standard (%)	nd	nd	nd	nd	nd	nd
Australia	Hardwood (ha)	1,200	800	400	300	600	700
	Softwood (ha)	10,900	11,400	12,200	12,800	12,100	11,900
	Total area (ha)	12,200	12,100	12,600	13,100	12,700	12,600
	Stocking standard (%)	100	100	96	100	100	99

nd, data not supplied.

[a] Combined data for New South Wales and the Australian Capital Territory.

[b] South Australia has only a small area of public hardwood plantation, and for some years data on their re establishment can be included in the softwood plantation re-establishment figures.

[c] Proportions calculated for softwood plantation area only.

Notes:

Data are re-establishment data as reported by major growers and managers, representing around 70% of the total plantation estate. There are no public plantations in Queensland or the Northern Territory.

Stocking standard results apply only to that proportion of the area re-established for which stocking data were provided.

Proportions calculated as weighted averages.

Totals may not tally due to rounding. Figures are rounded to the nearest 100 hectares.

Source: ABARES.

This table, together with other data for Indicator 2.1e, is available in Microsoft Excel via www.doi.org/10.25814/5bda8a9ed76d5

Total private plantation re-establishment in Australia averaged 25,900 hectares per year between 2011–12 and 2015–16, with 16,800 hectares (65%) occurring in softwood plantations and 9,200 hectares (35%) in hardwood plantations (Table 2.24). Victoria accounted for 11,000 hectares (42%) of Australia's average yearly re-established private plantation area, and Queensland contributed 5,000 hectares (19%). The average proportion of re-established private plantation area meeting stocking standards over the SOFR 2018 reporting period ranged from 92% in Tasmania and Victoria to 99% in Queensland.

Tasmania is the only jurisdiction to report trends in land use following harvest of commercial plantation forests. Table 2.25 provides information on the planned subsequent land use of Tasmanian public and private plantations harvested since 1999–2000. Subsequent land-use options comprise plantation re-establishment, conversion to non-forest land use, and re-establishment of native forest.

During the SOFR 2013 and SOFR 2018 reporting periods, the average annual areas of plantation harvested in Tasmania were similar, at 8,648 hectares and 8,489 hectares, respectively (Table 2.25). However, planned land-use outcomes after plantation harvest were different in the two periods. In the SOFR 2013 reporting period 2006–07 to 2010–11, an annual average of 378 hectares of harvested plantation was converted to non-forest use, whereas in the SOFR 2018 reporting period 2011–12 to 2015–16 an annual average of 1,621 hectares of harvested plantation was converted to non-forest use. This elevated rate of conversion to non-forest use commenced in 2013–14 (Table 2.25).

Table 2.24: Private plantation re-establishment and proportion meeting stocking standard, 2011–12 to 2015–16

Jurisdiction	Re-establishment	2011–12	2012–13	2013–14	2014–15	2015–16	Annual average
NSW	Hardwood (ha)[a]	0	0	0	0	0	0
	Softwood (ha)	100	900	200	2,000	2,700	1,200
	Total area (ha)	100	900	200	2,000	2,700	1,200
	Stocking standard (%)	100	100	100	100	88	94
Qld	Hardwood (ha)	200	100	300	200	300	200
	Softwood (ha)	4,500	2,700	3,700	5,600	7,100	4,700
	Total area (ha)	4,600	2,800	4,000	5,800	7,500	5,000
	Stocking standard (%)	100	100	99	97	100	99
SA	Hardwood (ha)[a]	0	0	0	0	0	0
	Softwood (ha)	1,300	500	1,000	900	4,000	1,500
	Total area (ha)	1,300	500	1,000	900	4,000	1,500
	Stocking standard (%)	99	100	98	89	100	97
Tas.	Hardwood (ha)	1,100	100	100	1,200	5,400	1,600
	Softwood (ha)	1,800	2,000	1,700	1,500	1,400	1,700
	Total area (ha)	2,900	2,100	1,800	2,800	6,900	3,300
	Stocking standard (%)	89	95	89	90	96	92
Vic.	Hardwood (ha)	5,600	2,100	2,800	3,400	2,800	3,300
	Softwood (ha)	5,700	7,100	7,900	7,900	9,600	7,600
	Total area (ha)	11,300	9,200	10,700	11,300	12,400	11,000
	Stocking standard (%)	93	95	88	89	97	92
WA and NT[b]	Hardwood (ha)	6,600	3,600	1,600	5,500	2,800	4,000
	Softwood (ha)[a]	0	0	0	0	0	0
	Total area (ha)	6,600	3,600	1,600	5,500	2,800	4,000
	Stocking standard (%)	98	100	100	100	83	97
Australia	Hardwood (ha)	13,500	6,000	4,800	10,300	11,300	9,200
	Softwood (ha)	13,300	13,100	14,500	17,900	24,900	16,800
	Total area (ha)	26,800	19,100	19,300	28,300	36,200	25,900
	Stocking standard (%)	95	97	94	93	94	95

a Annual re-establishment area figures of less than 50 hectares are rounded to zero.

b Combined data for Western Australia and the Northern Territory.

Notes:

Data are re-establishment data as reported by major growers and managers, representing around 70% of the total plantation estate. There are no private plantations in the Australian Capital Territory.

Stocking standard results apply only to that proportion of the area re-established for which stocking data were provided.

Proportions are calculated as weighted averages.

Totals may not tally due to rounding. Figures are rounded to the nearest 100 hectares.

Source: ABARES.

This table, together with other data for Indicator 2.1e, is available in Microsoft Excel via www.doi.org/10.25814/5bda8a9ed76d5

Table 2.26 reports the performance rating for re-establishment of public and private plantations in Tasmania, based on the performance assessment system used by the FPA. Stocking standards specify the minimum levels of growing stock to maintain a plantation. Forestry Tasmania[136] reports annually on the level of restocking achieved for all plantation establishment operations on state forest, with the stocking success of eucalypt plantations being reported two years after planting operations (FPA 2017a). From 2003–04, a compliance rating of 3.0 was considered the minimum acceptable level, with the maximum rating being 4.0. However, in 2014–15 the rating system was changed with 3.0 being both the acceptable level and the maximum rating. Operations on both private industrial and state forest plantations rated highly, with all years rating above the minimum standard of 3.0, at an average of 3.6 and 3.7 for private industrial operations and operations on state forests, respectively. Operations on private independent plantations rated lower, with an average of 3.5 and a range over time of 2.3–4.0.

136 From July 2017, Sustainable Timber Tasmania.

Table 2.25: Planned subsequent land use (hectares) of harvested plantation forest (public and private), Tasmania, 1999–2000 to 2015–16

		Planned subsequent land use		
Reporting year	**Total plantation harvested**	**Plantation re-establishment**	**Conversion to non-forest use[a]**	**Native forest re-establishment[b]**
1999–2000	3,650	3,600	50	0
2000–01	5,320	5,230	90	0
2001–02	5,710	5,350	360	0
2002–03	7,870	7,740	130	0
2003–04	8,670	8,250	420	0
2004–05	6,770	6,550	220	0
2005–06	8,100	7,590	510	0
2006–07	9,710	9,450	260	0
2007–08	10,370	9,760	610	0
2008–09	7,870	7,360	400	110
2009–10	8,460	7,940	280	240
2010–11	6,830	6,370	340	120
2011–12	4,203	3,691	350	162
2012–13	4,401	3,827	550	24
2013–14	9,301	7,515	1,496	290
2014–15	9,201	6,847	2,313	41
2015–16	15,337	11,879	3,394	64
Annual average for each SOFR reporting period				
1999–2000 to 2000–01	4,485	4,415	70	0
2001–02 to 2005–06	7,424	7,096	328	0
2006–07 to 2010–11	8,648	8,176	378	94
2011–12 to 2015–16	8,489	6,752	1,621	116

[a] Conversion of harvested plantation forest to non-forest land use primarily applies to private plantations. It is minor in state forest where it is restricted to infrastructure requirements (roads, powerlines and dams); such areas are not reported.

[b] Reflects the reforestation of streamside reserves with native species in plantations established prior to the introduction of the Forest Practices Code in 1987.

Source: FPA (2017a).

This table, together with other data for Indicator 2.1e, is available in Microsoft Excel via www.doi.org/10.25814/5bda8a9ed76d5

Radiata pine plantations, Glenelg Highway, Victoria.

Table 2.26: Annual assessment performance rating for re-establishment in plantation operations, Tasmania, 2003–04 to 2015–16

Reporting year	Private industrial	Private independent	State forest	All tenures
Rating scheme 2003–04 to 2013–14				
2003–04	4.0	4.0	3.9	4.0
2004–05	3.3	3.6	3.1	3.3
2005–06	3.9	4.0	3.6	3.8
2006–07	3.8	2.5	3.8	3.7
2007–08	3.6	4.0	3.8	3.7
2008–09	3.3	3.3	4.0	3.4
2009–10	3.4	3.0	3.9	3.4
2010–11	3.5	2.3	4.0	3.4
2011–12	3.3	3.5	3.0	3.3
2012–13	3.7	4.0	4.0	3.8
2013–14	4.0	4.0	–	4.0
Average	**3.6**	**3.5**	**3.7**	**3.6**
New rating system				
2014–15	3.0	3.0	–	3.0
2015–16	2.7	2.8	3.0	2.9

–, no plantation operations of that type were assessed that year.

Notes:

The rating scheme applied from 2003–04 to 2013–14 had a maximum rating of 4.0, with a rating of 3.0 being considered acceptable. A new rating scheme applied after 2014–15 where the rating of 3.0 was both the acceptable and the maximum rating. The 'all-tenures' (state-wide) performance rating is calculated as the weighted mean of the total sample (FPA 2016a).

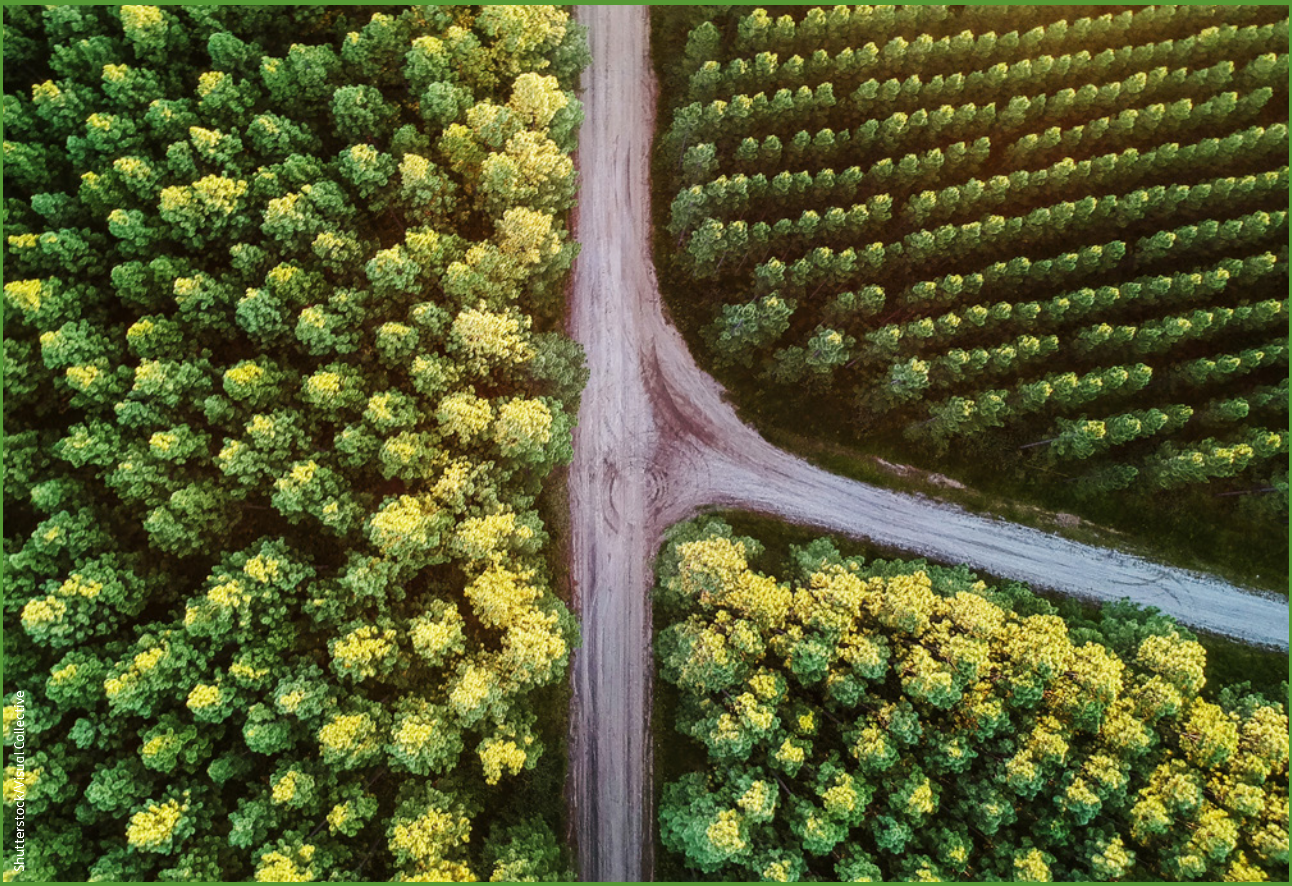
Data are for the random sample of Forest Practices Plans that were included in annual assessment program run by the FPA.

Source: FPA (2017a).

This table, together with other data for Indicator 2.1e, is available in Microsoft Excel via www.doi.org/10.25814/5bda8a9ed76d5

Criterion 3

Maintenance of ecosystem health and vitality



Shutterstock/Visual Collective

Beerburrum State Forest, Queensland.

Criterion 3 Maintenance of ecosystem health and vitality

Sustainable forest management aims to maintain ecosystem health and vitality while maintaining the productive capacity of native and plantation forests to provide the goods and services required by society.

This criterion contains two indicators that together aim to cover the range of agents and processes that affect the health and vitality of native forests and commercial plantations. The first indicator considers the scale and impact of vertebrate and invertebrate pests, pathogens and weeds, as well as environmental factors such as drought and extreme weather events. The second indicator considers the impacts of forest fire, and presents data on the area of forest burnt by planned and unplanned fires.

Forest health

Agents that affect forest health and vitality and that are considered in Indicator 3.1a include browsers, invertebrates (mainly insects), pathogens and weeds. Other potentially damaging processes that are considered include drought, extreme climatic events such as wind storms or cyclones, and climate change.

Australia's forests are adapted to and recover from many of these disturbances, particularly those that occur periodically where impacts are followed by periods of recovery.

Forest health surveillance is mainly undertaken in plantations, with the aim of detecting and identifying the extent of forest health issues such as disease, insect and vertebrate pests, weeds, and nutrient deficiencies, while monitoring the impacts of these on tree survival and growth. Detailed data on pathogens and areas affected are available for commercial plantations. Assessments for conservation reserves and multiple-use public native forests are mainly ratings of scale and impact of damage. Active management of agents affecting forest health is directed mainly at the protection of commercial values in multiple-use public and private native forests and plantations, and the protection of biodiversity and other forest values in all forests.

Ants feeding on lerps.

Fire

Fire is an intrinsic part of Australia's landscape, and affects biodiversity and other environmental values, as well as having important social and economic consequences. Eucalypt forests, in particular, accumulate large amounts of flammable fuel, and most eucalypt forest ecosystems burn naturally with a characteristic frequency, seasonality, and intensity (known collectively as the 'fire regime'), followed by regeneration and regrowth.

Indicator 3.1b outlines the ecological role of fire, the factors that affect fire frequency, seasonality and intensity across Australia, and reports the areas of planned and unplanned fire (bushfire) that occurred in each year of the reporting period 2011–12 to 2015–16. Because some areas of forest, especially in northern Australia, were burnt in multiple years of this period, the indicator reports separately the cumulative area of forest fire (the sum of the annual forest fire areas) and the total area of forest burnt (in which areas burnt multiple times are reported only once). The data sources and methods used to derive these values for SOFR 2018 have been significantly updated compared to those used for SOFR 2008 and SOFR 2013, and therefore the results cannot be directly compared across these reports.

Fire is also an important forest management tool in Australia's forests. Fire management experts generally consider that planned burning is an effective way to reduce fuel loads, promote forest regeneration after wood harvesting, promote the health of forest stands, maintain ecosystem processes and achieve other desired forest management outcomes. However, some people and community organisations have concerns for the effects of planned fire on flora and fauna, visual amenity, air quality and other values. Indicator 3.1b therefore also explains the role of planned fire, and provides a case study about the National Burning Project, which developed guidelines and frameworks for planned fires for use by Australia's fire management authorities.

This icon indicates data, maps or graphics from *Australia's State of the Forests Report 2018* that are available for electronic download. Data used in figures and tables in this criterion, together with higher resolution versions of maps, are available via www.doi.org/10.25814/5bda8e8ad76d6 and www.doi.org/10.25814/5be3bc4321162.

Indicator 3.1a

Scale and impact of agents and processes affecting forest health and vitality

Rationale

This indicator identifies the scale and impact on forest health of a variety of processes and agents, both natural and human-induced. Through the regular collection of this information, significant changes to the health and vitality of forest ecosystems can be monitored and measured.

Key points

- The agents having the greatest impact on forests over the period 2011 to 2016 differed between jurisdictions and forest types, and for some species between broad climatic regions.
  – A total of 25 introduced vertebrate pest species, and a total of 110 weed species, were reported as having an adverse effect on forests in one or more jurisdictions.
  – Introduced vertebrate pests with widespread adverse impacts on forests in more than one jurisdiction were deer, cats, rabbits, pigs, foxes and cane toads.
  – Weed species with widespread adverse impacts on forests in one or more jurisdictions were Gamba grass, bridal creeper, Mission grass, lantana, St Johns wort, prickly pear, and blackberry.
  – In most jurisdictions, a greater number of vertebrate and weed species were reported as damaging to forests in reserves and multiple-use forests than to plantations.
- Targeted control measures were implemented for feral goats, deer, cats, rabbits, pigs and foxes in forests in reserves in multiple jurisdictions during the reporting period. Control measures were applied in reserves for between 12 and 40 weed species in each of the six states and territories that provided data for forest in reserves.
- The range of native and established introduced pathogens and insect pests active during the period 2011–16 is comparable with previous reporting periods. However, for several of the insect pests of plantations previously reported to be most damaging, there were sharp declines over this period in the number of populations that required management.
- Myrtle rust (*Austropuccinia psidii*) is now present in all eastern states of Australia and in the Northern Territory. Currently, 380 native Australian species of the family Myrtaceae are known to be hosts of this pathogen.
  – The impact of myrtle rust is rapid and severe on species that are susceptible to the pathogen. Subtropical wet sclerophyll forest and rainforest communities that have mid-storey and understorey layers rich in species of the Myrtaceae family are being severely altered by myrtle rust.
  – Preliminary determinations have been made to list two widespread species of the Myrtaceae, *Rhodamnia rubescens* and *Rhodomyrtus psidioides*, as Critically Endangered under the New South Wales *Biodiversity Conservation Act 2016* due to the rapid decline of their populations after local arrival of the myrtle rust pathogen.
- Giant pine scale (*Marchalina hellenica*) was detected for the first time in Australia at two locations (Adelaide and Melbourne) in October 2014.
  – An eradication response was initiated in early 2015 under the Emergency Plant Pest Response Deed, and all known infested trees in the Adelaide incursion were destroyed by mid-2016.
  – However, eradication of the much larger Melbourne incursion was unsuccessful, and a decision to transition to management was made in October 2016.
- Forests affected by the extended drought that persisted in southern Australia until 2010 are showing signs of recovery. The activity of secondary pests and pathogens that attacked drought-stressed trees has also declined. There were no new instances of drought-related forest health impacts reported during the period 2011–16.
- The period 2011–16 continued the trend of increasing mean annual temperatures for Australia, with each year between 2013 and 2016 setting a new record for annual average temperature. Observations at carbon flux sites across southern Australia during the record heatwave of January 2013 showed that major forest and woodland ecosystems were resilient to that event.

Continued

Continues

Key points

- Most of the forests that suffered extensive damage from tropical cyclone Yasi in 2011 had shown strong signs of recovery two years later. In February 2015, tropical cyclone Marcia caused significant damage to pine plantations in the Byfield area, Queensland, with 600 thousand cubic metres of logs salvaged from damaged plantations.
- Extensive areas of mangrove along the southern coast of the Gulf of Carpentaria suffered rapid dieback and mortality in late 2015. The event coincided with unusually low sea-levels and several climate anomalies, which in combination are thought to have produced hypersaline conditions that were beyond levels tolerated by the mangrove species.
- Australia has developed a Plantation Forest Biosecurity Plan and a National Forest Biosecurity Surveillance Strategy Implementation Plan to strengthen surveillance systems and minimise the threats from forest pests and pathogens.

This indicator addresses the factors affecting the health and vitality of Australia's native forests and plantations. It focuses on the impacts of vertebrates, invertebrates, pathogens and weeds on forest health, but also covers other potentially damaging processes, such as drought, extreme climatic events and climate change. The active management of these agents in forests is directed mainly towards protecting commercial values in multiple-use public and private native and planted forests, and biodiversity and other forest values in all forests. It is important to note that many pests and diseases, particularly native ones, show cyclical patterns of impact, and while occasionally present in outbreaks are generally of minor concern.

Forest health and biosecurity

Australia has biosecurity strategies and systems to minimise the introduction of pests not currently in Australia[137], and to reduce the adverse impacts of new pest invasions, of exotic species that have become established in Australia, and of native species that regularly or periodically reach damaging population levels. Australia's Intergovernmental Agreement on Biosecurity (IGAB)[138] provides the overarching framework for formulating priorities and measures to reduce the adverse impact of pests on Australia. The recent National Forest Biosecurity Surveillance Strategy seeks to provide greater coordination between government and industry to minimise the threat to national biosecurity from pests and pathogens in forests and strengthen surveillance systems for early detection of new incursions of exotic pests and pathogens, and led to development of a National Forest Biosecurity Surveillance Strategy Implementation Plan[139]. Forest health surveillance activities relate to endemic (native) pests or established non-indigenous pests; biosecurity surveillance activities (for example at and around ports) relate to exotic pests not established in Australia.

The National Forest Biosecurity Surveillance Plan complements the earlier Plantation Forest Biosecurity Plan (version 2)[140] which was formally endorsed by the Plantation Forest Industry in November 2012, and the Australian Government and all state and territory governments in January 2013. Both documents list 20 exotic forest pests not currently present in Australia, deemed to be of high risk to Australian plantation forests (high-priority threats), and likely to cause significant damage if introduced. Formal active surveillance programs and national diagnostic protocols have been or are being developed for these 20 species.

Metrics for scale and impact, and extent of control

The key agents (such as pests, weeds and pathogens) that adversely affected forest health and vitality during the period 2011–16, and their scale and impact, were assessed by states and territories in each of the following categories: mammals; birds; amphibians and fish; insects and mites; plants, including weeds; and pathogens and diseases. Forest health experts within each state and territory nominated which agents were listed, and provided separate assessments for plantations, multiple-use public native forests and nature conservation reserves. The metric used to assess scale/impact (Table 3.1) combined the scale of distribution of the agent across the jurisdiction (restricted or widespread) with the overall impact across that affected area. For each agent listed by a jurisdiction, the extent of the control program used as a management response was also assessed (Table 3.1).

Agents not reported by a jurisdiction were either not present in that jurisdiction, or were present but not considered a key agent affecting forest health and vitality during the period 2011–16, or there was insufficient information available for their status to be assessed. The scores provide an indication of relative importance only, and should not be taken as absolute measures across states and territories.

137 A pest is any species, strain or biotype of plant, animal or pathogenic agent that is injurious to plants or plant products.

138 www.agriculture.gov.au/biosecurity/partnerships/nbc/intergovernmental-agreement-on-biosecurity

139 www.planthealthaustralia.com.au/wp-content/uploads/2018/03/National-Forest-Biosecurity-Surveillance-Strategy.pdf

140 ausfpa.com.au/wp-content/uploads/2016/02/Plantation-forest-biosecurity-plan.pdf

Table 3.1: Metrics used to assess scale/impact of damage by key agents affecting forest health and vitality in forests, and extent of control program

Scale/impact		
Scale	**Impact within the affected area**	**Score**
None or no response[a]	No or lesser impact by that agent	–
Restricted (<25%)	Adverse	1
Widespread (>25%)	Localised adverse	2
Widespread (>25%)	Widespread adverse	3
Control program		
Extent of control program		**Colour**
None or agent not listed		
Ad hoc (unplanned)		(yellow)
Limited targeted		(light orange)
Widespread targeted		(orange)
Widespread general		(red)
Eradication		(dark grey)

[a] Pest agents where the jurisdiction either gave no response or did not indicate a significant impact.

Vertebrate pests

Vertebrate animal pests include both introduced species that have become established as wild populations, and native species that can be damaging in some situations.

Many of the introduced vertebrate species have colonised large tracts of Australia to become nationally significant pests (West 2011). Their adverse impacts in forests include preying on, or competing with, native fauna; providing a vector for pathogens; digging that contributes to soil erosion and the spread of weeds; and direct damage to plants by browsing, trampling or rubbing. A small number of native species that feed on plants can also have adverse impacts when their populations increase beyond the carrying capacity of their habitat or when they feed on young planted trees.

Table 3.2 gives the total number of vertebrate species reported as damaging by six jurisdictions for different forest areas, and their average scale/impact score based on species with a score of 1, 2 or 3 within that jurisdiction. Many vertebrate pest species were reported across several jurisdictions; the distributions of others such as Asian water buffalo, camel, cane toad and starling reflected broad climatic regions or jurisdictions where the species has a significant impact within forests. The scale/impact metric for damage caused by vertebrates reported by jurisdictions was generally greatest for forests in reserves, and least for plantations (Table 3.2).

Introduced vertebrate species

Across jurisdictions, 25 introduced vertebrate species were reported as key agents causing damage to forests. With the exception of hare, camel and tilapia (various species of cichlid fish), all species had a scale/impact score of 2 or 3 in at least one jurisdiction. Table 3.3 lists the 20 introduced vertebrate species that were assessed as having the greatest impact in forests in reserves in the 2011–16 reporting period. Limited or widespread targeted control measures were applied to feral goats, deer, cats, rabbits, pigs and foxes in forest reserves in multiple jurisdictions during the reporting period. Ad hoc or no control measures were applied to other key vertebrate species. In New South Wales, wild dogs are actively managed across all land tenures, because of their wide-ranging movement and their damage to sheep grazing and other farming properties. Some species such as house mouse (*Mus musculus*) and black rat (*Rattus rattus*) are more widespread than apparent from Table 3.3, but caused impact on forests in only some jurisdictions.

Wild populations of many of these species have been present in Australia for more than a century. With the exception of targeted eradication programs on some islands, management is focused on protection of forests from ongoing damage rather than removal of the pest species, and in conservation forests management is focused on protection of biological

Table 3.2: Scale/impact of damage by vertebrate pests in public forests

	ACT	NSW	NT	Qld	SA	Vic.
Number of vertebrate species with a scale/impact score of 1, 2 or 3.						
Plantation	2	7	4	7[a]	15[b]	4
Multiple-use public native forest	n.d.[c]	1	11[d]	14	n.d.[e]	13
Nature conservation reserve	8	13	11	20	15	16
Average scale/impact score of the above species						
Plantation	1.0	1.0	1.0	1.0[a]	1.9[b]	1.5
Multiple-use public native forest	n.d.[c]	1.0	2.0[d]	2.0	n.d.[e]	2.0
Nature conservation reserve	2.1	2.1	1.9	1.9	2.1	1.7

n.d., no data.

[a] Response from HQPlantations.

[b] Plantations in South Australia have multiple permitted uses including recreational access, and may be on multiple-use public forest tenure.

[c] No separate response received for multiple-use public native forest in the Australian Capital Territory.

[d] Data for public native forests not in nature conservation reserves (there are no multiple-use public native forests in the Northern Territory).

[e] No separate response received for multiple-use public native forest in South Australia.

Notes:

Species numbers, scale/impact scores and tenures are as reported by jurisdictions and agencies. The rating system is explained in Table 3.1. Data were not received from Tasmania or Western Australia. Values shown are the total number of vertebrate species reported with a scale/impact score of 1, 2 or 3, and the average scale/impact score of those species.

This table, together with other data for Indicator 3.1a, is available in Microsoft Excel via www.doi.org/10.25814/5bda8e8ad76d6

CRITERION 3

3.1a

Table 3.3: Scale/impact of damage to forests in reserves caused by key introduced vertebrate species, and extent of control

Latin name	Common name	EPBC listing	ACT	NSW	NT	Qld.	SA	VIC
Mammals								
Bos taurus	Cattle (feral / stray)		–	–	2	3	–	–
Bubalus bubalis	Asian water buffalo		–	–	2	–	–	–
Canis lupus familiaris	Wild dogs (not dingoes)		–	–	1	1	–	3
Capra hircus	Feral goat	T	–	3	–	2^{M} 2^{I}	2	2
Cervus spp	Deer (including sambar and red deer)		2	3	–	1	2	3
Dama dama	Fallow deer		2	3	–	1	2	3
Equus asinus	Donkey		–	–	2	–	–	–
E. caballus	Horse		–	1	2	1	–	2
Felis catus	Feral cat	T	3	3	3	3	2	3
Lepus capensis	Hare		–	1	–	–	1	1
Mus musculus	House mouse		–	–	–	1^{I}	3	1
Oryctolagus cuniculus	Rabbit	T	2	3	-	1	3	2
Rattus rattus/R. norvegicus	Introduced rats	T^{I}	–	–	–	1^{I}	3	1
Sus scrofa	Feral pig	T	2	3	3	3	1	2
Vulpes vulpes	Fox	T	3	3	–	3	3	3
Birds								
Passer domesticus	Sparrow		–	–	–	–	2	–
Sturnus vulgaris	Starling		–	–	–	–	2	–
Fish								
Cyprinus carpio	Carp		–	–	–	2	–	–
Gambusia affinis	Mosquito fish		–	1	1	2	–	–
Amphibians								
Rhinella marina	Cane toad	T	–	1	3	3	–	–

T, species listed as a Key Threatening Process under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act); ^{M}, mainland scale/impact only; ^{I}, offshore island scale/impact only.

Notes:
Numerical values show scale/level of impact; cell shading shows extent of control (see Table 3.1).
Species listed are the 20 introduced vertebrate species (or taxa, or taxa groups) with the highest sum of scale/impact scores across the five responding jurisdictions.
Source: data and assessment from states and territories. Data were not received from Tasmania or Western Australia.

This table, together with other data for Indicator 3.1a, is available in Microsoft Excel via www.doi.org/10.25814/5bda8e8ad76d6

assets. The impacts of seven of the introduced species listed in Table 3.3 are currently listed as a Threatening Process under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), and Threat Abatement Plans have been prepared for each of these seven species.

Actions to reduce or mitigate the effect of feral predators such as foxes and cats on forest fauna are undertaken in several states. Since 1996, the Western Shield program in Western Australia[141] has involved the aerial and ground deployment of baits containing the naturally occurring plant toxin 1080 (sodium fluoroacetate), and more recently a new bait attractive to feral cats (Eradicat®). In 2016, the annual program applied baits to 2.4 million hectares of forests on public lands. The success of the program has led to a reduction of at least 55% of the number of foxes in baited areas in the south-west of Western Australia, with populations of at least 53 threatened mammal, bird and reptile species remaining in existence in baited areas. Since 1998, a range of physical items were collected in Tasmania that indicated fox activity in that state which, along with reports of fox sightings from members of the public, led the Tasmanian Government to run a fox eradication program from 2006 to 2014. No physical evidence of fox activity has been collected in Tasmania since July 2011.

Management targeted at these introduced vertebrate pests is generally integrated management using a suite of tools, and depending on the pest is either localised or widespread. A collection of resources and tools available to support this management was developed by the Invasive Animals Cooperative Research Centre (CRC) and is maintained by the Centre for Invasive Species Solutions[142]. The Invasive Animals CRC is developing new tools to augment those already available, including the recent development of a new strain of rabbit haemorrhagic disease virus (Wishart and Cox 2016) for release in 2017.

[141] www.dpaw.wa.gov.au/management/pests-diseases/westernshield

[142] See the *PestSmart Connect* portal, www.pestsmart.org.au

Native vertebrate species

Adverse impacts from kangaroos, wallabies and brushtail possums in the period 2011–16 were mainly restricted to plantations in Tasmania, Victoria and southern NSW, and multiple-use forest in Tasmania, as well as on some islands. The scale/impact of damage was similar to that in previous reporting periods, and was primarily associated with shoot browsing of young trees, bark stripping of 3–6 years-old *Pinus radiata* by wallabies, and upper stem girdling of mid-age trees by brushtail possums. The scale and impact of damage by possums and wallabies is considered higher in Tasmania than in Victoria and NSW.

Over-abundant populations of the aggressively territorial Noisy Miner (*Manorina melanocephala*) and Bell Miner (*M. melanophrys*) continue to have adverse impacts in altered native forest ecosystems in eastern Australia. Those adverse impacts include the direct effect of reduced avian diversity, and the indirect effect of declining forest health associated with increased defoliation because of depleted populations of insectivorous birds. In 2014, over-abundance of the Noisy Miner was listed as a Key Threatening Process under the EPBC Act[143]. In 2008, forest eucalypt dieback associated with over-abundant psyllids and Bell Miner was listed as a Key Threatening Process under the NSW *Threatened Species Conservation Act 1995*[144]. A review of the status of Bell-Miner-Associated Dieback (BMAD) was recently completed (Silver and Carnegie 2017).

A high population density of koalas in the Cape Otway area, Victoria, between 2011 and 2013 caused severe defoliation and death of manna gum (*Eucalyptus viminalis*) in several hundred hectares of woodland. By the end of 2013, the koala population had suffered high mortality from starvation (Whisson et al. 2016).

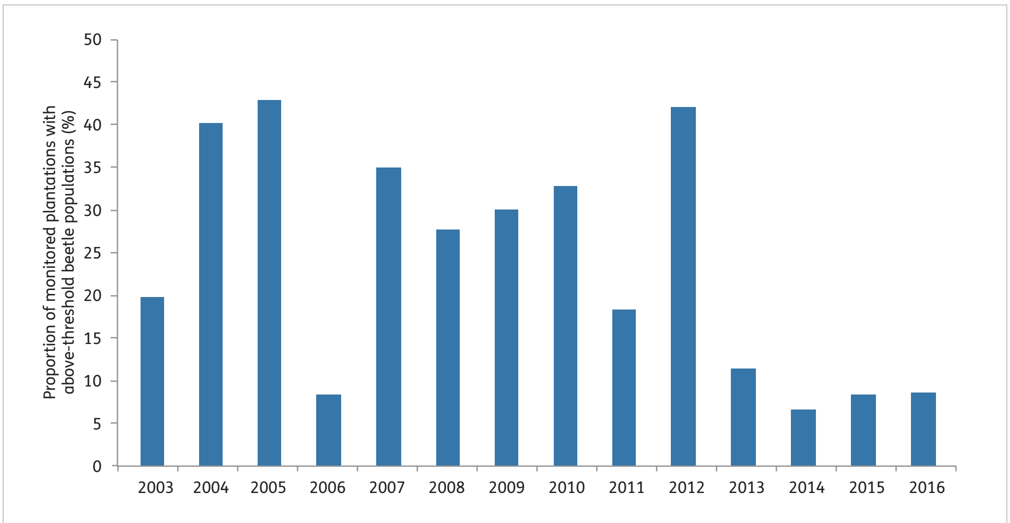
Invertebrate pests

A great diversity of native invertebrates (mostly insects), and a smaller number of introduced species, inhabit forests and can periodically increase in population to cause extensive damage. The populations of most pest species fluctuate in response to climate, particularly drought events, and to a suite of natural enemies. For the most damaging pest species, active management to prevent adverse impacts is needed. Such management, which is mainly restricted to plantation situations, can involve the use of natural enemies of the pest, silvicultural treatments, or the use of pesticides.

Insect pests affecting hardwood plantations

Chrysomelid leaf beetles remain the most widely reported invertebrate pest of eucalypt plantations. In Tasmania, *Paropsisterna bimaculata* is the main species of leaf beetle and is managed using an Integrated Pest Management strategy. This involves monitoring to detect damaging populations and to inform decisions on the need for control with chemical insecticides if natural controls prove insufficient. Populations in 2012 were high and comparable with those of the previous 5-year period, but in 2013 and subsequent years there was a sharp drop in the proportion of populations exceeding the threshold for triggering control actions, particularly in plantations in northern Tasmania (Figure 3.1). The reasons for this decline have not been established. Another leaf beetle species, *Paropsisterna m-fuscum*, is widespread in young (1–2 year-old) southern blue gum (*Eucalyptus globulus*) plantations in Western Australia, but causes little damage because routine soil injection with the insecticide Clothianidin deters the insect from feeding on planted seedlings.

Figure 3.1: Proportion of annually monitored eucalypt plantations on public land in Tasmania that had populations of leaf beetles (*Paropsisterna* spp.) that exceeded the economic injury threshold



Note: Extensive bushfires contributed to the low proportion for 2006.

Source: Annual Stewardship Reports, Sustainable Timber Tasmania[145]

The data used to create this figure, together with other data for Indicator 3.1a, are available in Microsoft Excel via www.doi.org/10.25814/5bda8e8ad76d6

[143] www.environment.gov.au/system/files/pages/a564219c-dd63-4187-a578-6e3cddc7ca31/files/noisy-miner-ktp-advice.pdf

[144] Now subsumed into the New South Wales *Biodiversity Conservation Act 2016*.

[145] Until July 2017, Forestry Tasmania.

Gonipterus "unnamed species 2" is widespread in the western region of the Western Australian hardwood plantation estate. Plantations in the lower productivity areas of this region require protection with insecticide between the ages of 2–5 years to prevent substantial reductions in growth. *G. platensis* has caused severe defoliation on the driest sites in localised areas in Tasmania and Western Australia.

Spring beetles (*Liparetus* and *Heteronyx* species) caused severe damage to young (1–2 year-old) eucalypt plantations in Western Australia in localised areas adjacent to poorly managed native forest remnants that have a grassy understorey. Autumn gum moth (*Mnesampela privata*) has caused little damage in Western Australia and only localised small outbreaks in Tasmania. Christmas beetles (*Anoplognathus* spp.) caused severe damage to many Dunn's white gum (*E. dunnii*) plantations in northern NSW in 2015–2016. Damage from stem-boring insects (*Aenetus* and *Poracantha*) was present in about 10% of the area of young eucalypt plantations in northern NSW.

Insect pests affecting softwood plantations

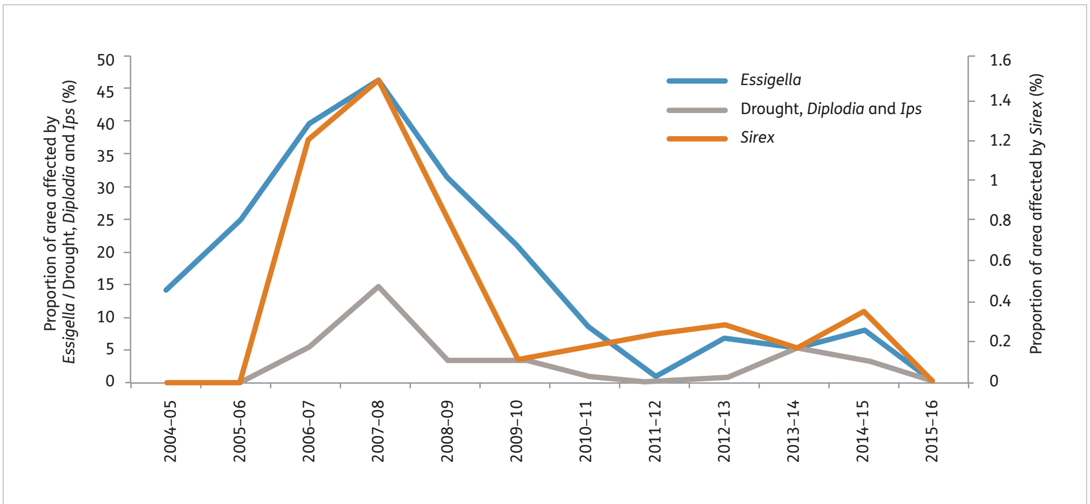
Three introduced insect pests caused extensive damage to radiata pine (*Pinus radiata*) plantations in the eastern states: sirex wood wasp (*Sirex noctilio*), five-spined bark beetle (*Ips grandicollis*) and Monterey pine aphid (*Essigella californica*). The activity of these pests is tightly linked to drought events. The extended drought between 1996 and 2010 in eastern Australia, which peaked in 2006, was associated with a sharp increase in the area of *P. radiata* plantations that suffered damage from each of these pests (Figure 3.2). Since drought-breaking rains in 2010 and 2011, the area of *P. radiata* plantation suffering damage has reduced to low levels (Figure 3.2).

Silvicultural treatments (primarily thinning of plantation stands) and introduced biological controls are used to minimise adverse impacts from *Sirex*, *Ips* and *Essigella*. The parasitoids *Roptrocerus xylophagorum* and *Dendrosoter sulcatus* were introduced into Australia in the 1980s to limit numbers of *I. grandicollis*. The parasitoid *Diaeretus essigellae* was released in Australia in 2009 to reduce numbers of *E. californica*, and by 2014 had successfully established in three of the five major *P. radiata* plantation regions in NSW and five of the eight regions in Victoria. Several parasitic wasps (*Ibalia leucospoides*, *Megarhyssa nortoni*, *Rhyssa* spp. and *Schlettererius cinctipes*) and the parasitic nematode *Beddingia siricidicola* have been introduced to limit numbers of *Sirex noctilio*. The *Sirex* biological control program requires ongoing management, particularly to maintain virulent cultures of the nematode, and is coordinated through the National Sirex Coordination Committee[146]. *Sirex* populations are regularly checked to monitor the levels of nematode parasitism. Recent checks found the *Ibalia* parasite in 30% and 60% of *Sirex* wasps in Victoria and NSW, respectively. Background populations of the parasitic nematode persisted in most eastern states, although levels of parasitism were low in Victoria.

Damage to plantations at Byfield, Queensland, from tropical cyclone Marcia resulted in a sharp rise in populations of native and exotic bark beetles (Scolytidae) that attacked wind-blown trees. Galleries (tunnels) of wood-boring insects and their associated blue-stain fungi impacted on wood quality.

Giant pine scale (*Marchalina hellenica*), a sap-sucking pest that attacks the trees in the family Pinaceae including *P. radiata*, was first detected in Australia in October 2014 at two locations, Adelaide and Melbourne. An eradication response made under the Emergency Plant Pest Response Deed was initiated in early 2015, and all known infested trees at the Adelaide incursion were located and destroyed by

Figure 3.2: Proportion of the annual area of *Pinus radiata* plantation on public land in New South Wales that was affected by drought, pests and pathogens between 2004–05 and 2015–16



Source: FCNSW (2016d)

The data used to create this figure, together with other data for Indicator 3.1a, are available in Microsoft Excel via www.doi.org/10.25814/5bda8e8ad76d6

[146] australiansirex.com.au/

mid-2016. The Melbourne incursion was much larger and it was deemed neither technically feasible nor cost-effective to remove and destroy infested trees. Giant pine scale has not been found in other parts of Australia, nor has it been detected in any pine plantations. However, it poses a threat to Australia's softwood plantation industry. As a result, a decision to transition to management was made in October 2016.

Insect pests affecting native forests

The scale and impact of insect pests in native forest was much lower in the 2011–16 reporting period than the previous reporting period of 2006–11.

Psyllids (*Cardiaspina* spp.) were the most damaging insect pest affecting native forests in 2011–16. Large populations caused severe defoliation in river red gum (*Eucalyptus camaldulensis*) forests in many parts of Victoria and South Australia. High *Cardiaspina* populations led to Bell-Miner-Associated Dieback of wet sclerophyll forests in northern NSW.

The large outbreak of gum-leaf skeletoniser (*Uraba lugens*) that severely defoliated about 250 thousand hectares of jarrah (*E. marginata*) forest in Western Australia in 2010–11 abated, and forests have since recovered (Wills and Farr 2016). That and previous outbreaks of *U. lugens* in jarrah forests occurred in the wetter parts of the forest after the breaking of prolonged droughts (Wills and Farr 2016). The large *Phoracantha semipunctata* outbreak that killed many jarrah and marri (*Corymbia calophylla*) trees following the severe drought in 2009–10 restricted to the areas most severely affected by drought-related canopy dieback: populations of the beetles did not subsequently spread onto trees that were not dieback-affected from the drought (Seaton et al. 2015). The outbreaks of cup-moth (*Doratifera*) in Victoria and Tasmania that commenced in the 2006–11 reporting period abated, and the forests have recovered well by the end of the current 5-year period.

Pathogens

Pathogens affecting hardwood plantations

Species of *Teratosphaeria* (formerly *Mycosphaerella*) causing leaf disease were the pathogens most commonly reported in *Eucalyptus* plantations. Kirramyces leaf disease (*T. eucalypti*), which caused extensive severe defoliation of shining gum (*Eucalyptus nitens*) in Tasmania and Victoria in the wet summers of 2010–11 and 2012–13, became much less prevalent between 2014–16 as lower rainfall conditions returned. Severe defoliation was restricted to localised areas of the north-eastern highlands of Tasmania and the Gippsland and Otway regions of Victoria that continued to experience moist conditions more regularly than the broader plantation estate. Some plantations in the central north of Tasmania that suffered complete defoliation in the 2010–11 epidemic failed to recover, resulting in the death of several hundred hectares of mid-rotation trees (Figure 3.3).

Leaf disease of young (<3 year-old) *E. globulus* plantations associated with a suite of *Teratosphaeria* species is becoming more prevalent in Western Australia. Contributing to this is the establishment of new plantations closer to the coast (between Margaret River and Albany) where rainfall is higher. Disease is also present at higher rates in large plantation blocks on sand plains where a mix of age classes maintains an ongoing source of inoculum to infect new plantations soon after they are planted.

Myrtle rust (*Austropuccinia psidii*[147]) caused little damage in blackbutt (*E. pilularis*), flooded gum (*E. grandis*) and Gympie messmate (*E. cloeziana*) plantations in northern NSW. Only 5% of young (6 month-old to 2 year-old) plantations were infected, and in these plantations infection incidence was less than 1% of trees. Disease was not detected in plantations beyond 3 years of age.

Phytophthora root-rot of *E. nitens*, due to *Phytophthora cinnamomi*, became much less prevalent in northern Tasmania in the 2011–16 period. The decline in prevalence was attributed to lowland sites being increasingly replanted with the less-susceptible species *E. globulus*. *Eucalyptus nitens* plantations in the Otway and Gippsland regions of Victoria continued to suffer mortality from phytophthora root-rot.

Canker diseases were much less prevalent during the period 2011–2016. The most significant was a scattered low incidence of cankers caused by *Holocryphia eucalypti* (formerly *Endothia gyrosa*) associated with attack by stem-boring insects in drought-stressed mid-rotation *Eucalyptus nitens* plantations in northern Tasmania. A total of 480 hectares was affected over the 5-year period.

Figure 3.3: Mortality in a mid-rotation *Eucalyptus nitens* plantation in northern Tasmania following complete defoliation by *Kirramyces* leaf disease

[147] Previously referred to by the names *Puccinia psidii* and *Uredo rangelii*.

CRITERION 3
3.1a

Pathogens affecting softwood plantations

The suite of pathogens affecting softwood plantations remained unchanged from previous reporting periods.

Spring needle cast (SNC) caused by the fungus *Cyclaneusma minus* continues to be the most damaging pathogen impact on *Pinus radiata* in Tasmania. An increasing proportion of the Tasmanian plantation estate now has planting stock with higher resistance to SNC. SNC is also the most widespread pathogen in Victoria and South Australian plantations, and is affecting an increasing area of *P. radiata* plantations in the Tumut area of NSW.

Diplodia canker (*Sphaeropsis sapinea*) was widespread in *P. radiata* plantations in all eastern states, but at reduced levels compared with the previous 5-year period. In Victoria, localised outbreaks were primarily associated with damage from hail and storms.

In north-east Victoria, up to 3,000 hectares of plantation have been treated for Dothistroma needle blight (caused by *Dothistroma septosporum*) each year since 2011. Elsewhere levels of Dothistroma needle blight in *P. radiata* remained generally low, but outbreaks that required chemical control occurred in localised "hot-spots", mainly in the Northern Tablelands of NSW and in fog-prone valleys in the Noojee area of Victoria. Small outbreaks also occurred in the Otway Ranges of Victoria, but no treatment is carried out in this region.

Pathogens affecting native forests

The introduced pathogens *Phytophthora cinnamomi* (phytophthora root-rot) and *Austropuccinia psidii* (myrtle rust) are the most damaging diseases in native forests because of the broad suite of highly susceptible species that they affect. Native pathogens, by comparison, damage a narrow range of susceptible species, and their host plants have higher levels of resistance (presumably as a result of co-evolution).

Myrtle rust (*Austropuccinia psidii*) remains the most significant pathogen threat to native forests. The pathogen spread rapidly northwards along the eastern seaboard of NSW and Queensland in the 1–2 years following its arrival in 2010, and now occupies much of its predicted climatically optimal range. In the 2011–16 period, the number of known host species increased considerably, and marked changes occurred in the composition and structure of some forest communities after infection. Currently, 380 native Australian species of the Myrtaceae family are known to be hosts of this pathogen (Berthon et al. 2018), and impact on the more susceptible species is both rapid and severe. A detailed description of the impacts of myrtle rust is provided in Case Study 3.1.

Mapping of phytophthora dieback in publicly managed native forest in Western Australia is updated annually and targets areas where timber harvesting plans are being prepared. At the end of 2016, the cumulative total area mapped as dieback-affected based on standard protocols (DEC 2009) was 274 thousand hectares, with 78% of that area being multiple-use public native forest, 20% nature conservation reserves, and 2% other Crown land. Basic mapping through testing and field surveillance is carried out in Victoria, where a model has been developed to help land managers assess the risk of management activities and determine the recommended hygiene conditions. Elsewhere in Australia, the forest area affected by *P. cinnamomi* is not mapped; overall, the extent and impact were reported to be little different from the previous reporting period of 2006–11. In Tasmania, only one significant new extension of *P. cinnamomi* into native forest was reported, namely the Peter Murrell Nature Reserve, which is within a large suburban area and has high levels of public use, and was therefore at greater risk of accidental introduction of the pathogen.

Root-rots and butt-rots caused by *Armillaria* species, notably *A. luteobubalina*, are widespread in tall, closed forests in south-western Western Australia, Victoria and Tasmania. Patch mortality from spread of the fungus between trees occurs in localised areas, particularly in karri (*E. diversicolor*) forests in Western Australia. However, scattered mortality of individual plants, often during the first 1–2 years after forest regeneration, is more typical. There were no reports of elevated levels of *Armillaria* for the period 2011–16.

Mortality of myrtle beech (*Nothofagus cunninghamii*) due to myrtle wilt (*Chalara australis*) is the only significant pathogen impact in temperate rainforests of Tasmania and Victoria. Since 2012, an increase in the levels of mortality in *N. cunninghamii* has been observed throughout Tasmania. Assessment of a long-term monitoring plot (Arve Loop) in 2015 recorded 11% recent mortality (Jeörg Parschau, unpublished data) after two decades of low mortality rates (as reported in Packham et al. 2008). No significant change in the status of myrtle wilt in Victoria was reported, other than detections around new roads.

In south-western Western Australia, regular monitoring of a canker disease of marri (*Corymbia calophylla*) caused by the

Myrtle beech (*Nothofagus cunninghamii*) tree killed by myrtle wilt, cool temperate rainforest, Liffey Falls State Reserve, Tasmania.

native fungus *Quambalaria coyrecup* was conducted between 2001 and 2014. The extent of the disease increased over the period, with 10% of trees becoming infected and 7% being killed by girdling cankers (Paap et al. 2017).

Dieback and other syndromes in native forests

A wide range of chronic or episodic crown dieback syndromes occur to some degree in native forests in all states and territories, often causing significant tree mortality and consequential ecosystem impacts. These events are usually caused by combinations of factors such as climatic stresses, poor land management practices, defoliating insect outbreaks, and an imbalance in insect predator levels. Canker-causing fungi such as *Holochryphia eucalypti* (formerly *Endothia gyrosa*) and *Botryosphaeria* species, and stem-boring insects such as *Phoracantha* species, can have a secondary role. In most cases, there is considerable uncertainty as to the actual mechanism by which the various proposed causal factors combine to produce the dieback syndrome.

Bell-Miner-Associated Dieback of moist sclerophyll forests in New South Wales and Victoria has been observed for more than a century. The syndrome is linked to forest areas that have high populations of Bell Miner birds (*Manorina melanophrys*) and elevated populations of psyllids. The most significant damage is found in Sydney blue gum (*Eucalyptus saligna*) forests in northern New South Wales (Silver and Carnegie 2017). The NSW Department of Primary Industries (Forest Science) has undertaken extensive aerial surveys to update mapping of the extent of Bell-Miner-Associated Dieback.

A syndrome known as Monaro dieback has resulted in the dieback and mortality of substantial areas of *E. viminalis* over the past decade in the Monaro region of southern New South Wales. The affected area in 2013 was 2,000 square kilometres (Ross and Brack 2015) at the drier limit of the natural distribution of *E. viminalis*, but drought is unlikely to be the sole causal factor because symptoms continued to develop after the wet years of 2010–12. Other possible contributing factors examined included populations of *Gonipterus* weevils, grazing history, burning history, and forest structural complexity.

Extensive dieback and mortality of *E. viminalis* was also reported in northern Tasmania. Symptoms first became evident in 2014, and the affected trees showed copious bleeding of gum on their stem. Similar symptoms were seen in *E. globulus* plantations in the same general area, and with affected plantation trees having large gum pockets in the growth ring of the previous growing season (2012–13), which was a period of record heatwave. It has not been established whether the syndrome in *E. viminalis* is the same as that in *E. globulus*, nor whether high temperatures alone can trigger such symptoms.

A severe dieback and mortality event affecting mangrove along the southern coast of the Gulf of Carpentaria occurred in late 2015. This event is described in Case Study 3.2.

Weeds

More than 2,800 exotic plant species have become established as pests in Australia[148]. Species such as blackberry (*Rubus fruticosus* and other *Rubus* spp.) and lantana (*Lantana camara*) compete with native flora and can become locally dominant, reducing biodiversity and other values; they can also affect tree establishment, growth and product yield in commercial forest plantations and production native forests. Exotic grasses such as gamba grass (*Andropogon gayanus*) and buffel grass (*Cenchrus ciliaris*) greatly elevate the severity of fires in northern Australia; changes to fire regimes due to these grass species have the potential to affect forest stands in the region[149].

Across jurisdictions, 110 weed species were reported as key agents causing damage to forests, including introduced grasses, herbs, vines and aquatic plants, and native and introduced tree and shrub species. Table 3.4 gives the total number of weed species reported by five jurisdictions by forest tenure, and average scale/impact scores for species with a score of 1–3 within that jurisdiction. The species reported by each jurisdiction reflected weed distributions and broad climatic regions. Species reported by more than one jurisdiction included kikuyu grass (*Pennisetum clandestinum*), serrated tussock (*Nassella trichotoma*), willow (*Salix* spp.), blackberry, sweet briar (*Rosa rubiginosa*), Scotch broom (*Cytisus scoparius*) lantana, African boxthorn (*Lycium ferocissimum*), rubber vine (*Cryptostegia madagascariensis*) and cat's claw vine (*Dolichandra unguis-cati*).

The five states and territories that provided data reported some level of control measure in forest in nature conservation reserves for between 12 and 40 key weed species for each jurisdiction. Few weed species were the subject of widespread control or eradication measures. Within forest in nature conservation reserves, widespread general control measures were applied to Crofton weed (*Eupatorium* spp.) in New South Wales, to briar (*Rubus* spp.) and *Nassella trichotoma* in the Australian Capital Territory, and to bellyache bush (*Jatropha gossypiifolia*) in the Northern Territory. Eradication measures were applied to water hyacinth (*Eichhornia crassipes*), orange hawkweed (*Hieracium aurantiacum*), honey locust (*Gleditsia triacanthos*) and bitou bush (*Chrysanthemoides monilifera*) in Queensland, and to Leucaena (*Leucaena leucocephala*) within forest on reserves on islands.

The 25 introduced weeds identified as having the most impact in Australia's forests in nature conservation reserves over the period 2011–16 are listed in Table 3.5. Eleven of these 25 weeds are included on the national list of Weeds of National Significance[150], and nationally co-ordinated strategic plans have been developed for the management of each of these Weeds of National Significance. Three introduced grasses present in northern Australia and listed in Table 3.4 (gamba grass, mission grass and para grass) were also listed as a Key Threatening Process under the EPBC Act in 2009[151], and a

[148] soe.environment.gov.au/science/soe/2011-report/8-biodiversity/3-pressures/3-9-invasive-species

[149] www.environment.gov.au/biodiversity/threatened/threat-abatement-advices/invasive-pasture-grasses-introduction

[150] www.environment.gov.au/biodiversity/invasive/weeds/weeds/lists/wons.html

[151] www.environment.gov.au/biodiversity/threatened/threat-abatement-advices/invasive-pasture-grasses-introduction

Table 3.4: Scale/impact of damage by weeds in public forests

	ACT	NSW	NT	QLD	SA
Number of weed species with a scale/impact score of 1, 2 or 3					
Plantation	6	10	3	5[a]	19[b]
Multiple-use public native forest	n.d.[c]	n.d.[c]	26[d]	44	n.d.[e]
Nature conservation reserve	12	35	20	46	22
Average scale/impact score of the above species					
Plantation	2.5	1.4	1.0	2.0[a]	1.4[b]
Multiple-use public native forest	n.d.[c]	n.d.[c]	1.4[d]	1.4	n.d.[e]
Nature conservation reserve	1.8	1.7	1.4	1.2	1.4

n.d., no data.

a Response from HQPlantations.

b Plantations in South Australia have multiple permitted uses including recreational access, and may be on multiple-use public forest tenure.

c No separate response received for multiple-use public native forest in the Australian Capital Territory or New South Wales.

d Data for public native forests not in nature conservation reserves (there are no multiple-use public native forests in the Northern Territory).

e No separate response received for multiple-use forest in South Australia.

Notes:

Species numbers, scale/impact scores and tenures are as reported by jurisdictions and agencies. The rating system is explained in Table 3.1. Data were not received from Tasmania or Western Australia. Values shown are the total number of weed species reported with a scale/impact score of 1, 2 or 3, and the average scale/impact score of those species.

This table, together with other data for Indicator 3.1a, is available in Microsoft Excel via www.doi.org/10.25814/5bda8e8ad76d6

Table 3.5: Scale/impact of damage to forests in reserves of the 25 weeds of highest scale/impact, by jurisdiction

Latin name	Common name	ACT	NSW	NT	QLD	SA
*Andropogon gayanus**	Gamba grass	–	–	3	2	–
*Asparagus asparagoides**	Bridal creeper	–	2	–	–	3
Baccharis halimifolia	Groundsel	–	2	–	1	–
Cenchros polystachios	Mission grass (perennial)	–	–	3	2	–
*Chrysanthemoides monilifera**	Boneseed	–	2	–	1	2
*Cytisus scoparius**	Scotch broom	1	2	–	–	2
Echium plantagineum	Paterson's curse	2	2	–	–	1
Genista monspessulana	Cape broom	–	–	–	–	2
Hyparrhenia hirta	Coolatai grass	–	2	–	2	–
Hypericum perforatum	St Johns wort	2	3	–	–	–
*Lantana camara**	Lantana	–	3	1	3	–
Leucaena leucocephala	Coffee bush	–	–	1	2[M] 1[I]	–
*Lycium ferocissimum**	African boxthorn	–	2	–	1	2
*Nassella trichotoma**	Serrated tussock	2	2	–	–	–
Opuntia spp*	Prickly pear	–	3	–	–	1
Pinus spp	Pines	–	2	–	1	1
Rosa rubiginosa	Sweet briar	1	2	–		–
*Rubus anglocandicans / R. fruticosus**	Blackberry	–	3	–	1	2
Rubus spp	Briar	3	–	–	–	–
Salix spp*.	Willows	–	2	–	–	2
Sporobolus spp.	Giants rat's tail grass	–	1	–	2	1
Themeda quadrivalvis	Grader grass	–	–	1	2	–
*Ulex europaeus**	Gorse	–	1	–	–	2
Urochloa mutica	Para grass	–	-	2	1	–
Xanthium occidentale	Noogoora burr	–	2	2	–	–

*, Weeds of National Significance; [I], island populations; [M], mainland populations.

Notes:

Numerical values show scale/level of impact, and cell shading shows extent of control (see Table 3.1).

Species listed are the weed species (or taxa, or taxa groups) ranked highest by the sum of their scale/impact scores across the five responding jurisdictions.

Source: data and assessment from states and territories. Data were not received from Tasmania, Victoria or Western Australia.

This table, together with other data for Indicator 3.1a, is available in Microsoft Excel via www.doi.org/10.25814/5bda8e8ad76d6

Threat Abatement Plan has been prepared (Commonwealth of Australia 2012)[152].

Management to reduce the impact on forests of established weeds is usually coordinated regionally through Natural Resource Management regions, and funded through competitive grants such as those awarded through the Caring for our Country program[153]. For example, African boxthorn was added to the list of Weeds of National Significance in 2012, and a large control program for this species in the Yorke Peninsula in South Australia was conducted using aerially applied granular herbicide.

For established weeds, priority is given to preventing spread into areas that are currently largely free of the weed. An example of this has been the response to the first detection of buffel grass (*Cenchrus ciliaris*) in Victoria in 2014. Delimiting surveys, treatment of known infestations and public awareness campaigns have been implemented in response to the detection (James et al. 2016) to prevent the establishment of buffel grass in north-western Victoria where it would threaten mallee ecological communities.

For potentially invasive species that have not become widely established, eradication may be feasible. The National Four Tropical Weeds Eradication Program in Queensland and NSW is an example[154]. This eradication program commenced in 2001 and targets five species (*Limnocharis flava*, *Mikania micrantha* and three *Miconia* species) in Queensland and NSW that are invasive in waterways and rainforest. Surveillance and monitoring of known infestations has intensified since 2010, and the detection rate of mature plants has declined from 2.5 plants per 100 hectares searched in 2010, to 0.6 plants per 100 hectares searched in 2016 (Jeffrey and Brooks 2016).

Climatic events and climate change

Drought

There were no damaging drought events reported for the period 2011–16.

Areas of the northern jarrah forests that suffered dieback and mortality following the severe drought in 2009–10 showed good recovery four years later (Matusick et al. 2016). In the 1–2 years following the drought event, a higher proportion of *Eucalyptus marginata* than *Corymbia calophylla* had died or were showing advanced dieback (Ruthrof et al. 2015). However, four years after the event, a combination of seedling regeneration and resprouting from surviving, dieback-affected trees resulted in the affected areas having a similar species composition to that prior to the drought (Matusick et al. 2016) although forest structure was greatly altered.

Wind and storm damage

Tropical cyclone Marcia (February 2015) caused extensive damage to 12 thousand hectares of mid-rotation southern pine plantations in the Byfield area, central Queensland (Figure 3.4). Approximately 600 thousand tonnes of logs were salvaged from affected plantations in the 18 months after the cyclone, and some were exported, primarily to China[155]. Native forest in the Byfield National Park and in the Shoalwater Bay Training Area also suffered severe wind damage, particularly on Townshend Island where trees were completely defoliated[156].

Cyclone Yasi caused extensive and severe damage to forests in the Mission Beach–Tully area in February 2011. Data from reconnaissance flights conducted by the Queensland Parks and Wildlife Service in 2011 and 2013 (Holloway 2013) showed that most forest communities had recovered well, but there were four communities experiencing longer-term consequences.

- Canopy damage to open eucalypt forests fringing rainforests resulted in rainforest species invading the understorey, making it more difficult to conduct the prescribed burns needed to maintain eucalypt forest.
- Patches of lowland rainforests have been extensively colonised by native *Calamus* (lawyer cane) and exotic *Rubus* species.
- There has been little regeneration in melaleuca woodlands in swales behind beaches that experienced extensive blow-down but were not subsequently burnt.
- Lastly, mangrove communities in riverine estuaries suffered extensive post-cyclone mortality, possibly as the result of inundation beyond normal tolerances during storm surges.

[152] www.environment.gov.au/system/files/pages/99dfad7e-9feb-4da1-826b-fdf5740ffa5e/files/northern-australia-introduced-grasses.pdf

[153] The Caring for our Country program was combined with the National Landcare Program in 2013. www.nrm.gov.au/news-and-resources/resources/previous-programmes

[154] www.daf.qld.gov.au/business-priorities/plants/weeds-pest-animals-ants/weeds/four-tropical-weeds-eradication-program

[155] *Queensland Times* 27 June 2017.

[156] www.bom.gov.au/cyclone/history/marcia.shtml#winddmg

Figure 3.4: Wind-damaged pine plantation at Byfield, Queensland, following Cyclone Marcia


Queensland Department of Agriculture and Fisheries

Climate change

Australia is predicted to experience warmer temperatures, altered rainfall patterns, more severe droughts, more intense rain events and more heatwaves over the course of the 21st century (CSIRO and Bureau of Meteorology 2015). The long-term consequences for Australia's forests of these predicted changes in climate is yet to be understood, but monitoring of and research on responses to individual climate events or changes may provide some early indications.

The period 2011–16 continued the trend of increasing mean annual temperatures for Australia, which commenced around 1950 (Figure 3.5). Each year between 2013 and 2016 set a new record for mean annual temperature, and heatwave conditions occurred on several occasions, most notably during January 2013, which was Australia's warmest month on record (Bureau of Meteorology 2014). Measurements made at several flux sites operated through the Terrestrial Ecosystem Research Network[157] (Figure 3.6) tracked the responses of the main forest ecosystems in southern Australia during this heatwave (Van Gorsel et al. 2016). The measurements showed that forests at all the sites were resilient to the heatwave, although the water-limited woodland sites became net sources of CO_2 during the heatwave event.

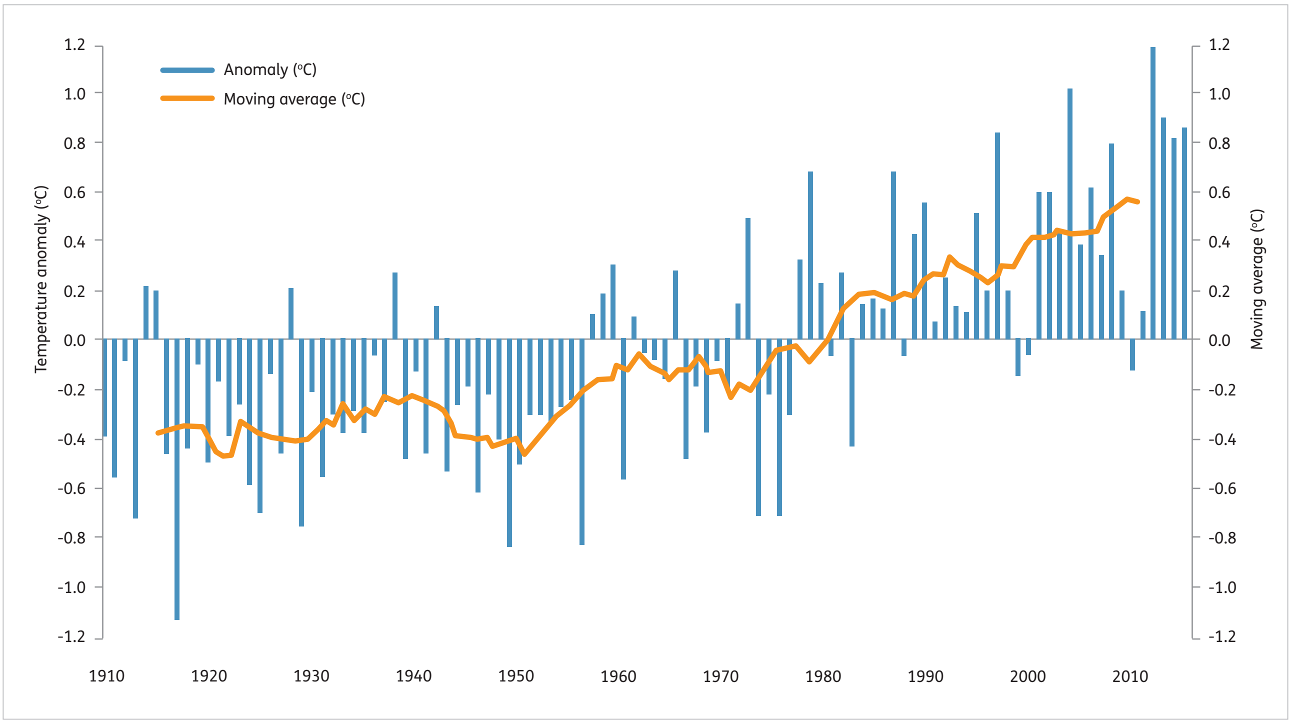
Generally, predictions of the changes in productivity and vulnerability of Australia's forests under predicted future climates have, to date, relied on predictions from process-based models (e.g. Battaglia et al. 2009). More recently, analysis of data from forest inventory plots with a long-term history of measurement has found that the maximum productivity of eucalypt native forests on mesic (non-water-limited) sites occurred at cooler sites, suggesting that warming temperatures would reduce productivity of these forests (Bowman et al. 2014). This is supported by early results from three flux sites in tall, wet eucalypt forests (Warra in southern Tasmania, Wallaby Creek in the Victorian Highlands and Tumbarumba in southern NSW), which have showed a strong latitudinal gradient (north to south) of declining productivity with increasing temperatures[158].

The effects of the prolonged drought experienced in southern Australia between 1996 and 2010 (the Millennium Drought) were reported in SOFR 2013. That drought caused widespread mortality and secondary insect attack in both eucalypt native forests and pine plantations. In the northern jarrah forests of south-western Western Australia, dieback and mortality was greater in jarrah (*Eucalyptus marginata*) than in marri (*Corymbia calophylla*), suggesting that marri might replace jarrah if such events were to become more frequent (Ruthrof et al. 2015). However, resprouting and regeneration during 2011–16 resulted in no shift in species composition although forest structure was greatly altered (Matusick et al. 2016). In other areas, species composition has

[157] www.tern.org.au/

[158] Tim Wardlaw, University of Tasmania, unpublished data.

Figure 3.5: Australia's mean annual temperature anomaly from 1910–2016



Bars show the temperature anomaly: the difference between each annual average temperature and the 1961–90 average temperature.
Solid line shows 11-year moving average of the temperature anomaly.
Data source: www.bom.gov.au/climate/current/annual/aus/2016/#tabs=Temperature (see Bureau of Meteorology 2017).

The data used to create this figure, together with other data for Indicator 3.1a, are available in Microsoft Excel via www.doi.org/10.25814/5bda8e8ad76d6

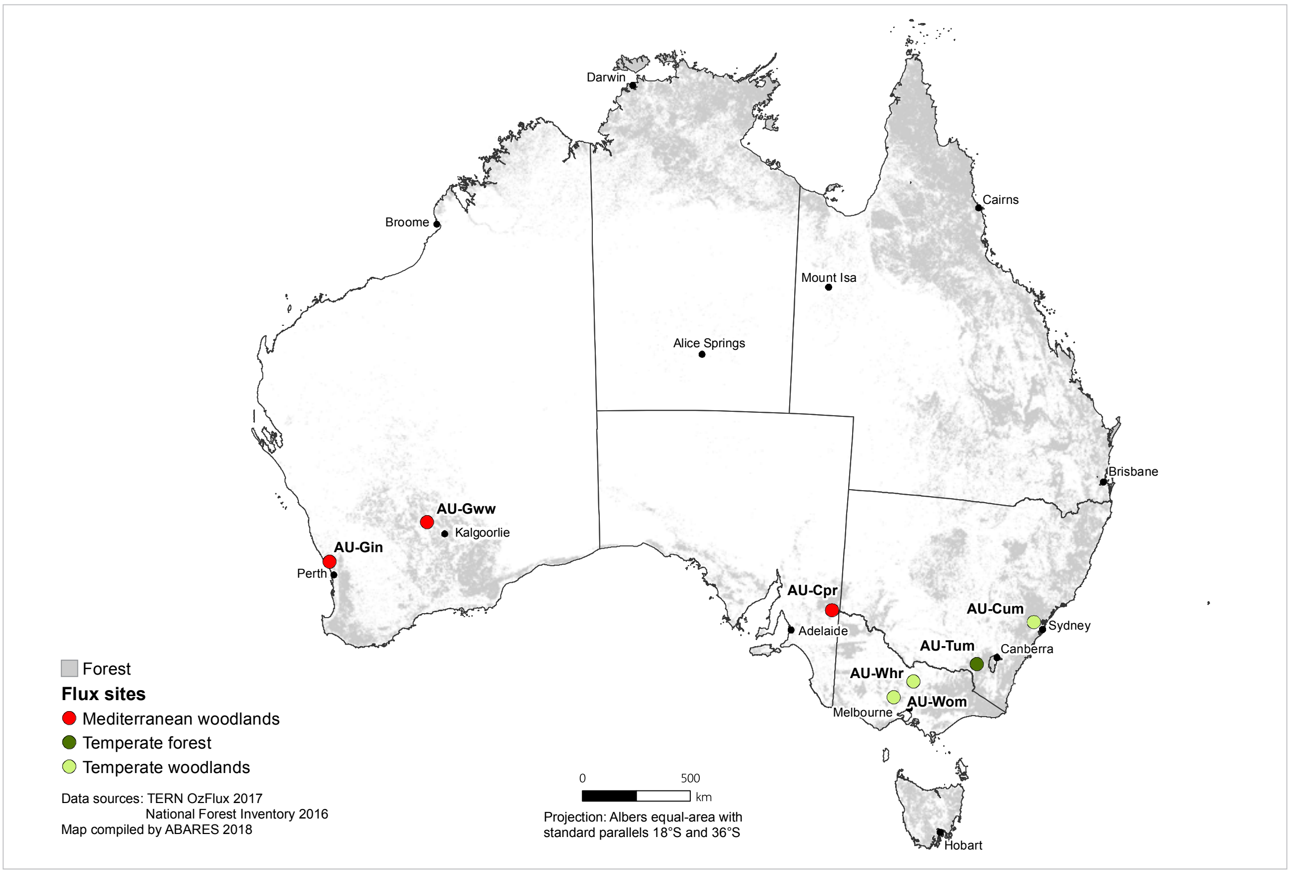
changed in response to prolonged lower rainfall. Sustained lower rainfall conditions between 1970–1996 in south-eastern Australia resulted in increased dominance of more drought-tolerant species, notably *Allocasuarina* spp. in some eucalypt woodlands (Zeeman et al. 2014), with the intense drought between 1996–2010 amplifying the shift towards *Allocasuarina* spp.

There is also a direct effect of increased atmospheric CO_2 concentration on forests. The commissioning in 2012 of Australia's EucFACE facility[159] in a mature forest red gum (*E. tereticornis*) woodland at Cumberland Plains, New South Wales, allowed this to be studied. Initial results are that the forest shows greater water-use efficiency under elevated CO_2, but consequential productivity gains are not realised because of phosphorus limitation. Different patterns of loss to herbivory are also expected, as the abundance of several arthropod groups declined under elevated CO_2 conditions.

The sustained shift in the Australian climate since 1970 has prompted work to develop adaptation strategies to help mitigate adverse effects. Many adaptation options are based on stronger deployment of existing forest management practices. Interventionist management in protected areas would require societal and policy shifts (Keenan and Nitschke 2016). The AdaptNRM initiative[160] makes extensive use of tools to predict vulnerabilities in future climates at fine spatial scales, and focuses on restoration plantings to assist natural migration as local climates change (CSIRO and Bureau of Meteorology 2015). Coupling the prediction of future climate with species distribution records can map where the climatic range of a species may occur in the future (Williams et al. 2015), allowing planning of strategic approaches such as vegetation corridors to assist migration (Prober et al. 2015b). An alternative approach is active translocation of selected genotypes of species to areas that match future climates, and eucalypts are a particular current focus for this approach (Prober et al. 2015a; Prober et al. 2016; Harrison et al. 2017).

[159] www.westernsydney.edu.au/hawkesburyinstitute/facilities/EucFACE
[160] adaptnrm.csiro.au/

Figure 3.6: Flux measurement sites in the TERN OzFlux facility that observed forest function during the 2013 heatwave



Red dots, sites in Mediterranean woodlands; light green dots, sites in temperate woodlands; dark green dot, site in temperate forest. Forest types as described by OzFlux. Map reproduced from Van Gorsel et al. (2016).

A higher resolution version of this map, together with other maps for Indicator 3.1a, is available via www.doi.org/10.25814/5be3bc4321162

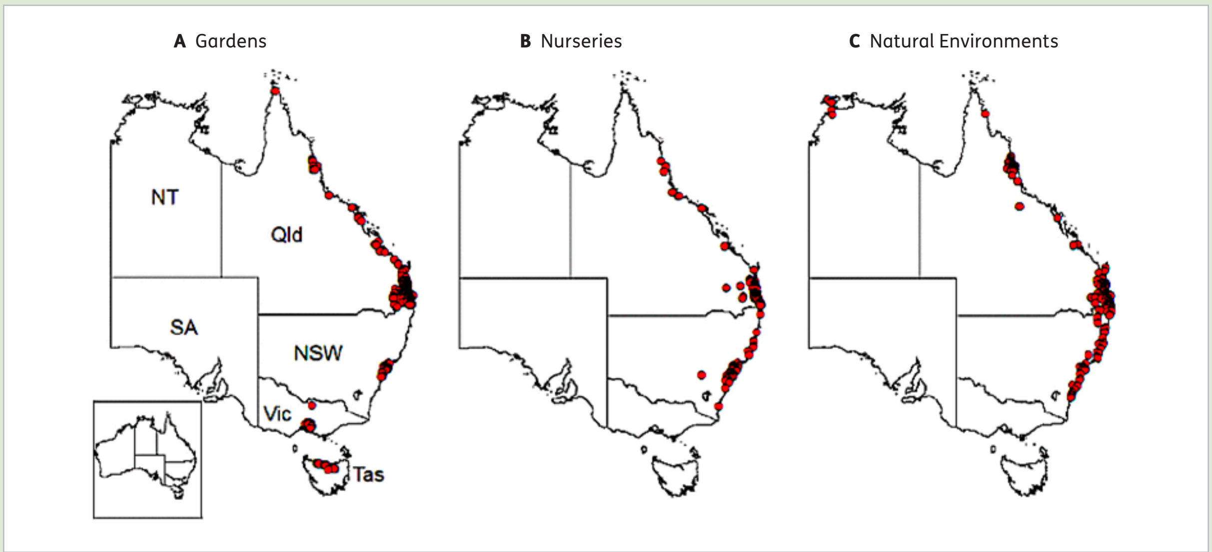
Case study 3.1: Myrtle rust

Myrtle rust (*Austropuccinia psidii*), a strain of guava or eucalypt rust, was detected for the first time in Australia in April 2010 on the central coast of New South Wales (Carnegie et al. 2010). After an initial emergency response, eradication of the rust was determined to be not technically feasible and a decision to transition to management was made in December 2010. SOFR 2013 detailed the spread and effects of myrtle rust in the first 1–2 years after its arrival in Australia. In the five years since, the spread of myrtle rust along the eastern seaboard has stabilised, but new infections have been detected in Tasmania and the Northern Territory (Figure 3.7). The myrtle rust detections in Tasmania, like those in Victoria, currently remain confined to cultivated plants in gardens and nurseries.

When myrtle rust first arrived in Australia, there was considerable uncertainty as to its identity and relatedness to *Puccinia psidii* in South America (Carnegie and Lidbetter 2012). Knowing the identity of a rust is fundamentally important, as it underpins biosecurity measures, provides stable input for breeding programs for rust resistance, and allows effective prioritisation of management efforts. It is now known that the Australian strain of myrtle rust is the same as that found in South America, and is unrelated to other species of *Puccinia*. A new genus, *Austropuccinia*, was subsequently created to accommodate the species (Beenken 2017). A single strain of *A. psidii* is present in Australia, and isolates taken from a range of infected sites are genetically identical (Sandhu et al. 2016). The Australian strain is the same as one present in Hawaii, China, New Caledonia and Indonesia (Machado et al. 2015). This strain has only recently been identified in South America (Granados et al. 2017) and it remains unclear whether it originates from there.

Research and monitoring is measuring the impact that myrtle rust has on populations of individual species in natural ecosystems, and on the composition of forest communities. Preliminary determinations have been made to list two widespread species, *Rhodamnia rubescens* and *Rhodomyrtus psidioides*, as Critically Endangered under the New South Wales *Biodiversity Conservation Act 2016* because of the rapid impacts and ongoing threat from myrtle rust, which has caused large reductions in their population size[161]. Both species were common understorey shrubs or small trees in rainforests and wet sclerophyll forests along the coastal hinterland extending from central New South Wales to southern Queensland. Carnegie et al. (2016) found that myrtle rust was present in all 43 sampled stands of *Rhodamnia rubescens* and all 18 sampled stands of *Rhodomyrtus psidioides*, and that healthy *Rhodamnia rubescens* were killed in less than 18 months after exposure to myrtle rust. In two stands surveyed, all *Rhodomyrtus psidiodes* individuals had died (Figure 3.8).

Figure 3.7: Known infections of *Austropuccinia psidii* in Australia as at June 2016



Maps reproduced from Berthon et al. (2018) with permission.

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[161] www.environment.nsw.gov.au/resources/threatenedspecies/determinations/PDRhodrubesCR.pdf; www.environment.nsw.gov.au/resources/threatenedspecies/determinations/PDRhodpsidCR.pdf

Continues

Myrtle rust can also alter the composition and structure of the plant communities more broadly, with extensive damage to several rust-infested subtropical wet sclerophyll forests that are rich in species of Myrtaceae (Pegg et al. 2017). Rapid loss of the most rust-susceptible species of the Myrtaceae that dominate the mid- and understorey layer creates gaps that are being filled by less-susceptible species, including noxious weeds such as lantana (Figure 3.9).

Singh et al. (2016) found that 7.8% of Australia's hardwood plantation estate was located in areas climatically suitable for myrtle rust. However, in contrast with the severe disease seen in natural forests, myrtle rust currently has minimal impact in eucalypt plantations. Carnegie (2015) surveyed 55 plantations less than 2 years old in regions climatically suited to the disease. Myrtle rust was found in less than 10% of plantations, and only in those that were adjacent to rust-affected native forests. Only a small proportion of trees (<1%) showed disease symptoms, and disease did not persist once the plantations grew beyond three years of age. The strain of *Austropuccinia psidii* present in Australia can cause severe disease in many eucalypt species when artificially inoculated in greenhouse environments, but it appears that it has limited capacity to cause disease by natural infection in eucalypt plantations (Carnegie and Lidbetter 2012; Morin et al. 2012; Potts et al. 2016). The evidence gathered in the first seven years after the introduction of myrtle rust into Australia indicates a greater threat to conservation values than to wood production in plantations. This conclusion relies on maintaining strong biosecurity measures to reduce the risk of other strains of *A. psidii* becoming established in Australia.

A better understanding, and prioritisation, of the species and communities most at risk from the current strain of myrtle rust will also be required to manage the threat to conservation values. There is currently information on the susceptibility of approximately one-sixth of the 2126 species of the Myrtaceae family in Australia. A total of 23 high-priority species were identified amongst the 1285 species of Myrtaceae that occur in areas predicted to be climatically suitable for myrtle rust (Berthon et al. 2018).

Figure 3.8: Dead *Rhodomyrtus psidioides* in natural forest stand in north coastal New South Wales infected with myrtle rust

Figure 3.9: Extensive branch dieback in susceptible species of the Myrtaceae in the mid- and understorey layers of a rust-infected subtropical wet sclerophyll forest at Tallebudgera Valley, Queensland

Names of species indicate dieback of individuals of that species.

Case study 3.2: Mangrove dieback

Mangrove forests along the southern coast of the Gulf of Carpentaria experienced a sudden and extensive dieback event in 2015. An area of between 7 thousand and 10 thousand hectares along a 700-km stretch of coastline was affected, which is among the largest mass-death events ever reported for mangrove ecosystems. The two common mangrove species in the Gulf, *Rhizophora stylosa* and *Avicennia marina*, were both affected.

Because of its remoteness, reports of the dieback event only began to emerge in early 2016. Three aerial and field surveys in June, October and November 2016, combined with analysis and validation of satellite imagery, mapped affected areas and described the patterns of damage (Duke et al. 2017). Dieback occurred in 6% of the mangrove cover from Roper River estuary in the Northern Territory, east to Karumba in Queensland, but was most severe in those catchments draining into the central section of the southern coastline of the Gulf. In the worst-affected area, the Robinson River catchment, 26% of the mangrove cover was lost.

There was a strong spatial patterning of dieback. Mangroves occupying the highest points of the intertidal zone were most affected. In areas with less extensive dieback, narrow bands of dieback occurred in mangroves fringing saltmarshes along the inland edge of the intertidal zone (Figure 3.10, left-hand panel). In areas with a high level of impact, dieback affected mangroves throughout the intertidal zone (Figure 3.10, right-hand panel). Mangroves lining estuaries were less affected.

Visual symptoms were first noticed by residents of the Karumba area (at the south-eastern corner of the Gulf) at the end of the 2015 dry season, in mid to late November 2015 (Duke et al. 2017). However, analysis of satellite imagery indicated anomalous reductions in greenness of mangrove areas began appearing at the beginning of the dry season, around March 2015 (Harris et al. 2017). The 2015 dry season along the southern coast of the Gulf was characterised by a period of unusually low sea levels during an intense El Niño event, coupled with the co-occurrence of several climatic anomalies. This combination of conditions is considered to have resulted in hypersaline conditions in the mangrove ecosystem.

Similar conditions were recorded at around the same time and associated with a separate small dieback event at Mangrove Bay near Ningaloo Reef in Western Australia. Regular monitoring of the Mangrove Bay site since 2001 has shown two dieback events over the 15-year period: the 2015–2016 event and an earlier event in 2002–2003 (Lovelock et al. 2017). Both of these events coincided with periodic minima in sea levels and maxima in soil-pore salinity (Figure 3.11).

Proving the mechanism that links climate anomalies and mangrove dieback would allow consideration of how to reduce the risk of such dieback events recurring.

Figure 3.10: Aerial views of mangrove dieback in the Gulf of Carpentaria

Left panel, areas with dieback restricted to the inland edge of the intertidal zone; right panel, areas with a high level of dieback throughout the intertidal zone.

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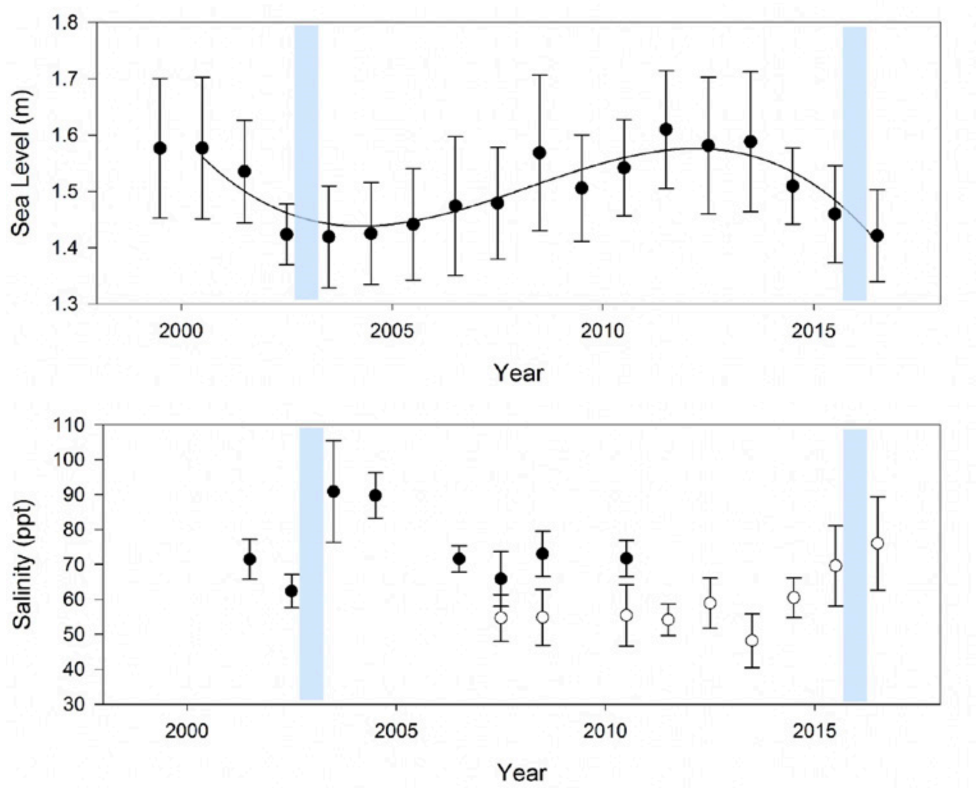
Figure 3.11: Sea level and mean soil-pore salinity at Mangrove Bay, Western Australia



Blue bars indicate the timing of mangrove dieback events; black and white circles represent two different monitoring campaigns; error bars are standard deviations; ppt, parts per thousand. Reproduced with permission from Lovelock et al. (2017).

Indicator 3.1b

Area of forest burnt by planned and unplanned fire

Rationale

This indicator is used to provide an understanding of the impact of fire on forests through the reporting of planned and unplanned fire. Fire is an important part of many forest ecosystems in Australia and may have either positive or negative impacts on forest health and vitality.

Key points

- The fire regime (the frequency, seasonality and intensity of burning of an area over a period of time) is a major determinant of many aspects of Australia's forest ecosystems.
  - Unplanned fires (bushfires) occur naturally in many forest ecosystems, or can be lit accidentally or deliberately.
  - Planned fire is used as a forest management tool in fire-adapted forest types for forest regeneration, to promote regeneration after harvest, to maintain forest health and ecological processes, and to reduce fuel loads and thereby increase the ability to manage bushfires and protect vulnerable communities.
- This indicator presents separately the cumulative area of fire in forest in the period 2011–12 to 2015–16, calculated as the sum of the individual forest fire areas for these five years; and the total area of forest burnt once or more over the period 2011–16, in which areas burnt multiple times, that is, in more than one year of this period, are reported only once.
- The area of fire in Australia's forests was 26.9 million hectares in 2011–12, 27.4 million hectares in 2012–13, 15.5 million hectares in 2013–14, 21.2 million hectares in 2014–15 and 14.9 million hectares in 2015–16. The cumulative area of fire in forest across this five-year period was 106 million hectares.
  - The largest cumulative areas of fire in forest over this five-year period were in Queensland (50 million hectares) and the Northern Territory (46 million hectares).
  - The cumulative area of fire in forest of 106 million hectares comprised 73 million hectares (69%) of unplanned fire and 33 million hectares (31%) of planned fire. A larger proportion of the forest area was burnt by planned fire in Western Australia than in other state or territory (other than the ACT, for which no unplanned forest fire was reported).
  - The cumulative area of fire in forest over the five-year period 2011–12 to 2015–16 includes large areas of forest, especially in northern Australia, that were burnt more than once over this period.
- When areas of forest burnt in multiple years are allowed for, the total area of forest burnt one or more times during the period 2011–12 to 2015–16 was 55 million hectares (41% of Australia's total forest area). The balance, 59% of Australia's forest area, did not experience fire in this period.
  - Tasmania (6%) and South Australia (6%) had the lowest proportions of forest area burnt one or more times during this period, while the Northern Territory (84%) had the highest proportion.
  - Of the total area of forest burnt during this five-year period, 29 million hectares were burnt multiple times, including 15 million hectares in the Northern Territory and 13 million hectares in Queensland.
- Most fires in southern Australia occurred in nature conservation reserves, whereas most fires in northern Australia occurred in leasehold or private forest.
- The area of fire in Australia's forests in each year from 2011–12 to 2015–16 was determined using spatial data provided by the states and territories, derived in turn from a combination of ground-based and remotely sensed sources. Fires were allocated as planned or unplanned by state and territory agencies, or according to state and territory agencies guidelines.
  - The new data and approaches have also allowed a more accurate view of the area of forest burnt in more than one year of the five-year reporting period.
  - However, changes in data sources, and improvements in data collection and reporting, mean that the annual forest fire areas reported in SOFR 2018 (particularly for northern Australia) cannot be compared to the areas reported in previous SOFRs.

This indicator reports on the area of forest burnt by planned or unplanned fires in the five years of the period 2011–12 to 2015–16. Monthly fire data are collated and reported annually, by financial year. The data are then reported both as the cumulative area of forest fire in the five-year period, and as the total area of forest burnt during the period.

The *cumulative area of fire in forest* in the five-year period is the sum of the annual forest fire area totals. Some areas of forest burnt in multiple years of the reporting period, and thus over a five-year period the cumulative area of fire in forest substantially exceeds the total area of forest that experienced fire. Over many years, the cumulative area of fire in forest would exceed the total area of forest in a region.

For SOFR 2018, this indicator therefore also reports the *total area of forest burnt* one or more times during the period, a metric that counts an area of burnt forest only once no matter how many times it burns in a reporting period. The total area of forest burnt can never exceed the total area of forest in a region.

Policy and coordination of fire management in Australia

The *National Bushfire Management Policy Statement for Forests and Rangelands* (FFMG 2014) outlines Australian, state and territory government objectives and policies for the management of landscape-level fire in Australia's forests and rangelands. The statement was developed by the Forest Fire Management Group, a national body within the Australian Government ministerial council structure, which has the role of providing information to governments on major forest fire-related issues, policies and practices affecting land management.

The Australasian Fire and Emergencies Authorities Council is the national peak organisation that provides advice on a range of policies and standards. Research on bushfires is performed by a number of organisations, including the Bushfire and Natural Hazards Cooperative Research Centre[162], which brings together experts from universities, fire and emergency management agencies, CSIRO, and other Australian, state and territory government organisations for long-term programs of collaborative research.

Fire in Australian forests

Fire is an intrinsic part of Australia's landscape, and bushfires have been an important factor in Australian ecosystems for millions of years. Much of Australia's native vegetation has evolved to be tolerant of fire, and many plant species require fire to regenerate, with adaptations that promote the spread of fire. The fire regime (the frequency, seasonality and intensity of burning of an area over a period of time) is a major determinant of many aspects of Australia's forest ecosystems.

Indigenous Australians have long used fire as a land-management tool. Planned fire is currently used by land managers to manage vegetation, and to protect properties from uncontrolled bushfire by reducing fuel loads.

The main factors required for propagation of fire are the presence of fuel, oxygen and an ignition source. Fires can originate from human activity and from natural causes, with lightning nearly always the natural source of fire. Fire intensity and the speed at which a fire spreads depend on fuel load and arrangement, fuel moisture, prevailing temperature, wind speed and slope angle. The most intense fires occur when temperatures are high, humidity is low, winds are strong, and the arrangement of fuel allows rapid propagation. Box 3.1 summarises the occurrence of bushfires in Australia. Detailed geographic descriptions of Australia's fire regimes have also been published (Murphy et al. 2013).

Planned and unplanned fires

Planned fires are fires lit in accordance with a fire management plan or planned burning program for fuel reduction, ecological or silvicultural purposes, or as part of bushfire control efforts; they are also called 'prescribed burns' or sometimes 'fuel reduction burns'.

Unplanned fires are fires that have started naturally (usually by lightning), accidentally or deliberately (such as by arson) but not as part of a program of prescribed burning; they are also called bushfires or wildfires.

Planned fires are scheduled for times of the year when temperature, humidity and fuel loads enable fire control, yet still allow achievement of burning targets. Planned fires can become unplanned fires if they escape containment lines and become uncontrolled.

Unplanned fires

The extent and intensity of unplanned fires, or bushfires, vary with latitude and seasonal rainfall (see Box 3.1), and the drivers of fire are substantially different across the continent:

- The incidence of fire in northern Australia is essentially limited by fuel loads, and low-intensity fires burn over large areas in each dry season.
- The incidence of fire in southern Australia is essentially limited by fuel dryness, and some areas of south-eastern and south-western Australia are prone to severe bushfires: hot, dry and windy summer conditions, especially following periods of drought, lead to fires in eucalypt forest that are often very intense and difficult to control. Such bushfires can result in the loss of human life, and destroy assets such as buildings, fences, bridges and powerlines as well as standing stocks of wood (native forest and plantations). They can also have a significant impact on ecological values, and affect water supplies.
- Bushfires are rare in the tropical rainforests of northern Australia, and are occasional in the subtropical, temperate and cool-temperate rainforests of southern Australia. However, during prolonged droughts even these forests can be damaged by fire entering from adjacent grasslands or eucalypt forests.

[162] www.bnhcrc.com.au/

Recovery by epicormic shoots after bushfire, Erica, Victoria.

Climate change and weather pattern variability are among the key factors that are predicted to affect the future occurrence and severity of bushfires. Projected increases in summer temperatures and declines in rainfall are predicted to exacerbate the risk of fire and increase the challenges associated with fire management.

More frequent and intense bushfires could also increase the incidence and severity of certain pests, diseases and weeds. For example, populations of bark beetles (*Ips* spp.) may increase in response to a higher availability of fire-damaged (dead, dying or stressed) trees that can be colonised. Furthermore, forests affected by pests, diseases and weeds may become more vulnerable to bushfires as a result of increases in fuel loads due to tree mortality (Singh et al. 2010). Indicator 3.1a provides more information on pests, diseases and weeds affecting forest health.

Planned burning

Planned or prescribed burning is the deliberate use of fire to achieve particular management objectives, and is an important management tool on both public and private land. Case study 3.3 on the *National Burning Project: Prescribed Burning Guidelines and Frameworks* describes how the principles underpinning planned burns were articulated and put into practice. Management objectives for planned burns can include reducing the levels of flammable fuels (fuel reduction burning), protection and enhancement of biodiversity in fire-adapted ecosystems, and promoting regeneration after wood harvesting; not all of these objectives are necessarily served equally by the same burn frequency or intensity.

Planned burning does not prevent unplanned fires. However, in some ecological communities previous planned burning can reduce the intensity of unplanned fires, aid control efforts by widening the range of weather and other conditions under which an unplanned fire may be controlled, and potentially allow firefighters to break the run of large fires (McCaw 2013). This can lead to a reduced area of unplanned fire, and a lower impact.

In the tropical savannas of northern Australia, woodland forests with a grassy understorey are part of a patchy landscape mosaic. Rapid growth occurs in the wet season, and this is converted to fuel during the dry season, with an increased risk of high-intensity fires late in the dry season. Up to 50% of some northern Australian landscapes may be burnt in a single year, and most areas burn at least once every three years. Land managers in northern savannas are increasingly employing traditional, early dry-season burning techniques, where burning occurs at low intensity and in a patchy mosaic, so as to reduce the risk of extensive, high-intensity late-season fire and consequential carbon dioxide emissions. Complete suppression of fire, on the other hand, can lead to increased tree and shrub invasion, which may adversely affect biodiversity and habitat values and reduce pastoral productivity, and can also lead to cumulative increases in fuel loads and an associated increased fire risk. Case study 5.3 in Indicator 5.1a on the Western Arnhem Land Fire Abatement project describes one such planned burning program in northern Australia.

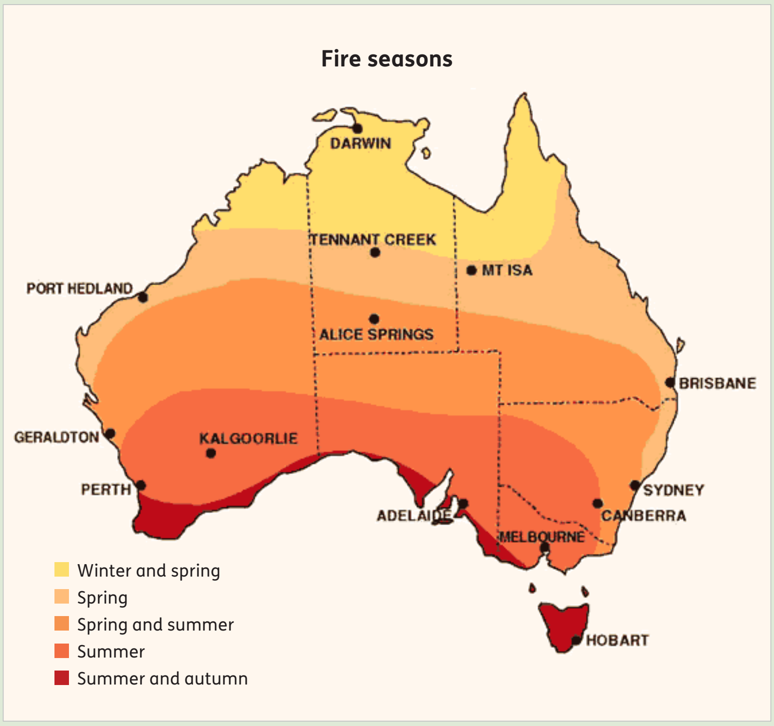
Box 3.1: Where and when do bushfires occur?

The Australian climate is generally hot, dry and prone to drought. At any time of the year, some parts of Australia are prone to bushfire, with the widely varied fire seasons reflecting the continent's different weather patterns (Figure 3.12). For most of south-eastern and south-western Australia, the fire danger period is summer and autumn. For areas in northern New South Wales and southern Queensland, peak risk usually occurs in spring and early summer. Most fires in the Northern Territory, Queensland and northern Western Australia are in the monsoonal dry season, which coincides with the southern winter and spring.

Bushfires in eucalypt forests tend to occur when fuel loads have dried out, usually following periods of low rainfall and high temperatures. In grasslands, however, and in woodlands with a grassy understorey, fires frequently occur after good periods of rainfall which result in abundant growth that dries out in subsequent hot weather.

The potential for extreme fire weather varies greatly throughout Australia, both in frequency and severity. The greatest extent of fire is in the Northern Territory and northern areas of Western Australia and Queensland, where there are large, sparsely settled areas with few roads, and where dry-season fires started by lightning or other causes burn large areas. Most loss of life and economic damage occurs in the areas around cities and regional towns in south-eastern and south-western Australia, where homes are commonly in close proximity to flammable vegetation.

Figure 3.12: Distribution of bushfire seasonality across Australia



Map source: Bureau of Meteorology (www.bom.gov.au/weather-services/bushfire/about-bushfire-weather.shtml); see also Luke and MacArthur (1978)

Source: Adapted text from Geoscience Australia (www.ga.gov.au/scientific-topics/hazards/bushfire)

The EcoFire project in the Kimberley, Western Australia (Legge et al. 2011), a partnership between landholders, private conservation organisations and government agencies, is also working to use planned early dry-season fires to minimise the area of extensive, intense, uncontrolled and unplanned mid-to-late dry season fires and thereby improve habitat quality and the proportion of long-unburnt vegetation across the landscape.

Prescribed burning for fuel reduction needs to bring together contrasting expectations: the public expectation that fuel hazards will be managed to protect life and property, and concerns that inappropriate burning will affect biodiversity and other values (McCaw 2013). Prescribed burning regimes will have undue impacts if burning is more frequent, intense or uniform than the natural fire regime for a particular ecological community, or if it occurs at times of the year when natural processes are adversely affected. Area targets for fuel-reduction burning can be designed to balance community safety and asset protection with protection of ecological values and maintenance of ecological processes. Whether or not area targets are achieved depends on weather and fuel conditions: unseasonably warm, dry or windy weather can make prescribed burning too risky, and unseasonably cold or wet weather can make prescribed burning ineffective.

Case study 3.3: National Burning Project: Prescribed Burning Guidelines and Frameworks

Prescribed burning (also referred to as 'planned burning') is defined by the Australasian Fire and Emergency Service Authorities Council (AFAC) as

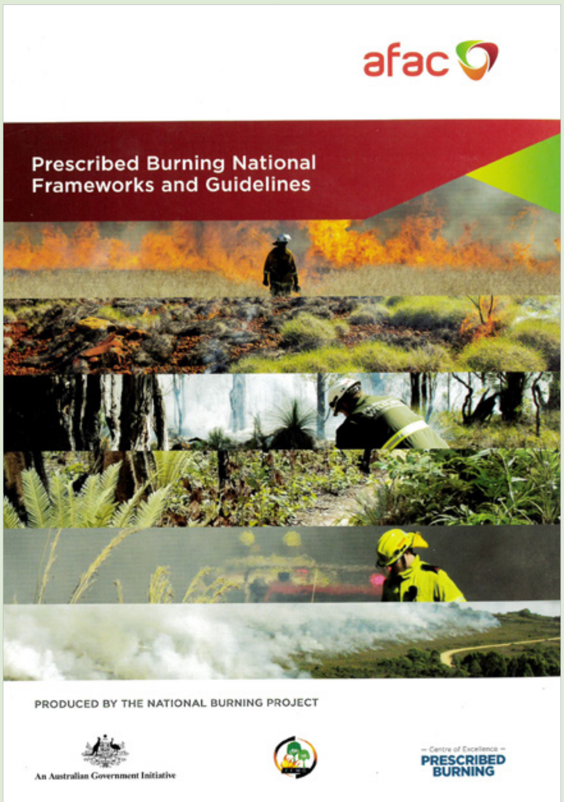
> *"The controlled application of fire under specified environmental conditions to a predetermined area and at the time, intensity and rate of spread required to attain planned resource management objectives"* (AFAC 2012).

Fire managers use prescribed burning as an effective way to manage fuel accumulation, maintain ecosystem processes and achieve silvicultural outcomes in forests and woodlands. However, some people and community organisations have concerns for the effects on flora and fauna, visual amenity, air quality and other values. The risk to people and assets from fires escaping from planned burning areas is also an issue.

For these and other reasons, many enquiries over the years (for example, House of Representatives Select Committee 2003; Ellis et al. 2004) have recommended the development of nationally agreed principles and practices for prescribed burning. AFAC and the Forest Fire Management Group (FFMG) initiated the National Burning Project to address those recommendations (Sparkes 2017). AFAC is the national council for fire and emergency services; FFMG is a committee of Australian and New Zealand land management agencies and representatives from research, education and the forest industry that provides a forum and centre of expertise on forest fire management and control. The National Burning Project was funded by AFAC members and the Commonwealth Government National Bushfire Mitigation Program.

The aim of the National Burning Project was to develop guidelines and frameworks for a more holistic and consistent approach to prescribed burning. The project started in 2011 and, by completion in 2017, had delivered a suite of policy and procedural documents that addresses all aspects of prescribed burning. These documents, all available through the Australian Disaster Resilience Knowledge Hub[163], include:

- An *Overview of Prescribed Burning in Australasia*.
- A *National Position on Prescribed Burning*: this confirms 10 principles for prescribed burning, including that prescribed burning is used to reduce the quantity, extent and connectivity of fuel hazards, and that protection of human life is the highest priority in prescribed burning operations.
- *National Guidelines for Prescribed Burning Strategic and Program Planning*: this lays down principles for strategic, program and operational planning.
- *Best Practice Principles for Prescribed Burning*.
- National risk management frameworks to address ecological, fuel management, smoke, greenhouse gas emissions and operational safety risks arising from prescribed burning.
- Training manuals for a range of prescribed burning competencies, from support roles to managing complex prescribed burns.
- A large number of case studies and reviews of science, best practice and capability.



AFAC *Prescribed Burning National Framework and Guidelines*, which presents the key documents of the National Burning Program.

163 knowledge.aidr.org.au/resources/national-prescribed-burning-guidelines-and-frameworks/

Determining the extent of fire in Australia's forests: data sources and analysis

Australia has no nationally coordinated approach to the systematic mapping and reporting of fire areas. For reporting in SOFR 2018, annual spatial coverages of fires for the period 2011–12 to 2015–16 were therefore sourced from each state and territory separately, either by direct provision by the state or territory or from the North Australia and Rangelands Fire Information (NAFI) website[164]. Most jurisdictions create their fire area dataset from multiple sources, including satellite imagery, aerial photography, aerial reconnaissance, and operational and on ground knowledge and measurement.

Meaningful datasets of fires or burnt areas in woodland forests, such as the savannas of northern Australia, can be derived from satellite-based platforms carrying Advanced Very High Resolution Radiometer (AVHRR[165]), Moderate-resolution Imaging Spectroradiometer (MODIS[166]) and Landsat ETM[167] sensors. The different satellites detect areas affected by fire in different ways (for example, through hot-spots, smoke plumes or vegetation changes), and combining the fire area data from different sensors gives a fire area statement that is larger than that from each satellite individually.

The extent and distribution of fire or burnt areas in open or closed forests, such as in the forests of southern Australia, is determined by combining satellite data with ground-based measurements and high-resolution aerial photography. Spatial data collated in this way were provided by the Australian Capital Territory, New South Wales, South Australia, Tasmania, Victoria and Western Australia. For these jurisdictions, each fire was allocated as either unplanned or planned by the jurisdiction that provided the data, as the seasonal distribution of planned and unplanned fires differs between jurisdictions.

Fire area provided by the Northern Territory and Queensland were derived solely from remote sensing. Fire area data provided by the Northern Territory were derived from the NAFI website, which combines MODIS satellite data with data from satellites carrying an AVHRR sensor, and also incorporates Landsat satellite data. Queensland agencies provided data from NAFI as well as Landsat data used in the Queensland Statewide Landcover and Trees Study program, with these two datasets being combined by ABARES.

For the Northern Territory and Queensland, the allocation of fires as unplanned or planned was based on their month of occurrence. Northern Territory fires occurring from January to July were allocated as planned fires, while those occurring from August to December were allocated as unplanned fires. Queensland fires occurring between January and June were allocated as planned fires, while those occurring between July and December were allocated as unplanned fires.

The data indicated that some areas had burnt more than once in any one financial year. In such situations, only the first fire in that year (whether planned or unplanned) was retained in the data. This approach had only a small (<2%) effect on total area figures.

The fire datasets for each jurisdiction were then intersected with the forest cover dataset (Indicator 1.1a) to produce forest fire statistics.

Large areas of northern Australia were reported as having burnt in multiple years of the five-year reporting period, (2011–12 to 2015–16). This indicator therefore reports separately the *cumulative area of fire in forest* (the sum of the five individual-year forest fire areas; this counts every time an area of forest was burnt in the five-year period) and the *total area of forest burnt* (in which a burnt area of forest is counted only once in the five-year period, even if it was burnt more than once in that period). SOFR 2008 and SOFR 2013 reported only the cumulative area of fire in forest in the five-year reporting period (the sum of the five individual-year areas).

Both the data sources and the methods used to derive area of forest fire for SOFR 2018 are different to those used for SOFR 2008 and SOFR 2013, and therefore the results cannot be directly compared between these reports. This is particularly so for Northern Territory, Queensland and northern Western Australia, where only the MODIS dataset was used for SOFR 2008 and SOFR 2013, compared to the wider range of datasets used for SOFR 2018. Furthermore, different algorithms and data resolutions were used in analysis of the fire datasets reported in SOFR 2018. Lastly, a larger and more accurate forest coverage was used for SOFR 2018, particularly in the Northern Territory (see Indicator 1.1a).

Area of forest fire

The national area of fire in forest in each year over the period 2011–12 to 2015–16, by jurisdiction, is shown in Figure 3.13, separately by planned and unplanned fire. Across the reporting period, the area of unplanned forest fire was highest for reporting years 2011–12 and 2012–13, these annual areas being more than twice the area burnt by unplanned fire in 2013–14 (Figure 3.13). In contrast, the annual area of planned forest fire remained relatively constant over the reporting period. Overall, these trends are driven by differences in fire areas between years in northern Australia.

The area of forest fire in each year over the period 2011–12 to 2015–16 is shown for each jurisdiction in Table 3.6, separately by planned and unplanned fire, as well as the cumulative total area of fire in forest in each jurisdiction for this five-year period. The data for Western Australia are shown separately for southern and northern Western Australia (south and north of the Tropic of Capricorn) due to differences in climate and fire management in these regions.

164 www.firenorth.org.au/nafi3/
165 noaasis.noaa.gov/NOAASIS/ml/avhrr.html
166 modis.gsfc.nasa.gov/
167 landsat.gsfc.nasa.gov/

Table 3.6: Area of forest fire, 2011–12 to 2015 16, by year and jurisdiction, separately for planned and unplanned fire ('000 hectares)

Jurisdiction	Forest fire area					Cumulative area of fire in forest, 2011–12 to 2015–16[a]	Proportion of cumulative area of fire in forest, 2011–12 to 2015–16
	2011–12	2012–13	2013–14	2014–15	2015–16		
Planned fire							
ACT	0	9	0	3	5	17	0.1%
NSW	75	221	125	122	248	791	2.4%
NT	3,810	1,969	2,475	3,059	1,853	13,166	40%
Qld	2,700	2,371	3,102	3,056	1,930	13,159	40%
SA	7	11	2	2	3	24	0.1%
Tas.	10	14	10	23	4	60	0.2%
Vic.	99	118	46	146	118	526	1.6%
WA	1,536	1,484	828	651	686	5,184	16%
southern WA[b]	96	35	80	139	155	504	1.5%
northern WA[c]	1,441	1,450	748	512	531	4,681	14%
Australia	**8,236**	**6,197**	**6,587**	**7,061**	**4,847**	**32,927**	**100%**
Unplanned fire							
ACT	0	0	0	0	0	0	0.0%
NSW	11	318	485	119	41	975	1.3%
NT	6,299	8,107	4,310	7,532	6,152	32,399	44%
Qld	11,940	12,360	3,088	6,082	3,273	36,743	50%
SA	6	28	221	8	16	279	0.4%
Tas.	3	51	7	6	80	147	0.2%
Vic.	2	136	318	28	14	498	0.7%
WA	363	153	467	398	457	1,837	2.5%
southern WA[b]	104	70	26	155	313	668	0.9%
northern WA[c]	259	83	441	243	143	1,169	1.6%
Australia	**18,623**	**21,154**	**8,896**	**14,174**	**10,032**	**72,880**	**100%**
All fire							
ACT	0	9	0	3	5	17	0.0%
NSW	85	540	610	241	289	1,766	1.7%
NT	10,109	10,076	6,784	10,591	8,004	45,565	43%
Qld	14,640	14,731	6,190	9,138	5,203	49,902	47%
SA	13	39	222	10	19	302	0.3%
Tas.	13	65	18	29	84	208	0.2%
Vic.	100	255	363	174	132	1,025	1.0%
WA	1,899	1,637	1,294	1,049	1,142	7,022	6.6%
southern WA[b]	199	104	106	294	469	1,172	1.1%
northern WA[c]	1,700	1,533	1,189	755	674	5,849	5.5%
Australia	**26,860**	**27,351**	**15,483**	**21,235**	**14,879**	**105,807**	**100%**

[a] Cumulative area of fire in forest is the sum of the five annual area totals, and therefore counts multiple times any forest areas that were burnt in two or more years of the five-year period. This metric can therefore exceed the total forest area.

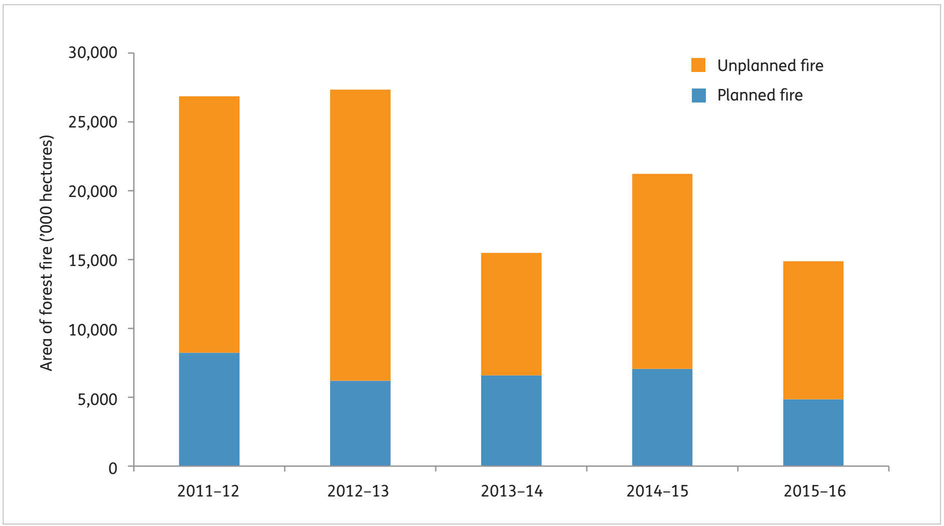
[b] Data for forest south of the Tropic of Capricorn, calculated using an interim area mask.

[c] Data for forest north of the Tropic of Capricorn, calculated using an interim area mask.

Totals may not tally due to rounding.

This table, together with other data for Indicator 3.1b, is available in Microsoft Excel via www.doi.org/10.25814/5bda8e8ad76d6

Figure 3.13: Area of planned and unplanned forest fire ('000 hectares) by year



The data used to create this figure, together with other data for Indicator 3.1b, are available in Microsoft Excel via www.doi.org/10.25814/5bda8e8ad76d6

The area of forest burnt nationally in any one year from 2011–12 to 2015–16 varied from 15 million hectares to 27 million hectares (Figure 3.13). Summing these figures gives the cumulative area of fire in forest over this period as 106 million hectares (Table 3.6). Forest areas that are burnt on multiple occasions during the reporting period are counted multiple times in this total. The largest cumulative areas of fire in forest were Queensland (50 million hectares, 47% of the national total) and the Northern Territory (46 million hectares, 43% of the national total). Together, these two jurisdictions accounted for 90% (95 million hectares) of the cumulative total of all fire in forest in the period 2011–12 to 2015–16.

Nationally, over the period 2011–12 to 2015–16 the cumulative area of fire in forest of 106 million hectares comprised 73 million hectares of unplanned fire (69% of the total) and 33 million hectares of planned fire (31% of the total). The proportion of the cumulative area of forest that was burnt by planned fire varied between jurisdictions, from 8% in South Australia to 80% for the northern part of Western Australia (and 100% in the ACT, for which no unplanned forest fire was reported in the period). The cumulative area of unplanned fire in forest was greater than the cumulative area of planned fire in forest in all jurisdictions except the Australian Capital Territory, Victoria and Western Australia. Queensland and the Northern Territory had the largest cumulative areas of planned fire in forest in the period 2011–12 to 2015–16 (each 13 million hectares), as well as the largest cumulative areas of unplanned forest fire in forest (37 and 32 million hectares, respectively). There was also a substantial cumulative area of planned fire in forest (4.7 million hectares) in the northern part of Western Australia (Table 3.6).

Area of forest burnt one or more times

Spatial analysis of the fire areas in the individual years of the five-year reporting period 2011–12 to 2015–16 showed that most areas of forest burnt in southern Australia burnt only once during this period. On the other hand, large areas of forest were burnt multiple times during this reporting period, especially in northern Australia. Figure 3.14 (see page 269) shows the distribution of burnt forest in Australia by the number of times each hectare was burnt in the period 2011–12 to 2015–16.

Forest areas burnt in more than one year of the period 2011–12 to 2015–16 contribute multiple times to the cumulative area of fire in forest presented in Table 3.6, depending on the number of years in which each such area was burnt. When fire areas burnt in multiple years are allowed for, the total area of forest that was burnt once or more in the period 2011–12 to 2015–16 was determined as 55 million hectares, which is 41% of Australia's forest area (Table 3.7). This is the total area impacted by fire once or more during the reporting period, and is represented as the various colour areas labelled 1–5 on Figure 3.14.

The largest areas of forest burnt in the period 2011–12 to 2015–16 were in Queensland (28 million hectares, 55% of Queensland's total forest area, and 52% of the total national area of forest burnt) and the Northern Territory (20 million hectares, 84% of the Northern Territory's total forest area, and 37% of the total national area of forest burnt) (Table 3.7).

Of the total area of forest burnt in the period 2011–12 to 2015–16, 29 million hectares (22% of Australia's forest area) was burnt multiple times. These areas of forest were almost completely confined to northern Australia (Figure 3.14), including substantial areas of forest in the Northern Territory (15 million hectares, 62% of the Northern Territory's total forest area), Queensland (13 million hectares, 25% of Queensland's total forest area) and northern Western Australia (1.8 million hectares, 49% of the total forest area

Table 3.7: Area of forest burnt by number of times burnt, by jurisdiction, 2011–12 to 2015–16 ('000 hectares)

			Forest area burnt, 2011–12 to 2015–16								
Jurisdiction	Total forest area	Forest area not burnt, 2011–12 to 2015–16	Area burnt one times	Area burnt two times	Area burnt three times	Area burnt four times	Area burnt five times	Area burnt one or more times[a]	Proportion of total jurisdictional forest area	Area burnt two or more times[b]	Proportion of total jurisdictional forest area
ACT	142	125	17	0	0	0	0	17	12%	0	0.0%
NSW	20,368	18,637	1,696	35	0	0	0	1,731	8%	35	0.2%
NT	23,735	3,689	5,434	6,836	5,106	2,212	459	20,046	84%	14,612	62%
Qld	51,830	23,539	15,397	6,913	3,708	1,809	463	28,291	55%	12,894	25%
SA	5,060	4,759	300	1	0	0	0	301	6%	1	0.0%
Tas.	3,699	3,495	200	4	0	0	0	204	6%	4	0.1%
Vic.	8,222	7,228	964	30	0	0	0	995	12%	30	0.4%
WA	20,981	17,737	1,447	589	660	324	224	3,244	15%	1,797	9%
southern WA[c]	17,357	16,220	1,107	25	4	1	0	1,136	7%	30	0.2%
northern WA[d]	3,624	1,516	341	564	656	323	224	2,108	58%	1,768	49%
Australia	**134,037**	**79,208**	**25,456**	**14,408**	**9,474**	**4,345**	**1,146**	**54,829**	**41%**	**29,374**	**22%**
Proportion of total national forest area	100%	59%	19%	11%	7%	3.2%	0.9%	41%		22%	

[a] Sum of the areas burnt one times, two times, three times, four times and five times in the period 2011–12 to 2015–16, giving the total area of forest burnt one or more times. The forest areas burnt on multiple occasions are counted only once in these totals.

[b] Sum of the areas burnt two times, three times, four times and five times in the period 2011–12 to 2015–16, giving the total area of forest burnt multiple times.

[c] Data for forest south of the Tropic of Capricorn, calculated using an interim area mask.

[d] Data for forest north of the Tropic of Capricorn, calculated using an interim area mask.

Note: Multiplying each area of forest burnt by the number of years in which it was burnt in the period 2011-12 to 2015-16, and summing the results, gives the cumulative area of forest fire over the reporting period (Table 3.6).

This table, together with other data for Indicator 3.1b, is available in Microsoft Excel via www.doi.org/10.25814/5bda8e8ad76d6

of northern Western Australia). A small area of forest was burnt in all five years of the reporting period (Table 3.7). Only very small areas of forest in southern Australia were burnt more than once between 2011–12 and 2015–16. Figure 3.15 (see page 270) shows the distribution of burnt forest in Australia coloured according to whether the area was burnt by planned fire, by unplanned fire, or by both planned and unplanned fires, in the period 2011–12 to 2015–16.

Nationally, 79 million hectares of forest (59% of Australia's forest area) were not burnt at all in the period 2011–12 to 2015–16 (Table 3.7, Figure 3.15). The jurisdictions with the highest proportions of forest area not burnt during this period were Tasmania (94%) and South Australia (94%).

The high fire frequency in northern Australia is driven by the characteristics of vegetation and climate. In open tropical forests with a grassy understorey, periods of prolific annual growth in the wet season are followed by rapid drying in the dry season, and lightning associated with storm events leads to frequent and extensive unplanned fires, especially late in the dry season. Case study 5.3 in Indicator 5.1a describes how planned burns early in the dry season, implemented by traditional owners and land managers, are being used to reduce the extent and impact of unplanned fires late in the dryseason.

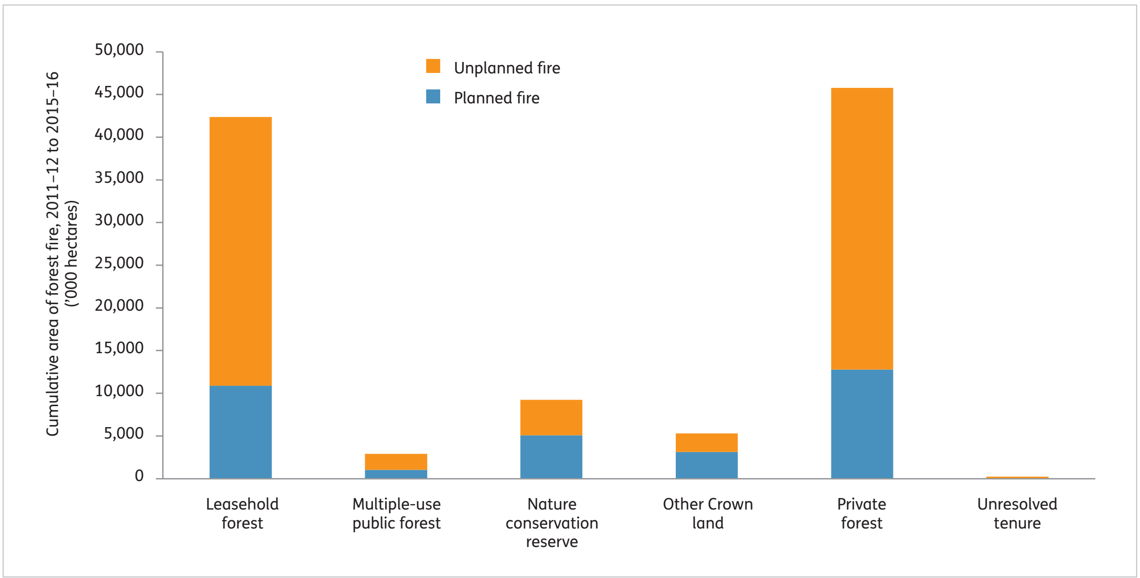
Tenure of forest areas burnt by planned and unplanned fire

The cumulative area of fire in forest over the period 2011–12 to 2015–16 in different forest tenures is shown in Table 3.8, separately by planned and unplanned fire, and by jurisdiction. Of the cumulative area of fire in forest of 106 million hectares over this period, the largest areas nationally were in leasehold forest (42 million hectares) and private forest (46 million hectares) (Figure 3.16). The large areas of fire in leasehold and private tenure forests derive from the large areas of forests in these tenures across northern Australia where the majority of forest fire occurs, rather than from the nature of land management across tenures.

The ratio of planned fire to unplanned fire in this period varied by tenure (Figure 3.16) and jurisdiction (Table 3.8). In nature conservation reserves, 55% of the cumulative forest fire area for 2011–12 to 2015–16 was planned fire, whereas in leasehold and private forests 26% and 24% respectively of the cumulative forest fire area for 2011–12 to 2015–16 was planned fire. The area proportions of fire that was planned in multiple-use public forest in Victoria and in southern Western Australia were substantially higher than the national average for that tenure, at 64% and 69% respectively. All fire in the ACT in this period was planned fire.

Analysis of the area of forest burnt in the period 2011–12 to 2015–16 in different tenures (Table 3.9), by jurisdiction, shows a similar pattern. Of the total forest area of 55 million hectares burnt in this period, the largest areas nationally were in leasehold forest (24 million hectares, which is 51% of the total national area of forest on that tenure) and private forest (20 million hectares, which is 47% of the total national area of forest on that tenure). Forest burnt on these two tenures comprises 88% of the total area of forest burnt in Australia in this period.

Figure 3.16: Cumulative area of planned and unplanned forest fire by tenure, 2011–12 to 2015–16



The data used to create this figure, together with other data for Indicator 3.1b, are available in Microsoft Excel via www.doi.org/10.25814/5bda8e8ad76d6

Table 3.8: Cumulative area of fire in forest, 2011–12 to 2015–16, by tenure and jurisdiction, separately for planned and unplanned fire

	Forest fire area ('000 hectares)						
Jurisdiction	Leasehold forest	Multiple-use public forest	Nature conservation reserve	Other Crown land	Private forest	Unresolved tenure	Total
Planned fire							
ACT	0	1	16	0	0	0	17
NSW	5	83	622	20	61	1	791
NT	4,132	0	5	1,294	7,728	8	13,166
Qld	6,527	412	1,114	536	4,524	46	13,159
SA	1	1	21	0	1	0	24
Tas.	0	23	22	12	4	0	60
Vic.	0	279	223	18	6	0	526
WA	210	240	3,045	1,241	449	0	5,184
southern WA[a]	3	240	228	22	11	0	504
northern WA[b]	207	0	2,817	1,218	438	0	4,681
Australia	**10,874**	**1,039**	**5,067**	**3,121**	**12,773**	**54**	**32,927**
Unplanned fire							
ACT	0	0	0	0	0	0	0
NSW	18	131	479	28	320	0	975
NT	9,722	0	18	747	21,899	14	32,399
Qld	21,562	1,409	2,250	855	10,511	156	36,743
SA	47	10	181	2	38	0	279
Tas.	0	48	34	28	37	0	147
Vic.	0	159	303	3	33	0	498
WA	140	107	910	510	170	0	1,837
southern WA[a]	29	107	349	127	56	0	668
northern WA[b]	110	0	561	384	114	0	1,169
Australia	**31,488**	**1,864**	**4,175**	**2,174**	**33,008**	**170**	**72,880**
All fire							
ACT	0	1	16	0	0	0	17
NSW	22	214	1,100	48	380	1	1,766
NT	13,853	0	22	2,041	29,627	22	45,565
Qld	28,090	1,820	3,364	1,391	15,035	202	49,902
SA	48	11	202	2	39	0	302
Tas.	0	71	56	41	40	0	208
Vic.	0	438	526	21	39	0	1,025
WA	349	347	3,955	1,751	619	0	7,022
southern WA[a]	32	347	576	149	67	0	1,172
northern WA[b]	317	0	3,379	1,602	552	0	5,850
Australia	**42,362**	**2,903**	**9,242**	**5,295**	**46,229**	**225**	**105,807**

[a] Data for forest south of the Tropic of Capricorn, calculated using an interim area mask.
[b] Data for forest north of the Tropic of Capricorn, calculated using an interim area mask.

This table, together with other data for Indicator 3.1b, is available in Microsoft Excel via www.doi.org/10.25814/5bda8e8ad76d6

The largest area of forest burnt by fire in southern Australia in this period was in nature conservation reserves (a total of 2.4 million hectares); this was also the case in each jurisdiction in southern Australia except for Tasmania, where the largest forest area burnt was in multiple-use public forests (Table 3.9). In the Northern Territory, the largest area of forest burnt by fire was on private land (12 million hectares) followed by leasehold land (7.1 million hectares), whereas in Queensland the largest area of forest burnt by fire was on leasehold land (17 million hectares) followed by private land (7.1 million hectares).

Burnt snowgums (*Eucalyptus pauciflora*) above the Guthega River, New South Wales.

Table 3.9: Area of forest burnt, by jurisdiction and tenure, 2011–12 to 2015–16

	Forest area burnt, 2011–12 to 2015–16 ('000 hectares)							
Jurisdiction	Leasehold forest	Multiple-use public forest	Nature conservation reserve	Other Crown land	Private forest	Unresolved tenure	Total	Proportion of total area burnt
ACT	0	1	16	0	0	0	17	0.0%
NSW	22	207	1,076	48	377	1	1,731	3.2%
NT	7,098	0	8	811	12,115	13	20,046	37%
Qld	16,524	1,528	2,121	801	7,165	153	28,291	52%
SA	48	11	201	2	39	0	301	0.5%
Tas.	0	70	54	40	40	0	204	0.4%
Vic.	0	424	510	21	39	0	995	1.8%
WA	202	334	1,642	740	326	0	3,244	5.9%
southern WA[a]	29	334	563	146	65	0	1,136	2.1%
northern WA[b]	173	0	1,079	594	262	0	2,108	3.8%
Australia	**23,894**	**2,574**	**5,629**	**2,464**	**20,101**	**167**	**54,830**	**100%**
Forest area burnt as a proportion of total forest area of that tenure[c]	51%	24%	26%	22%	47%	21%	100%	

[a] Data for forest south of the Tropic of Capricorn, calculated using an interim area mask.

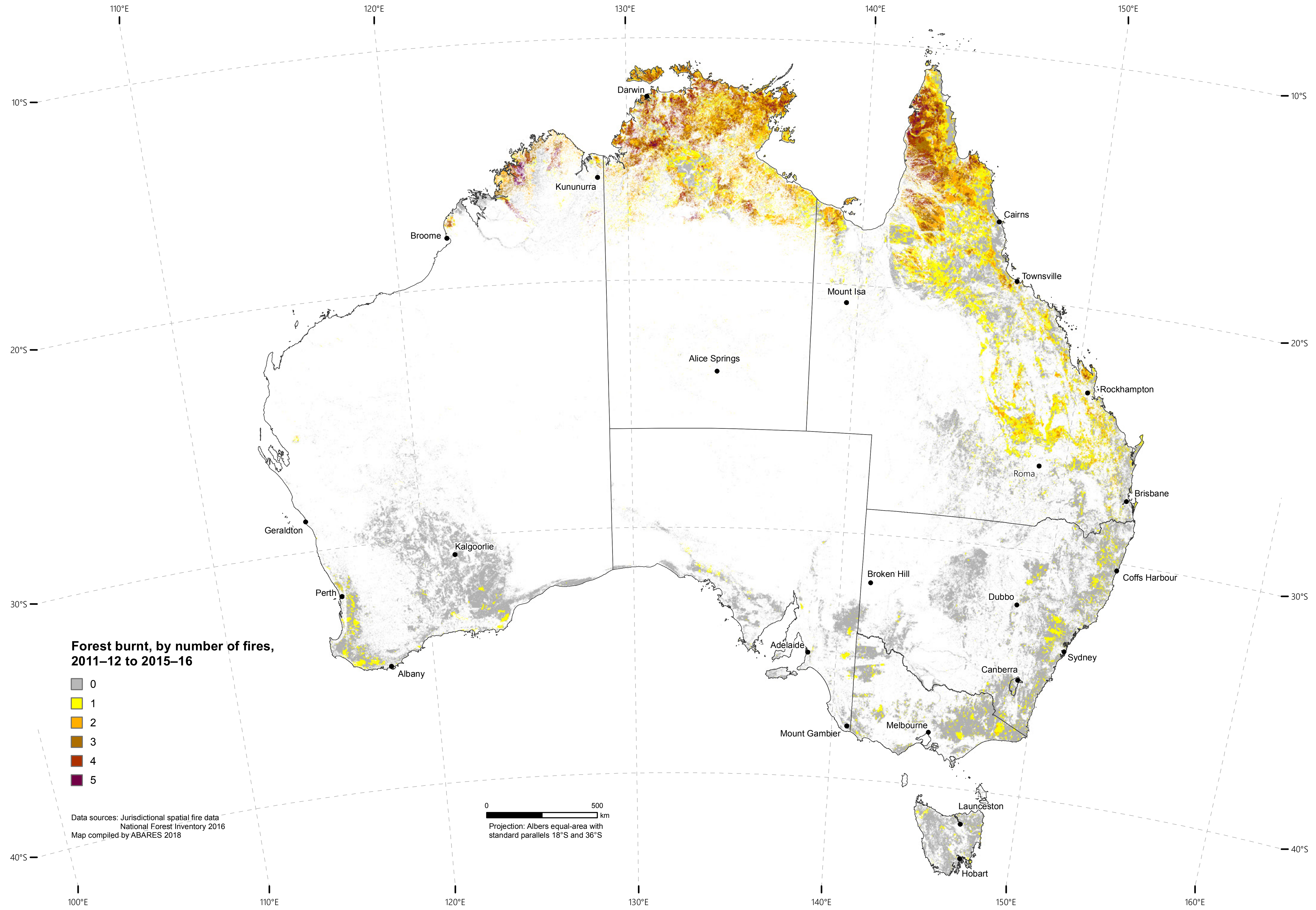
[b] Data for forest north of the Tropic of Capricorn, calculated using an interim area mask.

[c] Table 1.7, Indicator 1.1a, shows forest area totals by tenure.

Includes both planned and unplanned fire. Forest areas burnt on multiple occasions are counted only once in these figures.

This table, together with other data for Indicator 3.1b, is available in Microsoft Excel via www.doi.org/10.25814/5bda8e8ad76d6

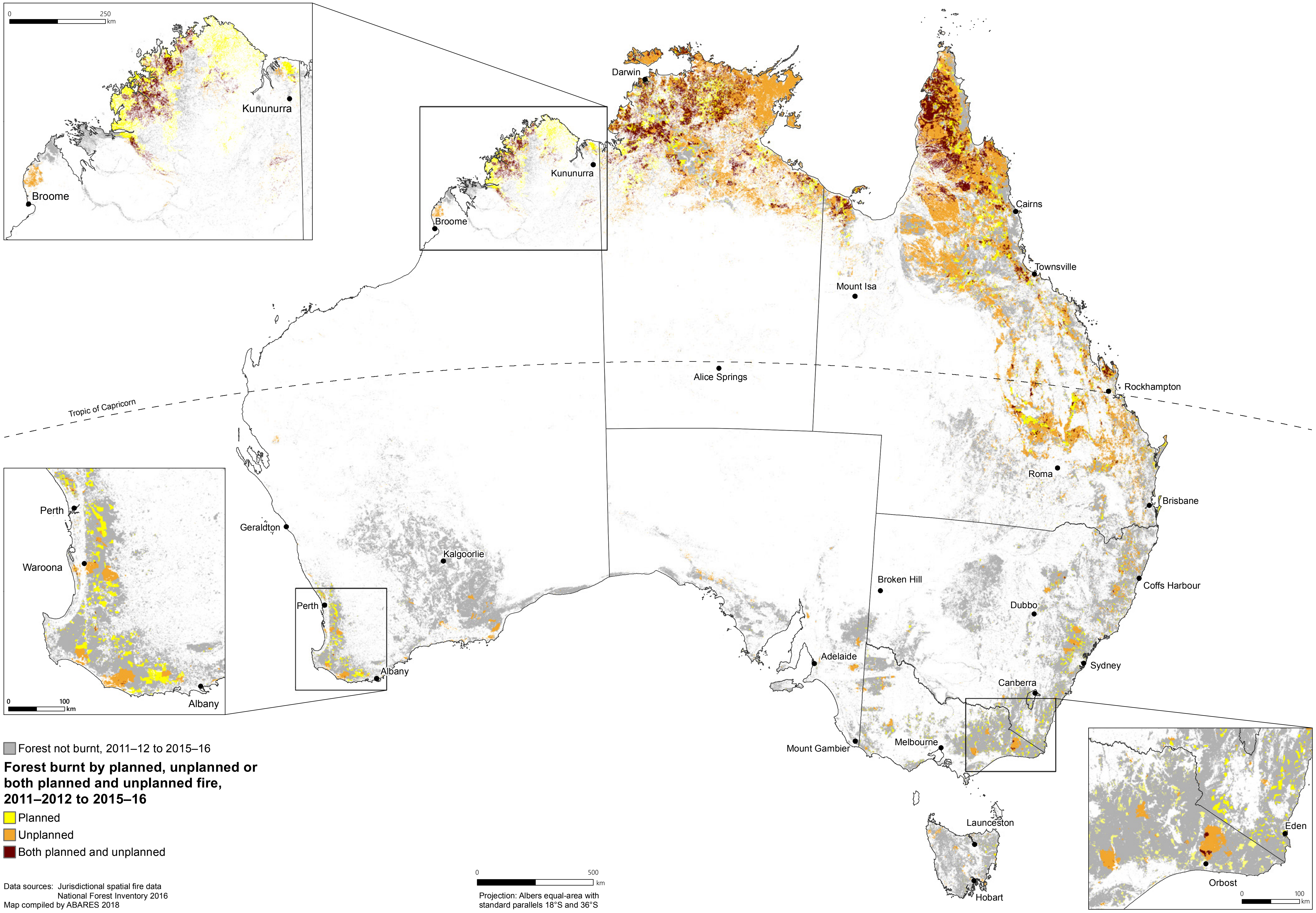
Figure 3.14: Forest burnt, by number of fires, 2011–12 to 2015–16



Note: Fire frequency is the number of years in the five-year reporting period in which a forest area was reported as being burnt. Occasionally, an area was reported as having burnt more than once in a year; in such situations, only the first fire in that year was retained in the data.

A higher resolution version of this map is available via www.doi.org/10.25814/5be3bc4321162

Figure 3.15: Forest burnt, 2011–12 to 2015–16, by planned, unplanned, or planned and unplanned fire



A higher resolution version of this map, together with other data and maps for Indicator 3.1b, is available via www.doi.org/10.25814/5be3bc4321162

Case study 3.4: The Waroona bushfire, south-west Western Australia

The Waroona bushfire was ignited by lightning in the Murray River valley south-east of Dwellingup, Western Australia, and was detected by satellite hotspot imagery early on the morning of 06 January 2016. Burning under prevailing east to north-east winds, the fire made a series of major runs to the west, eventually burning to the Indian Ocean near Lake Preston, some 50 kilometres from the point of ignition. Around sunset on 07 January, the fire burned through the town of Yarloop, resulting in the loss of two lives, destruction of more than 100 homes, and severe damage to other buildings and infrastructure.

The fire burnt a total area of 69,165 hectares, making it the second largest individual fire in the south-west since the Dwellingup fires of January 1961. The Waroona fire was notable for the scale, complexity and duration of suppression operations, and for its significant social and economic impacts on the south-west community. The loss of homes, businesses and infrastructure in the town of Yarloop was so severe that the future viability of the community was questioned (Michael 2016).

A total of around 35,000 hectares of native forest were burned, including many thousands of hectares burnt by high-intensity fire causing complete crown scorch and canopy defoliation (Figure 3.17). Widespread mortality of the above-ground parts of even mature trees occurred in severely burnt forest, and it will be many decades before the regrowth of basal sprouts leads to re-establishment of a forest of comparable structure. In the meantime, standing dead stags will pose an ongoing safety issue for forest users, and will make fire management more difficult. Further, as these dead stags collapse and fall, it is likely that there will be a temporary shortage of large hollows which are used by large birds, including owls and black cockatoos. Changes in forest structure resulting from the impacts of severe bushfire will thus have long-term impacts on biodiversity, ecosystem health and vitality, as well as productive capacity and water values.

During the evening of 06 January 2016, the fire burnt through forest subject to bauxite mining operations, and large areas of young forest on rehabilitated mine sites were severely burnt (Figure 3.18).

The fire also burnt 3,300 hectares of commercial *Pinus pinaster* plantations on the Swan coastal plain, ranging in age from 3 to 40 years (Figure 3.19). Older plantations were subject to salvage harvesting operations to recover commercial wood products, but this was not possible in younger plantations because the trees were too small to produce saleable products. An estimated 500 thousand cubic metres of logs were lost, equivalent to about seven months of supply to processing industries (FPC 2016). In addition to the direct costs associated with re-establishing burnt plantations, the fire will affect the supply of logs to wood processing industries for several years.

The exceptionally high intensity and rate of spread of this fire is attributable to a number of factors (Government of Western Australia 2016).

- Firstly, rainfall in the region in the previous year was in the lowest 10% of records, and this was also a notably warm year; Dwellingup, for example, experienced its warmest year in 75 years of records. Forest fuels were consequently significantly drier than average for the time of year.
- Secondly, fire weather conditions at the time of the fire were sufficiently extreme to enable pyrocumulonimbus events to develop (Figure 3.20). These resulted in turbulence in the upper atmosphere that carried many large burning embers large distances and induced lightning strikes, substantially increasing the rate of spread of the fire (Peace et al. 2017).

Figure 3.17: Widespread mortality of the above-ground parts of mature *Eucalyptus megacarpa* and *E. patens* in severely burnt forest near Willowdale

Figure 3.18: Immediate impact of severe fire in young forest rehabilitated following bauxite mining near Mt William, Western Australia

CRITERION 3

3.1b

Continued

Continues

- Lastly, heavy fuel loads in forests and farmland and inaccessible terrain played a major role in the extreme fire intensity, rate of spread and difficulty of suppression and containment. For example, there were substantial areas of long-unburnt forest within the fire area, including the rehabilitated mine sites from which fuel reduction burning was excluded to protect the regenerating vegetation.

The Waroona bushfire therefore highlighted the importance of effective fuel management in bushland close to settlements, as well as across the broader landscape.

Source: Department of Biodiversity, Conservation and Attractions, Western Australia.

Figure 3.19: Plantation of *Pinus pinaster* burnt by high intensity crown fire

Figure 3.20: Pyrocumulonimbus cloud above the Waroona fire

Criterion 4

Conservation and maintenance of soil and water resources

Olga Kashubin

Royal National Park and Hacking River from Bungoona Lookout.

Criterion 4 Conservation and maintenance of soil and water resources

This criterion is concerned with two of the fundamental components of a forest ecosystem: soil and water. Forests are important for soil conservation because they contribute directly to soil production and maintenance, and prevent or reduce soil erosion. Forested catchments also provide and protect high-quality water supplies for a range of uses.

This criterion has five indicators, the first of which is relevant to both soil and water. The second and third indicators address soil, while the remaining two indicators focus on water.

Management of forest for protective functions

Most areas of forest in Australia are managed for multiple purposes, so the identification of forest areas managed primarily to protect soil or water is not straightforward. In Indicator 4.1a, this area is calculated from the area of forest in public formal and informal nature conservation reserves, the area of multiple-use public forest that is protected by prescription (such as steep slopes, erodible soil types and riparian – streamside – zones), and the area of forest in catchments managed specifically for water supply.

Disturbances that can directly affect soil and water in forested areas include road construction and maintenance, wood harvesting, fire, grazing, recreation, and the activities of feral animals. The regulatory systems in place to control and limit the effects of such disturbances are described and assessed in this criterion.

In catchments where forests have been removed or degraded, protective functions can be improved by vegetation rehabilitation and reforestation. Tree-planting is therefore undertaken by government agencies, conservation organisations and community groups across Australia to protect riparian zones, counter rising water tables and salinity, provide wildlife corridors, and prevent or minimise soil erosion.

Management of risks to forest soils

The regulatory systems in place to manage the risks of soil erosion and of damage to soil physical properties in forests are described and assessed in Indicators 4.1b and 4.1c, respectively. These systems recognise that appropriate management of soils is fundamental to sustainable forest management. Minimising soil erosion protects soil and water values in forested areas, and is critical to maintaining many other forest values.

Soil erosion on forested lands can be minimised through careful planning and management of road crossings and forestry operations, with detailed prescriptions depending on the nature of particular forest soils and the activities being undertaken.

Indicator 4.1c addresses degradation of the soil physical properties (such as soil structure, density, texture, permeability, and water-holding capacity) that can affect seed germination and the growth and survival of trees, and that can lead to increased water runoff and soil erosion. It is important that forest management does not result in permanent adverse changes to soil physical properties.

Management of the risk to water quality and quantity

Indicators 4.1d and 4.1e address management of the risk to the quantity and quality, respectively, of water produced from forested catchments. In general, forested catchments provide a lower risk to water quantity and quality, and maintain water quantity and quality values, better than catchments carrying other, non-forest land uses. In Australia, large areas of forested land are used to provide reliable and clean supplies of water for human consumption, as well as for agricultural irrigation and industrial uses.

The quantity of water available in streams and rivers flowing from forested catchments depends, among other things, on the quantity of rainfall, the volume of water used by forest vegetation or otherwise evaporated, and the volume that enters groundwater systems. The amount of water used by a forest stand in turn depends on its age, density, species mix and growth rate. Major fire events influence water yields by changing the canopy cover and age-class structure of native forest, and changes in streamflow can last for decades after a severe fire. Management practices likely to increase or decrease water yields in forested catchments include the timing, scale and location of wood harvesting; the thinning of regrowth forest; management of planned and unplanned fires; and control of woody weeds. Establishing plantations on previously cleared land can also affect water yield from this land. The level of understanding of these processes, and research into improving that understanding, are assessed in Indicator 4.1d.

Forested catchments are highly valued as sources of drinking water because forest vegetation, soil and litter serve as natural filters, and the quality of water flowing from such catchments is therefore usually higher than from non-forested catchments. Natural disturbances such as bushfire can reduce water quality, for example through increased run-off resulting in increased erosion. Construction and maintenance of forest roads and tracks can also have adverse impacts, including through increased movement of sediment into streams and water bodies. In addition, water quality can be adversely affected by fertiliser and herbicide residues from runoff and spray drift. Indicator 4.1e therefore also assesses compliance with the protective measures employed routinely in Australian forests to protect water quality, as well as research into the effects of disturbance in forested catchments.

This icon indicates data, maps or graphics from *Australia's State of the Forests Report 2018* that are available for electronic download. Data used in figures and tables in this criterion are available via www.doi.org/10.25814/5bda9272d76d7.

Indicator 4.1a

Area of forest managed primarily for protective functions

Rationale

The area of forest land where priority is given to protecting soil and hydrological functions provides an indication of the emphasis being placed by society on the conservation of these values. This indicator includes areas managed to protect soil and water by excluding incompatible activities.

Key points

- The area of Australia's public forest managed primarily for protection of soil and water values is 36.6 million hectares (27% of Australia's total forest area).
  - This area includes formal nature conservation reserves, informal reserves in multiple-use public forests, forests protected by prescription (such as steep slopes, erodible soil types and riparian – streamside – zones where harvesting and road construction are not permitted), and forested catchments managed specifically for water supply.
  - The 27% of total forest area that is public forest managed primarily for protection of soil and water values is an increase from the 24% reported in SOFR 2013.
- A total of 1.3 million hectares of forested land is recorded as being managed specifically to supply water for human or industrial use.
  - Current data on this parameter are not available for all jurisdictions.
  - In catchments managed specifically for water supply, jurisdictions either do not allow any human activities to occur, or approve only limited activities. As far as possible, natural disturbances such as fire are also managed.
- National-level programs and other initiatives continue to encourage re-establishment, restoration and maintenance of native vegetation, including forests, for protective functions.

Forests are vital for soil conservation, preventing soil erosion, protecting water supplies and maintaining other ecosystem functions. States and territories have measures in place to recognise and safeguard these functions.

Area of public forest managed for protective functions in regards to soil and water

Identifying forest managed primarily for protective functions in regards to soil or water is not always straightforward. In most states and territories, forests in public nature conservation reserves may be considered as 'managed primarily for protective functions'. However, protection of soil and water is one of several forest management objectives in multiple-use public forests.

The area of forest reported in this indicator as managed primarily for protective functions in regards to soil and water is the area of public forest from which wood harvesting is excluded. This area therefore includes nature conservation reserves, and also those areas of multiple-use public forests from which wood harvesting is excluded such as steep slopes, erosion-prone soils and areas close to streams, as well as the relatively small area of forested land managed specifically for water supply. The notes for Table 4.1 give details of the areas included for each jurisdiction. There are insufficient data to estimate the area of forest on private land managed primarily for protective functions.

The area of public forest managed primarily for protection of soil and water values, across all tenures, totalled 36.6 million hectares in 2016 (Table 4.1). This is 27% of the total forest area in Australia, an increase from the 24% of total forest reported in SOFR 2013.

The increase in the area of public land managed primarily for protection of soil and water values compared to that reported in SOFR 2013 has resulted from the increase in Australia's reported forest area (see Indicator 1.1a), from the declaration of new nature conservation reserves, and from the establishment of new formal and informal reserves on multiple-use public forest. The increases in the Northern Territory, Western Australia, South Australia and the Australian Capital Territory are mostly due to the increase in Australia's reported forest area. In Tasmania and Queensland, the increases are due to changes in reported tenure and to additional reserves, including gazettal in Queensland of new Indigenous Protected Areas. The slight decrease in New South Wales is due to areas mapped as forest in SOFR 2013 being reclassified as non-forest in SOFR 2018 (see Indicator 1.1a).

Management of forests for protective functions in regards to soil and water

Some of the types of disturbance that can directly affect soil and water assets in forested areas are road and track construction and maintenance, infrastructure development, wood harvesting, fire, grazing, recreational activities, and disturbance by feral animals.

Codes of forest practice, and licences issued by regulatory authorities, set out precautionary and mitigation measures to be undertaken in riparian zones near waterways, in areas vulnerable to erosion and slope instability, and in water catchments more generally to minimise the impacts of disturbance, particularly from wood harvesting and road and track construction or maintenance. Specific legally and non-legally binding instruments exist in all states and territories to control and limit forest disturbances in designated water supply catchments. A summary of legal and non-legal instruments that are in place to protect forest areas is given in Indicator 7.1a.

In New South Wales, Environmental Protection Licences (EPLs) and codes of practice require that soil, water catchment, cultural and landscape values are protected by careful planning, location, construction and maintenance of roads and tracks, and regulation of their use. Areas of New South Wales state forests and private plantations are assessed for soil erosion hazard before wood harvesting commences, as part of the harvest planning process. An EPL is required for specified forestry activities in areas of state forest that come under an Integrated Forestry Operations Approval (IFOA); and an IFOA is required for any forestry operation on state forests or other Crown timber lands, including in the western part of the state not covered by a Regional Forest Agreement. The New South Wales Government has also implemented a Private Native Forestry Code of Practice that sets minimum operating standards for wood harvesting (EPA 2013b), including coverage of soil and water values. The *National Parks and Wildlife Regulation 2009* and other regulatory instruments provide protection from disturbance activities such as road construction or bushfire hazard reduction in conservation reserves.

In South Australia, various pieces of legislation and other instruments contribute to appropriate forest management to protect soil and water resources. These include the *Natural Resources Management (Commercial Forests) Amendment Act 2011*, the *Environment Protection Act 1993* (which includes special protection provisions for water quality in water protection areas), the eight regional Natural Resource Management Plans, the State Natural Resources Management Plan 2012–2017, and the *Guidelines for Plantation Forestry in South Australia 2009*.

In Victoria, many catchments supplying water for domestic, irrigation or other purposes, including some catchments containing forest, are protected under the *Catchment and Land Protection Act 1994*. This assists planners and those managing land disturbance or development activities to determine the suitability of proposed activities within these catchment areas. Once a catchment is declared, approvals for activities conducted under other statutes and statutory planning schemes must be referred to the responsible land management authority for approval. Victoria's Catchment

Table 4.1: Area of public forest managed primarily for protective functions including protection of soil and water values

	ACT[a]	NSW[b]	NT[a]	Qld[a]	SA[a]	Tas.	Vic.[b]	WA[b]	Australia	
					Area ('000 hectares)				Area ('000 hectares)	Proportion of total forest[c]
2016	120	6,111	5,847	8,889	2,614	2,086[a]	4,294	6,613	**36,573**	**27.3%**
2011	114	6,119	3,781	6,510	2,112	1,828[d]	4,318	5,026	**29,808**	**23.9%**

a Area figures for ACT, NT, Queensland and South Australia, and area figures for Tasmania for 2016, are the areas of forest in Collaborative Australian Protected Area Database (CAPAD), International Union for Conservation of Nature (IUCN) categories I–VI (see Indicator 1.1c), and do not include forests on informal reserves in multiple-use public forests.

b Area figures for New South Wales, Victoria and Western Australia are the areas of native forest in formal and informal reserves, and forests protected by prescription in multiple-use public forests (see Indicator 1.1c).

c Proportions for 2016 are based on total area of forest reported in SOFR 2018 (134.0 million hectares; see Indicator 1.1a). Proportions for 2011 were based on total area of forest reported in SOFR 2013 (124.8 million hectares).

d The area figure for Tasmania for 2013 is from *State of the forests Tasmania 2012* (FPA 2012b), and does not include the area of private land excluded from harvesting.

Source: ABARES; Australian Government Department of the Environment and Energy (CAPAD) for IUCN data; state and territory agencies.

This table, together with other data for Indicator 4.1a, is available in Microsoft Excel via www.doi.org/10.25814/5bda9272d76d7

Management Framework 2016, established under the *Victorian Water Act 1989*, includes a range of mechanisms to protect water supplies, including the declaration of water supply protection areas.

In the Northern Territory, the *Codes of Practice for Forestry Plantations* (DRPI 2004) consists of 26 goal statements that collectively cover the main requirements for sound plantation planning and management. The Northern Territory also has *Land Clearing Guidelines*[168] developed by the then Department of Natural Resources, Environment, the Arts and Sport[169]. The management of impacts on water resources and soil in the Northern Territory is also regulated under the *Water Act 2011*, *Waste Management and Pollution Control Act 2000* and *Soil Conservation and Land Utilisation Act 1985*.

In Tasmania, soil and water values are protected on forest land, particularly through the Forest Practices Code 2015 (FPA 2015b) and the *Tasmanian Reserve Management Code of Practice 2003* (Parks and Wildlife Service et al. 2003). The *Forest Practices Code 2015* (previously *Forest Practices Code 2000*) prescribes specific management measures for forest practices on any forest lands, particularly for activities associated with roads, harvesting or reforestation; a set of amendments to the code in 2015 provided standards for forest management, timber harvesting and other forest operations. The *Tasmanian Reserve Management Code of Practice 2003* aims to maintain or restore the natural quality of water and to maintain or restore natural soil processes and avoid soil degradation, within reserved lands.

In Queensland, the *Forestry Act 1959* requires state forests to be used and managed in a manner to protect water quality; the *Environmental Protection Act 1994* and the *Water Act 2000* are the main legislative instruments under which water is protected while supporting ecologically sustainable development. Risks to water quality from wood production are managed largely through codes of practice. In 2013, the Queensland Government introduced a range of self-assessable vegetation clearing codes (now called 'accepted development vegetation clearing codes'[170]) in accordance with the *Vegetation Management Act 1999*. For freehold land, the *Managing a native forest practice – A self-assessable vegetation clearing code (2014)* requires harvesting or removal of vegetation to be carried out in a way that maintains water quality values, through buffers and filter zones.

Area of public forest managed specifically to supply water for human or industrial use

A total of 1.27 million hectares of forested land is recorded as being managed exclusively to supply water for human or industrial use (Table 4.2). This area is a subset of areas of forest managed primarily for protection of soil and water values (Table 4.1). The exception is Western Australia where, in the south-west forest region, some wood harvesting is permitted in multiple-use public forest in catchments managed for water supply.

The Cotter catchment is almost wholly located within the Australian Capital Territory, and feeds into the Corin, Bendora and Cotter dams. Much of the 48 thousand hectares of the catchment area, which includes 44 thousand hectares in Namadgi National Park in the ACT as well as an adjacent area within NSW, is forested. The entire catchment is closed, with no farms or houses, and with restrictions on activities within the catchment in order to protect the quality of the water[171]. The figure of 48 thousand hectares of forest for the ACT in 2011 reported in SOFR 2013 is an error, as that figure includes that small area of the catchment that is in New South Wales.

In New South Wales, approximately 318 thousand hectares of forest are managed specifically for water supply in closed catchments from which human disturbance activities are excluded. These catchments are described further in Case study 7.1 *NSW Special Areas Strategic Plan of Management 2015*. The increase in the forest area reported for New South Wales has occurred because some land tenure categories were not included in the 2011 data reported in SOFR 2013.

In the Northern Territory, the Manton Dam and Darwin River Dam catchments are closed water catchments set aside solely for the protection of domestic water supply. The combined area of these catchments is 29 thousand hectares, much of which is forest.

Collectively, Victoria's declared water supply catchments cover 1.2 million hectares of nature conservation reserves, 1.8 million hectares of multiple-use forests, and 2.3 million hectares of other land, totalling 5.3 million hectares; on average, 68% of land within those catchments is forested (DEPI 2014d). This total includes 157 thousand hectares of closed catchments, which comprise approximately 77 thousand hectares of nature conservation reserves, 71 thousand hectares of multiple-use forests and 9 thousand hectares of private land.

Current data are not available for the area of forests in catchments explicitly managed for water production in Tasmania. Many catchments in the Comprehensive, Adequate, Representative (CAR) reserve system are used for water production, although the majority are not specifically reserved as water catchment areas. The 5 thousand hectares reported comprises forested catchments within Wellington Park and Mount Field National Park that are managed to supply drinking water to Hobart (FPA 2017a).

168 nt.gov.au/__data/assets/pdf_file/0007/236815/land-clearing-guidelines.pdf

169 From October 2012, the Department of Land Resource Management, and from September 2016, the Department of Environment and Natural Resources.

170 www.qld.gov.au/environment/land/vegetation/codes

171 www.iconwater.com.au/water-and-sewerage-system/water-and-sewerage-system/catchments.aspx

Table 4.2: Area of forest in catchments managed specifically to supply water for human or industrial use

	ACT	NSW	NT[a]	Qld	SA[b]	Tas.[c]	Vic.	WA	Australia	
	Area ('000 hectares)								Area ('000 hectares)	Proportion of total forest
2016	44	318[d]	29	n.a.	1	5	157	714	1,268	0.9%
2011	48	178[e]	29	n.a.	1	5	157	948[f]	1,366	1.1%

n.a., not available

a Includes forested and non-forested areas of catchments.

b Area of multiple-use public forest managed by ForestrySA (pine forests on land managed by SA Water); does not include native vegetation and grassland areas in reservoir protection areas. Area unchanged from that reported in SOFR 2008 as no significant change in the area, although some forest has been harvested and replanted.

c Tasmanian area figure from SOFR 2008.

d Forest in WaterNSW Protected & Special Areas on leasehold, multiple-use public forest and nature conservation reserves.

e Area of closed catchments on multiple-use public forest only.

f Includes only the public drinking water source areas on multiple-use public forest and conservation reserves in south-west of Western Australia.

This table, together with other data for Indicator 4.1a, is available in Microsoft Excel via www.doi.org/10.25814/5bda9272d76d7

In Western Australia, public drinking-water source areas include both underground water pollution-control areas and catchment areas, including water reserves. Catchments identified as sensitive to rises in saline groundwater are managed to minimise this risk; management has included re-establishing deep-rooted perennial vegetation over significant parts of the landscape. Several water reserves have been revoked since 2011 because they are no longer required for drinking water supply. The commercial pine plantation on the Gnangara Mound, north of Perth, is being reduced in size, and being replaced over time with other land covers or uses designed to increase the recharge of that water resource.

Revegetation for erosion control, New South Wales.

Rehabilitation and reforestation for protective functions

Many conservation organisations and community groups across Australia plant trees to protect riparian zones, manage ground water-tables and salinity, provide wildlife corridors and arrest soil erosion. These plantings include a large range of projects supported by the Australian and state and territory governments and the private sector. For example, through the '20 Million Trees Programme'[172], Landcare Australia has implemented revegetation projects aiming to establish tree-based ecosystems. To date these cover 3,500 hectares. While these projects are aimed primarily at restoration of wildlife habitat, they also provide soil conservation and water quality benefits.

172 landcareaustralia.org.au/our-programme/20-million-trees/

Indicator 4.1b

Management of the risk of soil erosion in forests

Rationale

This indicator assesses the extent to which the risk of soil erosion has been explicitly identified and addressed in forest management. The avoidance of soil erosion reflects the extent to which associated values, including soil fertility and water quality, are protected.

Key points

- All Australian states and territories have a combination of legally binding and non-legally binding instruments, such as legislation, regulations, licences, codes of forest practice, guidelines and management plans, which provide for the avoidance, prevention or mitigation of soil erosion that might result from activities on forested land. All jurisdictions also have processes to ensure compliance with measures to mitigate or prevent soil erosion.
- In some jurisdictions, the forest practices system contains comprehensive soil assessment measures for determining soil properties and managing soil erosion risk in multiple-use public forests.
- This indicator reports mainly on multiple-use public forest and nature conservation reserves because, in most jurisdictions, limited information is available for forested land under other tenures.

Soil erosion is the relocation of soil by environmental forces – that is, the loss of soil from one area and its deposition into another. Minimisation of soil erosion through avoidance, prevention or mitigation[173] is essential to protecting soil and water values in forested areas, and is critical to maintaining many other forest values. Soil conservation measures are therefore an essential part of sustainable forest management.

Soil erosion on forested lands can be minimised through careful planning and implementation of forest management activities. Management actions taken to minimise soil erosion can vary greatly, depending on the nature of the forest soil and the activities being undertaken. Key forest management considerations include the use of appropriate machinery, avoiding disturbance in high-risk areas, timing of activities, and retaining vegetation. Activities for which soil management needs to be considered include road and track construction and maintenance, operations in or near streams or riparian areas, construction of stream crossings, construction of extraction tracks or other temporary tracks, placement and management of log landings, wet-weather operations, and use of heavy machinery and operations on slopes.

This indicator reports on measures required with regard to soil erosion on forested land, and external auditing of compliance with implementation of these measures. The indicator reports mainly on multiple-use public forest and (to some extent) nature conservation reserves because, in most jurisdictions, limited information is available for forested land under other tenures. Performance ratings reported are the results of assessment by the jurisdictions, and review of documents published during the reporting period.

Legally binding and non-legally binding instruments in Australian state and territory jurisdictions provide guidance and measures to address soil erosion associated with forestry operations. Codes of forest practice, for example, generally require wood harvesting to occur in ways that prevent and/or mitigate soil erosion, particularly for locations that are most susceptible. Soil erosion can also result from bushfire and recreational activities, particularly around roads, walking trails, picnic areas and campsites. The risk of soil erosion caused by recreational activities is generally managed through appropriate design, construction, access to and use of relevant infrastructure, with access potentially limited during periods of rehabilitation after bushfire.

173 The term 'minimise' is used in this indicator to cover each of the different steps of avoiding, preventing and mitigating erosion. In this context, 'avoidance' is the selection of management actions that do not lead to erosion, 'prevention' is incorporation of provisions into actions so that erosion does not occur, and 'mitigation' is reducing the negative impacts of any erosion that results from management actions.

Instruments that address the risk of soil erosion

Measures that can be undertaken during forest operations to minimise soil erosion include:

- excluding identified vulnerable areas, including karst terrain, wetlands, and areas with high erosion hazard or landslip potential
- providing road drainage, such as well-designed culverts and table drains, and providing drainage to log extraction tracks such as cross-drains and drainage channels
- appropriate arrangement of log extraction tracks, for example by contouring, walk-over extraction, and appropriate location of log dumps and landings (such as on naturally flat land on ridges and saddles)
- minimising stream crossings, or using well-designed bridges, fords or natural causeways
- protecting riparian zones using buffers or filters
- ceasing operations or closing forests for defined periods of wet weather
- rehabilitating log landings and extraction tracks by, for example, ripping, replacement of topsoil, and/or planting.

In all jurisdictions, measures to minimise soil erosion were in place for the reporting period, but some do not cover all forest tenures. In Victoria and Tasmania, however, such measures apply to all forest harvesting operations regardless of tenure.

In the ACT, the legally binding instruments that address conservation and maintenance of soil resources are the *Public Unleased Land Act 2013*, the *Environment Protection Act 1997* and the *Nature Conservation Act 2014*. However, these instruments do not specify that the components listed in Table 4.3, Category 1, are to be taken into account in addressing the risk of soil erosion from forest disturbances. The ACT *Code of Forest Practice 2005*[174] is a non-legally binding instrument that recognises the importance of protecting soil from erosion and other degradation, and covers all components listed in Category 1 except for wind erosion. The code was reviewed by Smethurst et al. (2012) and its processes were deemed adequate for soil protection during plantation forestry activities in the ACT.

In Victoria, the *Sustainable Forests (Timber Harvesting) Regulations 2006* were revoked in 2014, and the *Code of Practice for Timber Production 2014*[175] is the key regulatory instrument that applies to timber production in public and private native forests and plantations in Victoria. It is a statutory document under the *Conservation, Forests and Lands Act 1987*. The code addresses the risk of soil erosion from disturbance activities such as rainfall, slope, soil erodibility, and management practices such as regeneration or establishment, timber harvesting and roading. Soil erosion is minimised by avoiding harvesting in inappropriate areas or slopes and undertaking necessary preventive measures. During or following wet weather conditions, timber harvesting operations are modified or where necessary suspended to minimise risks to soil values. Site preparation operations take into account the maintenance of soil values.

Environmental care principles of the Victorian *Code of Practice for Bushfire Management on Public Land 2012*[176] (DSE 2012) include a requirement that the soil be protected during fire management activities, either by preventing inappropriate destruction of its physical and chemical properties or by promoting stabilisation of bare or disturbed earth following disturbance. Under this code, the then Department of Sustainability and Environment (DSE[177]) must prepare maps that show areas that are particularly sensitive to soil disturbances, and these maps must be considered when planning the use of heavy machinery during firefighting operations. The code also includes a requirement to assess risk to natural values, including soil, in both the emergency stabilisation and recovery phases of bushfire response (DEPI 2014d).

New South Wales has legally binding instruments that address the risk of soil erosion in both the native forest and plantation estates. In the New South Wales multiple-use public forest estate, Integrated Forestry Operations Approvals (IFOAs) contain requirements for assessing and managing risks to soil erosion and risks of water pollution. The IFOAs contain the terms of a licence under the *Protection of the Environment Operations Act 1997* (NSW) (the 'environment protection licence'). The purposes of the environment protection licence include to control the carrying out of forestry operations, including harvesting, thinning and road construction, in a way that avoids, prevents or mitigates soil erosion. The *Private Native Forestry Code of Practice 2013*[178] aims to achieve these purposes for the private native forest estate in New South Wales.

Softwood and hardwood plantations in New South Wales are authorised under the *Plantation and Reafforestation (Code) Regulation 2001*, which prescribes standards and regulations relating to the protection of soil and water. Prescriptions cover buffer zones, slope limits, wet weather provisions, and road, crossing and drainage location, design and requirements for construction, maintenance and management during operations.

In New South Wales conservation reserves, the *National Parks and Wildlife Act 1974*, *National Parks and Wildlife Regulation 2009* and other codes, procedures and guidelines address the risk of soil erosion, including when environmental impact assessment is required prior to approval of and consent for works.

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174 www.environment.act.gov.au/__data/assets/pdf_file/0003/1126353/ACT-Code-of-Forest-Practices-2005.pdf

175 www.forestsandreserves.vic.gov.au/__data/assets/pdf_file/0016/29311/Code-of-Practice-for-Timber-Production-2014.pdf

176 www.ffm.vic.gov.au/__data/assets/pdf_file/0006/21300/Code-of-Practice-for-Bushfire-Management-on-Public-Land.pdf

177 From January 2015, the Department of Environment, Land, Water and Planning.

178 www.epa.nsw.gov.au/your-environment/native-forestry/about-private-native-forestry/private-native-forestry-code-practice ; see also www.lls.nsw.gov.au/sustainable-land-management/pnforestry

In the Northern Territory, the *Soil Conservation and Land Utilisation Act 1985* is the main legislation that provides powers to the Northern Territory Government for monitoring and controlling risks to soil resources. Under this Act, areas of land that are subject to soil erosion or areas at risk of potential soil erosion may be declared Areas of Erosion Hazard, and an area of land that is subject to soil erosion through use by the public may be declared a Restricted Use Area. Although the Act does not have specific reference to forestry, Soil Conservation Orders can be made by the Soil Commissioner to prescribe infrastructure planning, land use, and remediation practices to protect soil resources during any crop land preparation including plantation forests (Raison et al. 2012). The Northern Territory *Codes of Practice for Forestry Plantations* (DRPI 2004) contains goals that relate to the protection of soil values. The code was reviewed in 2012, with recommendations including addition of specific guidance for the protection of soil values during establishment, management and harvesting of plantations (Raison et al. 2012). *Land Clearing Guidelines* (Northern Territory Government 2010) provide some broad advice on how to minimise soil disturbance during the removal of native vegetation. In addition, management plans for conservation reserves include provisions to minimise soil erosion.

In Western Australia, the *Forest Management Plan 2004–2013* (CCWA 2004) and the *Forest Management Plan 2014–2023* (CCWA 2013) operate under the *Conservation and Land Management Act 1984*. Both plans focus on the management of state forest and timber reserves and plantations, and have aims that include protecting soil and water values. They prescribe measures to minimise unnecessary adverse soil disturbance, protect soil from erosion and prevent damage, as well as remedial measures to restore soil when damage occurs. All management activities prescribed in the plan are required to be conducted in accordance with associated manuals and guidelines such as *Soil and Water Conservation Guideline 2009* (DPaW 2009a), *Manual of Procedures for the Management of Soils Associated with Timber Harvesting in Native Forests 2010* (DPaW 2010) and *Manual for the Management of Surface Water 2009* (DPaW 2009b).

Western Australia's *Soil and Water Conservation Guideline 2009* sets out the key requirements for protecting soil, based on the types of disturbance, and limits activities for various levels of disturbance. Ten guiding principles are described to protect soils, including rehabilitation of damaged soil, and protection of soil from erosion as a result of wood harvesting and associated forest management activities. The *Manual of Procedures for the Management of Soils Associated with Timber Harvesting in Native Forests 2010* (DPaW 2010) provides guidance to reduce the extent and severity of soil disturbance associated with timber harvesting in native forests. It includes a trafficability index that defines soil management risk periods and permissible activities in relation to soil moisture, and introduces a precautionary planning approach to halt operations prior to exceeding allowable limits. During the reporting period, this manual was updated twice to support continual improvement in practices for the management of soil values during timber harvesting activities. The *Code of Practice for Fire Management 2008*[179] prescribes measures to manage fires while protecting soil stability and soil rehabilitation following disturbance to minimise the threat of soil erosion. *The Code of Practice for Timber Plantations in Western Australia* (FIFWA 2014) provides guidelines for soil protection in plantations in Western Australia.

In Tasmania, forestry activities are regulated by the Forest Practices Authority (FPA) in accordance with the *Forest Practices Act 1985*. The *Forest Practices Act 1985* requires assessment of risks to soils when a forest activity is carried out, irrespective of land tenure or forest type. Assessments are also commonly undertaken on public forests and large, industrially managed private forests in relation to road and site developments and ongoing maintenance, although these are not specified under the *Forest Practices Act 1985*. The *Forest Practices Code 2015*[180] (FPA 2015b) is legally enforceable under the Act for both public and private forest. The code requires forest practices to be conducted in a manner that maintains soil fertility and does not cause significant deviations from natural rates of erosion and landslides. Forest practices plans need to be prepared under Section 18 of the Act in accordance with the code, and contain instructions for protecting soil values during forestry operations such as timber harvesting and road construction.

In Queensland, State Forests are used and managed in a manner to conserve soil under the *Forestry Act 1959*. In 2013, the Queensland Government introduced self-assessable vegetation clearing codes (SACs) in accordance with the *Vegetation Management Act 1999*. The code *Managing a native forest practice*[181] (DNRM 2014) applies to native forest practices on freehold and Indigenous land, and regulates activities such as planting, silvicultural thinning and selective, very low intensity or small-scale harvesting. Snigging is not allowed in a filter zone, and roads and tracks are to be properly designed, located or managed to prevent accelerated soil erosion. Harvesting is restricted in wet weather when the soil is saturated. Fuel-reduction burning is timed to avoid periods of high-intensity rainfall, and is conducted at low fire intensity to leave unburnt litter and prevent accelerated soil erosion.

Plantation activities in Queensland are governed by several Acts, and associated subordinate legislation, policies and codes depending on the land tenure. Under the *Soil Conservation Act 1986*, plantation operators in Queensland are required to conserve soil resources and facilitate the implementation of soil conservation measures to mitigate soil erosion. *Timber Plantation Operations Code of Practice for Queensland 2015*[182] (Timber Queensland 2015) is a non-legally binding instrument. It requires a plantation management plan to be prepared prior to operations. Soil erosion is minimised by avoiding timber production in inappropriate areas or slopes, and using appropriate harvesting methods (e.g. cable

179 www.dpaw.wa.gov.au/images/documents/fire/fms-code-of-practice.pdf

180 www.fpa.tas.gov.au/fpa_services/planning_assistance/forest_practices_code

181 publications.qld.gov.au/dataset/self-assessable-vegetation-clearing-codes/resource/a73f5b44-008c-4f92-8644-f92e6caf6592

182 www.timberqueensland.com.au/Docs/Growing-Processing/Timber-Plantation-Operations-Code-of-Practice-Version-1.pdf

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harvesting or modified excavator based methods) where conventional harvest methods are considered unsafe or may threaten the stability of the soil or may have potential for adverse off-site effects. Soil erodibility and rainfall erosivity are considered when embankments, plantation roads and fill disposal areas are designed and managed to minimise soil erosion and mass movement.

In South Australia, under the *Forestry Regulations 2013* a person must not intentionally destroy, damage or disturb any soil in a public forest reserve without lawful authority. Plantation and other land managers have an obligation to manage and protect soil resources and prevent the degradation of land, primarily under the *Natural Resources Management Act 2004*. The *Guidelines for Plantation Forestry in South Australia 2009*[183] emphasize the importance of minimising soil disturbance, soil compaction and impact on run-off during plantation establishment, maintenance, harvesting and road construction. This is done through references to mandatory requirements and industry best-practice. Revised guidelines are due to come into operation in 2018.

Assessment of legal instruments and regulatory framework

The extent to which a regulatory framework requires the maintenance of soil values is rated according to the five categories used in previous SOFRs (Table 4.3), ranging from Category 1 (for regulatory instruments that are applicable to all erosion processes and that take into account many types of erosion risk) to Category 5 (for instruments that do not mention the need to address risks of soil erosion). The extent to which the risk of soil erosion is addressed by a state or territory's legally binding instruments (such as Acts) and non-legally binding instruments (such as codes of practice, guidelines and forest management plans) is assessed against these criteria in Table 4.4. The regulatory frameworks in a number of jurisdictions are now rated in a higher category than they were in SOFR 2013.

Table 4.3: Categories of the extent to which the regulatory framework requires the maintenance of soil values

Category	Category description
1	The instruments require rainfall intensity, slope, soil erodibility and management practices that result in soil disturbance to be taken into account in addressing the risk of soil erosion from disturbance activities, and the instruments are applicable to all erosion processes, including erosion due to wind, sheet, rill, gully, tunnel, stream bank, wave and mass movement.
2	The instruments address most of the components listed in category 1, and those not addressed are associated with low risks of soil erosion for the particular disturbance activity and geographical setting.
3	The instruments address most of the components listed in category 1 but do not specify all aspects or are limited in their application.
4	The instruments mention the need to address risks of soil erosion when conducting disturbance activities but do not specify the components listed in category 1.
5	The instruments do not mention the need to address risks of soil erosion.

Source: SOFR 2008.

Table 4.4: Assessed extent to which legally and non-legally binding instruments address the risk of soil erosion due to forest operations, road and trail works, and recreation activities

Instrument	Tenure	ACT	NSW	NT	Qld	SA	Tas.	Vic.	WA
Legally binding	Multiple-use public forests and plantations	4	1	1–4	2	4	1	1	4
	Public nature conservation reserves	4	1–2	1	n.a	4	1–2	1	4
	Leasehold land	4	1–2	1–4	2	4	n.r.	n.r.	n.r.
Non-legally binding	Multiple-use public forests and plantations	2	1	3	2	1–4	1	3	1[a]
	Public nature conservation reserves	2	1–3	3	n.a	n.a.	1–2	3	4
	Leasehold land	2	n.r.	3	n.a	1–4	n.r.	n.r.	n.r.

n.a., not applicable; n.r., not reported

[a] Based on ABARES assessment of the *Manual of Procedures for the Management of Soils Associated with Timber Harvesting in Native Forests 2010* (DPaW 2010).

Note: Categories for assessing the risk of soil erosion range from 1 (highest rating) to 5 (lowest rating): see Table 4.3. Each rating is an assessment by the relevant jurisdiction for the period 2011–16, except that data for Victoria are from SOFR 2013 and data for Tasmania are from FPA (2017a).

Source: State and territory agencies, and ABARES.

This table, together with other data for Indicator 4.1b, is available in Microsoft Excel via www.doi.org/10.25814/5bda9272d76d7

183 www.pir.sa.gov.au/__data/assets/pdf_file/0011/254765/guidelines_for_plantation_forestry_in_sa_web.pdf

Legally binding instruments regulating native forest harvesting are in place in New South Wales, Victoria, Tasmania, Western Australia and Queensland. Native forest harvesting is not allowed in the Australian Capital Territory or South Australia, and only limited harvesting occurs on private land in the Northern Territory. Overall, there has been no major change during the reporting period in the way legally and non-legally binding instruments address the risks to maintenance of soil values.

Assessment of erosion hazard

Erosion hazard is generally assessed using overlays of available information in geographic information systems. Relevant information includes erosion hazard maps, geographical settings such as slope, soil erodibility, rainfall intensity, and management practices that could contribute to soil erosion. This provides forest managers with information on the level and location of erosion hazards, which is then used to determine appropriate measures to minimise erosion risk. Examples of research designed to increase the knowledge base on soil erosion are given in Case Study 4.1.

The extent to which risks of soil erosion are assessed in planning processes is rated according to the four categories used in previous SOFRs. These categories are detailed in Table 4.5, and range from Category 1 (for a risk assessment system that takes account of erosion risks associated with rainfall intensity, slope, soil erodibility, and management practices that could contribute to soil disturbance) to Category 4 (for a risk assessment system that is ad hoc or does not take into account any erosion processes).

The area of multiple-use public forest for which disturbance activities were planned, the proportion of that area that was assessed for risk of soil erosion, and the extent to which risks of soil erosion are assessed in planning processes, are shown in Table 4.6, using the categories from Table 4.5.

Table 4.5: Categories of the extent to which the risks of soil erosion are assessed in planning processes

Category	Category description
1	The soil erosion risk assessment system comprehensively takes account of rainfall intensity, slope, soil erodibility and management practices that could contribute to soil disturbance.
2	The soil erosion risk assessment system takes into account most of the components listed in category 1, and those not addressed are associated with low risks to soil values for the particular disturbance activity and geographical setting.
3	The soil erosion risk assessment system takes into account some of the factors listed in category 1 or only partly accounts for these factors.
4	The soil erosion risk assessment system is ad hoc and/or does not take into account any of the factors listed in category 1.

Source: SOFR 2008.

Table 4.6: Area of multiple-use public forest where disturbance activities were planned, proportion assessed for risk of soil erosion, and assessed category

Disturbance activity	Metric	ACT	NSW	NT	Qld	SA	Tas.	Vic.	WA
Native forest harvesting and silviculture	Area (hectares)	0	17,000–32,000	n.a.	n.r.	0	n.r.	n.r.	n.r.
	Proportion assessed for risk of soil erosion (%)	n.a.	100	n.a.	100	n.a.	n.r.	n.r.	n.r.
	Assessed category[a]	n.a.	1	n.a.	2	n.a.	1	2	3
Plantation operations	Area (hectares)	627	7,000–10,000	n.a.	n.r.	n.r.	n.r.	n.r.	n.r.
	Proportion assessed for risk of soil erosion (%)	100	100	n.a.	n.r.	100	n.r.	n.r.	n.a.
	Assessed category[a]	1	1	n.a.	n.a.	1	1	n.a.	n.a.
Road construction and maintenance	Area (hectares)	n.r.	n.r.	n.a.	n.r.	n.r.	n.r.	n.r.	n.r.
	Proportion assessed for risk of soil erosion (%)	n.r.	n.r.	n.a.	n.r.	100	n.r.	n.r.	n.r.
	Assessed category[a]	n.a.	n.a.	n.a.	2	3	1	n.a.	3
Fire management	Area (hectares)	n.r.	20,000–40,000	n.a.	n.r.	n.r.	n.r.	n.r.	n.r.
	Proportion assessed for risk of soil erosion (%)	n.r.	n.r.	n.a.	n.r.	100	n.r.	90	n.a.
	Assessed category[a]	n.a.	3	n.a.	n.a.	3	1	2	n.a.

n.a. = not applicable; n.r. = not reported for this indicator

[a] The extent to which risks of soil erosion are assessed in planning processes varies between 1 (highest rating) and 5 (lowest rating): see Table 4.5 for details.

Note: NT has no multiple-use public forests. Areas harvested are reported in Indicator 2.1a.

Source: The data shown are from SOFR 2013 except for data for ACT and NSW, which were provided by the ACT Environment and Sustainable Development Directorate and Forestry Corporation of NSW, respectively. NSW figures are the range of annual areas across the five-year reporting period.

This table, together with other data for Indicator 4.1b, is available in Microsoft Excel via www.doi.org/10.25814/5bda9272d76d7

Data is available for Table 4.6 only for few activities and jurisdictions. However, there are regulatory instruments in all jurisdictions that require that the risks of soil erosion associated with the listed disturbance activities in multiple-use public forests be assessed, and that preventative and remediation practices are implemented.

In the ACT, a comprehensive soil erosion risk assessment is completed under the ACT *Code of Forest Practice 2005*[184] (Environment ACT 2005), which takes account of soil erodibility, rainfall intensity, slope and management practice. The code groups soil erodibility into five classes, provides guidance for plantation operations, and describes actions to be taken according to the soil erodibility class for a given area. All plantation areas where disturbance activities are planned during the reporting period were formally assessed for risk to soil erosion.

In South Australia, suitability of a site for plantation forestry is identified by assessing soil characteristics and classifying land capability classes. For example, soil properties are assessed and taken into account in operational planning within the Green Triangle Forest Products defined forest area in South Australia, to manage adverse changes to soil values (Green Triangle Forest Products 2015). Forest operations are planned on the basis that well-drained soils are more robust in winter, while heavier soils or soils with a water-retaining layer may be damaged by operations during the wetter months. In addition, regional natural resource management plans are prepared for multiple-use forest, nature conservation reserves and other crown lands that include a summary of threats and issues relating to soil, including erosion.

The Forestry Corporation of NSW undertakes comprehensive soil assessments as required under the Environmental Protection Licence for native forest operations and the *Plantations and Reafforestation (Code) Regulation 2001* for public and private plantations. These assess inherent soil erosion and water pollution, mass movement, dispersibility, and seasonality, with all four assessments applied during a pre-operational planning phase. Assessments are used to determine the level of protection required at each site to conserve soil values.

Under the *National Parks and Wildlife Act 1974* and *National Parks and Wildlife Regulation 2009*, the NSW National Parks and Wildlife Service is required to assess the environmental impacts of earthworks that are part of new road, track and trail construction or upgrades to the existing road, trail and track network. New trail construction requires a formal assessment under Part 5 of the *Environmental Planning and Assessment Act 1979*. Under the policy of the NSW National Parks and Wildlife Service, most maintenance also requires a conservation risk assessment. The *Bush Fire Environmental Assessment Code for New South Wales 2006* provides standards to prevent soil erosion and instability for bushfire hazard reduction works.

In Victoria, field assessments under the *Code of Practice for Timber Production 2014*[185] (DEPI 2014b) and the *Management Standards and Procedures for Timber Harvesting Operations in Victoria's State Forests 2014*[186] (DEPI 2014c) are conducted by DELWP and VicForests staff, to determine the soil erosion hazard and soil permeability classifications for an area proposed for timber harvesting operations. Forest Coupe Plans are prepared by VicForests for all areas planned for harvest, prior to operations commencing, and include a map of soil erosion hazard class and soil permeability class. Coupes are managed based on their highest erosion class, to ensure the risk of erosion is controlled.

In Tasmania, preparing a Forest Practices Plan under the *Forest Practices Code 2015*[187] (FPA 2015b) requires a detailed evaluation of soil properties. Erosion hazard assessment in Tasmanian forests includes a soil erodibility classification derived from observations of soil morphology (and soil mapping in some areas) and from laboratory soil erodibility data. The Code also takes into account the risk of landslides and the risks associated with operations in karst terrain. State forests are assessed to identify 'High Conservation Values' (HCVs), and additional management actions to protect these values are prescribed if required; the latest HCV assessment did not identify any forest where removal of trees through harvesting managed under the Forest Practices Code would have a critical effect on soil erosion. The *Guidelines for the Protection of Class 4 Streams* (FPA 2011a)[188] are used to classify Class 4 streams and adjacent riparian zones into one of five erosion hazard classes based on slope and soil erodibility, and to select the appropriate prescriptions for the type of operation being planned. Some soil types have required special consideration as they have proved to be less erodible that previously thought. For example, the Forest Practices Authority has recently developed *Prescriptions and guidelines for sustainable harvest of plantations on high and very high erodibility west coast dune sands* (FPA 2015b).

In Queensland, erosion risk is addressed in a code of practice attached as a required condition to public land timber sales permits issued under the authority of the *Forestry Act 1959*. A second edition of the *Guidelines for agricultural land evaluation in Queensland*[189] was published in 2015, and there are also regional land suitability frameworks. Under *Managing a native forest practice – A self-assessable code for managing a native forest practice (2014)*[190] (DNRM 2014), native forest operators assess the soil prior to forest operations for inherent erodibility, slope, slope length, ground cover and land erosivity to identify erosion hazards. Sites are excluded from operation where the hazard is rated high, unacceptable or unmanageable, while operational conditions (e.g. timing in relation to weather and techniques) are established to minimise the potential for damage where the hazard is rated acceptable.

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184 www.environment.act.gov.au/__data/assets/pdf_file/0003/1126353/ACT-Code-of-Forest-Practices-2005.pdf

185 www.forestsandreserves.vic.gov.au/__data/assets/pdf_file/0016/29311/Code-of-Practice-for-Timber-Production-2014.pdf

186 www.forestsandreserves.vic.gov.au/__data/assets/pdf_file/0023/29309/Management-Standards-and-Procedures-for-timber-harvesting-operations-in-Vics-State-forests-2014.pdf

187 www.fpa.tas.gov.au/fpa_services/planning_assistance/forest_practices_code

188 www.fpa.tas.gov.au/__data/assets/pdf_file/0014/110246/Guidelines_for_the_protection_of_Class_4_streams.pdf

189 publications.qld.gov.au/dataset/qld-agricultural-land-evaluation-guidelines

190 pfsq.net/wp-content/2017/03/2015-managing-native-forest-practice-code.pdf

Case study 4.1: Soil erosion knowledge base

This case study gives examples of research designed to increase the knowledge base on soil erosion in New South Wales.

'Paired catchment' studies detect the effects of wood harvesting and other disturbances by comparing stream flow and soil erosion in adjacent, similar, disturbed and undisturbed catchments. In one such study, Forestry Corporation of NSW researchers have monitored eight headwater catchments of the Karuah River in the Chichester State Forest since 1974. The catchments, which range from 15 to 100 hectares, were originally predominantly undisturbed tall eucalypt forest from 100 to over 500 years since disturbance, and with little evidence of fire. Weirs were installed at the outlet to each catchment so that stream flow and sediment carried in the streams could be measured.

After an initial period of monitoring to establish a baseline of stream flow and water quality, in 1983 a total of six catchments were subjected to various levels of wood harvesting, plantation establishment, road construction and other disturbance, while two were left undisturbed as controls. This is one of few studies to report long-term erosion rates for similar undisturbed and harvested sites in eastern Australia. Erosion rates ranged from 0.47 to 1.40 tonnes of sediment per hectare per year. There was no difference in sediment loads from the harvested and control catchments. The researchers concluded that harvesting in native forests followed by regeneration using best management practices does not cause significant soil erosion, or reduce water quality in the medium-term to long-term (Hancock et al. 2017).

Jamshidi et al. (2014) assessed annual changes in sediment loads in streams in four catchments in Kangaroo River State forest (NSW). Two catchments were selectively logged in 2007, while the other two were undisturbed. After selective logging, a greater amount of eroded sediments was transported to catchment outlets from steeply sloping areas close to catchment outlets during high rainfall events, than from distant hillslope areas. Vegetation cover recovered almost to its initial pre-logging condition after two years (2009), however sediment loads increased by up to 30% when more storm events were recorded in the same year. In all catchments, sediment delivery was influenced significantly more by rainfall than by changes in land cover. The study supports the current single-tree selection logging system as an environmentally sound land management strategy that minimises soil loss and sediment movement.

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Stream flow and sediment monitoring weir, Karuah catchment research, NSW.

In south-west Western Australia, during the reporting period the Department of Parks and Wildlife (DPaW) and the Forest Products Commission (FPC) have used soil landform maps in wood harvest planning and the management of soil erosion risks (DPaW 2016a). While there is no formal process in place to update soil data, field assessment continues to inform continual improvement in the understanding of soil disturbance and wood harvesting (DPaW 2016a).

Compliance with measures to mitigate impacts on soils

Compliance with requirements for minimisation of soil impacts is assessed in various ways across Australia, including by internal and external audits. The extent of compliance with prescribed mitigation measures for soil impacts is rated according to the seven categories used in previous SOFRs. These categories are detailed in Table 4.7, and range from Category 1 (for performance fully compliant with all requirements and outcomes, with minimal adverse impacts) to Category 7 (where no formal audit was conducted). Table 4.8 gives the compliance outcomes for some jurisdictions against these categories.

In Victoria, the Forest Audit Program (FAP) systematically assesses risks to soil attributes due to timber production operations through audits of compliance (DEPI 2014d). The Department of Environment, Land, Water and Planning (DELWP) has been responsible for the FAP since 2011, and commissions audits to measure industry compliance with the requirements set out in the *Code of Practice for Timber Production 2014*. According to the latest independent audit report, audited coupes were in compliance, with the majority of criteria achieving a compliance rate of 90% (URS Australia 2015). Coupes managed by VicForests and Department of Environment and Primary Industries (DEPI)[191] Forestry Services had an overall compliance score of 86% and 65% respectively for the 'water and soils' group of audit criteria (URS Australia 2015). Good practice was noted in the conservative classification of drainage lines; in prohibiting excavation of erosive subsoils; and in protection of soil close to active erosion points in coupes managed by DEPI Forestry

Table 4.7: Categories for the performance of forest managers in complying with prescribed mitigation measures for soil impacts

Category	Category description
1	Fully compliant with all process requirements and environmental outcome requirements, with minimal adverse impacts
2	Generally compliant with all process requirements and environmental outcome requirements, with minimal adverse impacts
3	Fully or generally compliant with all process requirements and environmental outcome requirements, but with moderate adverse impacts
4	Not generally compliant with process requirements and environmental outcome requirements, with minimal adverse impacts
5	Not generally compliant with process requirements and environmental outcome requirements, with significant adverse impacts
6	Insufficient or no objective evidence to make a judgment
7	No formal audit conducted

Source: SOFR 2008.

Table 4.8: Assessed compliance outcomes for soil impacts achieved in multiple-use public forests

Disturbance activity	ACT	NT	NSW	Qld	Vic.	SA	Tas.	WA
Native forest harvesting	n.a.	n.a.	2 (99%) 3 (1%)	1	3	n.a.	1	3
Plantation operations	1 (90%) 3 (10%)	n.a.	2 (90%) 5 (10%)	n.r.	2	3	1	4
Roads and trails	n.r.	n.a.	1–5	n.r.	2	3	1	4
Fire management	n.r.	n.a.	2, 6[a]	n.r.	2	3	1	4

n.a., not applicable; n.r., not reported

a '2' for conservation reserves; '6' for multiple-use state forests.

Notes: Data are for 2011–16, except that data for Vic. and Tas. are from SOFR 2013, and data for WA are from SOFR 2008. Categories for assessing compliance outcomes are described in Table 4.7, and vary between 1 (highest rating) and 7 (lowest rating). Each rating is an assessment by the relevant jurisdiction. There is no multiple-use public forest in the Northern Territory.

Source: State agencies.

This table, together with other data for Indicator 4.1b, is available in Microsoft Excel via www.doi.org/10.25814/5bda9272d76d7

191 Data from six coupes managed by DEPI Forestry Services in the Bendigo FMA are included in the data in URS Australia (2015): see also agriculture.vic.gov.au/agriculture/forestry/wood-utilisation-plans/bendigo-forest-management-area

Ripping and mounding parallel to the contour to minimise soil erosion at plantation establishment on farmland, Adelaide Hills, South Australia.

Services. Non-compliances related to lack of risk assessment on mass soil movement on steep slopes were identified in coupes managed by VicForests. DELWP also introduced a ‘rainforest spot checks’ program in 2015 to examine the performance of VicForests in the identification and protection of rainforest values.

The Western Australian Department of Parks and Wildlife[192] oversees the approvals, monitoring and compliance system for disturbance activities in state forests and timber reserves. The Department audits a range of forest management activities for compliance with requirements of the *Forest Management Plan 2014–2023* (CCWA 2013) under which the Forest Products Commission of Western Australia conducts forest operations. To minimise the risk of soil erosion, spreader banks are constructed across all extraction tracks and disturbed firebreaks upon completion of log extraction. The five jarrah coupes assessed all complied with erosion control measures (DPaW 2016c). The report on the end-of-term audit of the *Forest Management Plan 2004–2013* (CCWA 2013) noted that severe and highly visual forms of soil damage, such as rutting, puddling and mixing, were rarely seen in association with wood harvesting operations.

The Forestry Corporation of NSW (FCNSW) has a comprehensive soil assessment program for forestry operations, consisting of four modules (inherent soil erosion and water pollution assessment, mass movement assessment, dispersibility assessment, and seasonality), and is required to apply all four modules during pre-operational planning. Across 1,291 compliance checks, a total of 21 non-compliances were detected, and in one instance in 2015 FCNSW was fined by the Environment Protection Authority due to a failure to implement effective erosion and sediment control measures at a clearfell harvesting operation on a native hardwood plantation, when soil from a newly harvested plantation area washed into a waterway following a heavy rainfall event before replanting. Site-specific special protection measures, such as increasing the buffer widths around streams and sowing a cover crop immediately after harvesting, are now adopted in areas at high risk of soil erosion (FCNSW 2016d).

Native forest harvesting is not permitted in the Australian Capital Territory. Ninety percent of plantation operations in the Australian Capital Territory were fully compliant with all process requirements and environmental outcome requirements, with minimal adverse impacts; the other 10% were fully or generally compliant with all process requirements and environmental outcome requirements, but with moderate adverse impacts (Table 4.8).

In Queensland, monitoring and compliance systems are in place for native forest harvesting under the *Forestry Act 1959*. The Department of Agriculture, Fisheries and Forestry[193], and the Queensland Parks and Wildlife Service, as the custodians of State forests and timber reserves in Queensland,

[192] From July 2017, the Department of Biodiversity, Conservation and Attractions.

[193] From February 2015, the Department of Agriculture and Fisheries.

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audit native forest harvesting on State forests and timber reserves. Over the SOFR 2018 reporting period, there were no significant non-compliances or breaches reported for native forest activities authorised under the *Forestry Act 1959*.

In the Northern Territory, no significant non-compliance incidents or breaches under the *Soil Conservation and Land Utilization Act 2016* in regard to soil erosion on forest land were reported during the reporting period, and no infringement notices sent.

For South Australia, the *Forestry Regulations 2013* prohibit damaging soil and polluting streams. Data on breaches and non-compliance are not readily available, but are recorded in auditing processes for businesses that have forest certification. For example, as well as being bound by the *Forestry Regulations 2013*, softwood plantation manager OneFortyOne Plantations is voluntarily certified to the Australian Standard for Sustainable Forest Management (AS 4708). The most recent (June 2017) independent audit to ascertain compliance with the standard inspected a sample of 12 operational sites and found no instances of non-conformity.

In Tasmania, the Forest Practices Authority assesses forest practices that have been carried out under forest practices plans (FPP) certified under the *Forest Practices Act 1985*. Consistently high levels of compliance have been found for soil and water protection requirements issues on all tenures, demonstrating that operations are generally carried out to a very high standard and that only locally and sporadically do issues require attention (FPA 2017a).

Fire

Bushfire affects soils directly, for example through the loss of carbon and nutrients, and indirectly through rendering the soil more susceptible to erosion due to the reduction in vegetation cover. The likelihood of post-fire erosion depends on fire severity, rainfall intensity, aridity and hillslope morphology (Bell et al. 2014; Morris et al. 2012; Tulau 2015).

Catchments with vegetation communities that recover rapidly (such as by resprouting) have a substantially different post-bushfire response, with only minor erosional events, compared to vegetation communities that recover more slowly (such as if dominated by plants that regenerate only from seed) that can display serious post-bushfire erosion (Heath et al. 2014, 2016).

High-intensity rains 10 weeks after a bushfire in the Royal National Park, New South Wales, caused significant erosion from hillslopes, fire trails and walking tracks in a sandstone catchment (Atkinson 2012). Peak soil losses of 64 tonnes per hectare were recorded, compared to 2.5–8.0 tonnes per hectare from similar terrain in a relatively dry year. Similar high-rainfall events 3.5 years after the fire produced peak soil losses of 2.2 tonnes per hectare, and five years after the fire the soil loss rate had fallen to an average of 0.6 tonnes per hectare, approximately 1% of the peak soil loss rate.

Recovery from bushfires in the Warrumbungle National Park, New South Wales, in 2013 is the focus of a major program by NSW National Parks and Wildlife Service. An intense storm immediately following the bushfires caused flash-flooding and soil erosion, with an average soil loss of 150 tonnes per hectare (McInnes-Clarke et al. 2014).

Reducing bushfire severity reduces the potential for erosion issues. However, low-intensity fires such as prescribed burns can also increase the risk of erosion, particularly on erodible soils, where terrain is steep, or when there are subsequent, intense rain events. Morris et al. (2014) assessed erosion following prescribed burning in managed reserves in the Southern Mount Lofty Ranges in South Australia. Sediment movement was detected at half the prescribed burn sites, but its extent was minimal.

Indicator 4.1c

Management of the risk to soil physical properties in forests

Rationale

This indicator measures the extent to which the risk to soil physical properties in forests has been explicitly identified and addressed. The protection of soil physical properties, including minimising soil compaction and redistribution, affects soil integrity and, as a consequence, many associated values.

Key points

- In all states and territories, soil physical properties in forests are protected by a combination of legally binding and non-legally binding instruments, including legislation, regulations, licences, codes of practice, guidelines and management plans.
- In most jurisdictions, disturbance activities associated with forest management, such as wood harvesting and associated road and track construction and maintenance, were assessed for risk to soil physical properties, and protective measures were implemented.
- In most jurisdictions, the level of compliance with soil protection measures in multiple-use public forest has been assessed as high.

Appropriate management of soils as the substrate for forests is fundamental to sustainable forest management. Soil physical properties include soil structure, density, compaction, texture, permeability and water-holding capacity. Degradation of these properties can affect seed germination and growth and survival of trees, and can have other effects, such as increased water run-off and consequent erosion. It is therefore important that forest management operations do not result in permanent adverse changes to soil physical properties.

This indicator reports on the measures undertaken to minimise adverse impacts on soil physical properties on forested land. It focuses on multiple-use public forest and public nature conservation reserves because, generally, limited information is available for other forest tenures.

Impacts of forestry operations on soils

The principal impacts of forestry operations on the physical properties of soils are associated with wood production and include tree-felling and snigging or forwarding, activities at log dumps and log landings, preparing sites for regeneration or planting, and construction of roads, trails and log extraction tracks (snig tracks). Common potential impacts of these forest disturbance activities are soil compaction, soil movement, and removal of organic matter. The impact of heavy-tracked vehicles, in particular, on the physical characteristics of soils is immediate and generally obvious, but the degree of impact depends on the soil type, the soil moisture content, the loading pressure, and the duration and frequency of such pressure, including the number of times a vehicle passes over a track.

The physical impact on soils from wood harvesting can be minimised by using appropriate harvesting equipment, harvesting methods (e.g. walk-over slash, or cable or 'shovel' logging), planning the layout of extraction tracks, timing operations to avoid high soil moisture, and protection of soils with matting or cording. Modern harvesting vehicles and accumulated operational knowledge have combined to greatly reduce soil impacts (e.g. reducing ground pressure by using rubber-tyred vehicles).

In all states and territories, measures to protect soil physical properties were in place for the reporting period. In some jurisdictions, these have been implemented in multiple-use public forests for many years, but only in Victoria, South Australia and Tasmania are these measures applied to all wood harvesting operations, regardless of tenure.

A range of measures are undertaken to protect soil physical properties, varying with the nature of the soils, the seasonal conditions and the type of harvesting activities being undertaken. Measures undertaken to protect soil physical properties include:

- controls on placement of felled trees and log extraction operations in or near streams or riparian areas
- methods of construction and maintenance of extraction and other temporary tracks, including cording and matting
- size, placement and management of log dumps and log landings for storage, and loading of logs for transport
- selection of harvesting machines, including whether machines have tracks, tyres or chains
- machinery restrictions on slopes, and restrictions on clearing steep slopes for plantations
- wet-weather shutdowns.

Acid sulphate soils could cause problems for forest ecosystems if such soils were exposed through excavation activities. However, forestry operations are unlikely to create such problems because they do not generally involve substantial excavation.

Instruments that address risks to soil physical properties

The extent to which a regulatory framework requires the maintenance of soil physical properties is rated according to the five categories used in previous SOFRs. These categories are detailed in Table 4.9, and range from Category 1 (for regulatory instruments that take into account risks to soil physical properties from site factors, management factors and vehicle factors associated with disturbance activities) to Category 5 (for instruments that do not mention the need to address risks to soil physical properties). The extent to which the risks to soil physical properties are addressed by a state or territory's legally binding instruments (such as Acts) and non-legally binding instruments (such as codes of practice, guidelines and forest management plans) is assessed against these categories in Table 4.10.

The data in Table 4.10 show that there are regulatory instruments in place to manage risks to soil physical properties to varying degrees in all jurisdictions and for all tenures for which this was reported. Most of these

Table 4.9: Categories of the extent to which a regulatory framework requires the maintenance of soil physical properties

Category	Category description
1	The instruments require the following components to be taken into account in addressing the risk to soil physical properties from disturbance activities: • site factors, including the soil properties of moisture content, organic matter content, soil type and texture; presence of litter, trash or slash; slope; and rainfall distribution and intensity • management factors, including timing of operations (season), harvesting system, harvesting pattern and slash distribution • vehicle factors, including machine configuration, vehicle weight, dynamic load, tyre size, tyre inflation pressure, wheel slip, tracks or wheels, vibration, number of passes, vehicle speed, area affected, and whether logs are dragged, lifted or carried.
2	The instruments address most of the components listed in category 1, and those not addressed are associated with low risks to soil physical properties for the particular disturbance activity and geographical setting.
3	The instruments address most of the components listed in category 1 but do not specify all aspects or are limited in their application.
4	The instruments mention the need to address risks to soil physical properties when conducting disturbance activities but do not specify the components listed in category 1.
5	The instruments do not mention the need to address risks to soil physical properties.

Source: SOFR 2008.

Table 4.10: Assessed extent to which legally and non-legally binding instruments address the risk to soil physical properties from forest operations, road and trail works, fire management and recreation activities

Instrument	Tenure	ACT	NSW	NT	Qld	SA	Tas.	Vic.	WA
Legally binding	Multiple-use public forests	5	1–2	1–5[a]	2	4	1	1	4
	Public nature conservation reserves	5	4	2	n.r.	4	1–2	1	4
	Leasehold land	n.r.	n.r.	n.r.	2	4	n.r.	n.r.	n.r.
Non-legally binding	Multiple-use public forests	1	2	5	2	1	1	3	1
	Nature conservation reserves	1	5	5	n.r.	n.r.	1–2	3	4
	Leasehold land	n.r.	n.r.	n.r.	2	1	n.r.	n.r.	n.r.

n.r., not reported.

[a] Extent to which instruments address the risk to soil physical properties varies between 1 and 5 for different management disturbance activities.

Notes:

Data are for 2011–16 for ACT, NSW, NT, Qld, SA and Tas.; data are from SOFR 2013 for Vic., and are updated from SOFR 2013 for WA.

The extent to which instruments address the risk to soil physical properties varies between category 1 (highest rating) and category 5 (lowest rating): see Table 4.9. Each rating is an assessment by the relevant jurisdiction.

Source: State and territory agencies.

This table, together with other data for Indicator 4.1c, is available in Microsoft Excel via www.doi.org/10.25814/5bda9272d76d7 instruments rate highly for the number of factors that must be taken into account. The rating shown for multiple-use public forests in Western Australia has been refined since that reported in SOFR 2013 based on further assessment of the regulatory instruments. Ratings have not changed or were not reported in SOFR 2013 for other jurisdictions.

Operational-level requirements or guidance to manage impacts on soil physical properties are described in various legally and non-legally binding instruments, particularly codes of practice, at state or territory and regional levels. Legally binding instruments relating to soil physical properties are in place in New South Wales, the Northern Territory, South Australia, Tasmania, Victoria, Queensland and Western Australia.

The general principles of the codes of practice are that any potential damage is to be mitigated, logs are to be removed in a manner and by methods that do not result in significant soil disturbance, and damage caused by the forest management operation, including damage to soil physical properties, is to be repaired. Aspects that are covered in codes of forest practice include assessment and management of soil compaction, mitigating soil movement, creation and management of filter strips or buffers, and consideration of appropriate machinery to protect soil physical properties.

The Queensland Parks and Wildlife Service (QPWS) is the custodian of state forests and timber reserves in Queensland, with timber harvesting carried out according to the *Code of Practice for Native Forest Timber Production on the QPWS Forest Estate 2014*[194] (DNPRSR 2014). The code requires timber production activities to be regulated to prevent or minimise deterioration of the soil physical properties. It prescribes soil assessments to identify soil compaction hazards, with compaction ratings providing guidance for managing high-risk areas through restrictions on operations, vehicle movements or wet-season harvesting. The Queensland code covering native forest on freehold land, *Managing a native forest practice – A self-assessable vegetation clearing code*[195] (DNRM 2014), sets a minimum acceptable environmental management standard to ensure that soils are protected from compaction or mass movement. The code requires that harvesting, thinning, or maintenance or use of roads and tracks does not occur on any area while the soil is saturated. The *Timber Plantation Operations Code of Practice for Queensland (2015)*[196] (Timber Queensland 2015) covers private plantation forests and includes soil protection as one of its goals. The code requires that modified harvesting methods are used when conventional harvest methods may threaten soil structure and stability or have the potential for adverse off-site effects.

In New South Wales, the Forestry Corporation of NSW undertakes comprehensive soil assessments in multiple-use public forests, as required by Integrated Forestry Operations Approvals (IFOAs), and implements mitigation measures to protect soil physical properties in high-risk areas. Wood harvesting on Crown Timber Lands other than State Forests or Timber Reserves that are categorised as 'Protected Lands' must comply with the provisions of the *Soil Conservation Act 1938* (NSW), and requires authorisation from the Commissioner for Soil Conservation. Forest practices codes for wood harvesting in native forests and plantations specify provisions to minimise soil disturbance (including compaction or rutting) during tracking, snigging, wet weather, and machine/vehicle movement, by placing restrictions on or managing harvesting systems and slash distribution. Bark is used to protect soil from loading machinery at log dumps. The *Code of Practice for Plantation Forestry: New South Wales*[197] (Forests NSW 2005) was assessed by Smethurst et al. (2012), who found that existing code content and implementation processes were generally adequate for protecting soil resources, but also recommended strengthening of provisions for inter-rotational slash management.

The NSW National Parks and Wildlife Service conducts few operations that are likely to affect soil physical properties, but revegetation and rehabilitation works are needed to address areas of previous disturbance. For example, revegetation works are required for disused roads and quarries; this work involves treatment of soil compaction, including seeding and spreading of topsoil. Detailed assessment of soil physical properties is required for geotechnical reports prepared when planning high-risk structures, when roads and walking tracks need to be realigned due to failing substrates, and where acid sulphate soils are likely to be present.

In Tasmania, forest activities carried out under the *Forest Practices Act 1985* require an assessment of risks to soil physical properties in accordance with the Forest Practices Code (most recently the *Forest Practices Code 2015*[198], FPA 2015b), irrespective of land tenure or forest type. The code requires forest operations to be planned according to soil load-bearing capacity. Ground-based harvesting equipment is not to be used on saturated soils, and careful attention is paid to the location, construction and post-harvesting treatment of snig tracks and landings to minimise soil compaction, puddling and mixing. In wet conditions, slash and branches are placed on extraction tracks to minimise soil damage.

In Northern Territory, the *Codes of Practice for Forestry Plantations 2004* (DRPI 2004) prescribes minimisation of adverse impacts on soils, such as compaction caused by machinery traffic during wet weather, and compaction during site preparation. A recent review of the code (Raison et al. 2012) recommended development of a new and more comprehensive code that provided guidance or reference to supporting documentation on how to achieve soil conservation goals, and noted a near-term need to develop harvesting plans for plantations. This code is being revised.

In Victoria, the *Code of Practice for Timber Production 2014* (DEPI 2014b) covers operations in native and plantation forests. It requires each harvesting operation to have a Forest

194 www.npsr.qld.gov.au/managing/pdf/timber-production-qpws-estate.pdf

195 pfsq.net/wp-content/2017/03/2015-managing-native-forest-practice-code.pdf

196 www.timberqueensland.com.au/Docs/Growing-Processing/Timber-Plantation-Operations-Code-of-Practice-Version-1.pdf

197 www.forestrycorporation.com.au/__data/assets/pdf_file/0010/457174/FNSW-ForestPracticesCode-2005.pdf

198 www.fpa.tas.gov.au/fpa_services/planning_assistance/forest_practices_code

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Coupe Plan that describes measures to protect and rehabilitate soils including, for example, measures to protect soil physical properties, such as that machinery must not enter any set filter strip, except at stream crossings. The potential for mass soil movement must be assessed when operating on steep soils, and necessary preventative actions undertaken; these include only felling trees out of filter strips, and using techniques such as cable logging rather than ground-based machinery on slopes greater than 30 degrees. The *Code of Practice for Bushfire Management on Public Land 2012* (DSE 2012) seeks to protect soil by measures that minimise damage to soil physical properties, or that promote stabilisation of bare earth following disturbance.

Harvesting wood from native forests is not permitted in the Australian Capital Territory. Plantation forestry in the Australian Capital Territory achieves soil protection through the *ACT Code of Forest Practice* (Environment ACT 2005)[199] and related guidelines (Smethurst et al. 2012). All operations carried out within a plantation need to be conducted according to an operational plan based on the *ACT Code of Forest Practice*. The code recognises the importance of protection of soil from degrading processes, including compaction, and loss of nutrients, organic matter, or structure. It prescribes on-site slash retention rather than slash burning. The code also requires that soil compaction and rutting depth are considered when assessing the suitability of machinery for operations.

Western Australia's *Forest Management Plan 2014–2023* (CCWA 2013) and earlier plans prescribe activities to protect soil physical properties from threats of compaction and rutting as a result of use of heavy vehicles or inadequate rehabilitation of damaged soil. The Forest Products Commission is bound by the *Code of Practice for Timber Plantations in Western Australia* (FIFWA 2014), which requires that soil compaction be minimised when conducting operations, including by regulating any disturbance affecting soil stability, and applying wet weather restrictions to minimise soil damage.

In addition to the *Forest Management Plan*, there are other instruments in Western Australia that assist in the protection of soil physical properties. The *Soil and Water Conservation Guidelines 2009* (DEC 2009c) provides a number of guiding principles, supported by relevant strategies, for the conservation of soil values. The *Manual of Procedures for the Management of Soils Associated with Timber Harvesting in Native Forests 2010* (DPAW 2010) provides a guide for managing soil properties, including a trafficability index that defines soil management risk periods and permissible activities in relation to soil moisture. The manual also specifies the additional planning and approval requirements for operations during the wetter part of the year, and includes definitions of soil disturbance categories and procedures for assessing and monitoring soil disturbance. The *Code of Practice for Fire Management 2008*[200] (DEC 2008) requires managing fires to protect soil stability, physical and chemical properties and soil rehabilitation following disturbance.

In South Australia, legally binding instruments such as the *Environment Protection Act 1993* and the *Natural Resources Management Act 2004* mention the need to address risks to soil physical properties when conducting disturbance activities on forest land; however, they do not specify individual components of soil physical properties. Under the South Australian *Forestry Regulations 2013*, it is prohibited to intentionally destroy, damage or disturb, remove any soil, from a forest reserve. The importance of minimising soil disturbance and soil compaction are emphasized in the *Guidelines for Plantation Forestry in South Australia 2009*[201]. The planning of harvesting operations must consider site characteristics (slope, soil type and water courses), season, extraction and haulage routes, load sizes, and machinery movements, to minimise soil damage and subsequent impact on water run-off. The guidelines require land-use options and management practices to be selected based on the Plantation Forestry Land Capability Classification System, which in turn is based on soil physical properties such as drainage, texture, structure and depth. As an example, risks associated with poorly drained soils are managed by mounding planting lines, and restricting harvesting operations when soil is saturated.

Mounded planting lines to reduce water run-off in a plantation, Tasmania.

[199] www.environment.act.gov.au/parks-conservation/management_of_the_commercial_pine_plantation_estate

[200] www.dpaw.wa.gov.au/images/documents/fire/fms-code-of-practice.pdf

[201] www.pir.sa.gov.au/__data/assets/pdf_file/0011/254765/guidelines_for_plantation_forestry_in_sa_web.pdf

Assessment of risk to soil physical properties

The extent to which soil physical properties are assessed in planning processes across jurisdictions is rated according to the four categories used in previous SOFRs. These categories are detailed in Table 4.11, and range from Category 1 (for a soil physical properties risk assessment system that takes into account site factors, management factors and vehicle factors) to Category 4 (for an ad hoc risk assessment system that does not take into account any factors relevant to soil physical properties).

Table 4.12 shows that, for the jurisdictions for which data were provided, the codes of practice and other instruments in place generally require assessment of risks to soil physical properties. Assessment of the potential risk to soil physical properties is usually covered in the codes of practice and other instruments, and carried out by forest managers, in conjunction with an assessment of soil erosion hazard, using the various processes reported in Indicator 4.1b. Other than wood harvesting, the areas of which are reported in Indicator 2.1a, the area of multiple-use public forest for which disturbance activities are planned is not reported for most jurisdictions.

Table 4.11: Categories of the extent to which soil physical properties are assessed in planning processes

Category	Category description
1	The soil physical properties risk assessment system takes into account all the following factors: • site factors, including the soil properties of moisture content, organic matter content, soil type and texture; presence of litter, trash or slash; slope; and rainfall distribution and intensity. • management factors, including timing of operations (season), harvesting system, harvesting pattern and slash distribution. • vehicle factors, including machine configuration, vehicle weight, dynamic load, tyre size, tyre inflation pressure, wheel slip, tracks or wheels, vibration, number of passes, vehicle speed, area affected, and whether logs are dragged, lifted or carried.
2	The risk assessment system takes into account most of the components listed in category 1, and those not addressed are associated with low risks to soil physical properties for the particular disturbance activity and geographical setting.
3	The risk assessment system takes into account some of the factors listed in category 1 or only partly accounts for these factors.
4	The risk assessment system is ad hoc and/or does not take into account any of the factors listed in category 1.

Source: SOFR 2008.

Table 4.12: Area of multiple-use public forest where disturbance activities were planned, proportion assessed for risk to soil physical properties, and assessed category

Disturbance activity	Metric	ACT[a]	NSW	NT[a]	Qld	SA[a]	Tas.	Vic.	WA
Native forest harvesting and silviculture	Area (hectares)	n.a.	17,000–32,000	n.a.	n.r.	n.a.	n.a	n.r.	n.r.
	Assessed for risk to soil properties (%)	n.a.	100	n.a.	100	n.a.	100	100	100
	Assessment category[b]	n.a.	1	n.a.	2	n.a.	1	3	3
Plantation operations	Area (hectares)	627	7,000–10,000	n.a.	n.r.	n.r.	n.r.	n.r.	n.r.
	Assessed for risk to soil properties (%)	100	100	n.a.	n.a.	100	100	90	n.r.
	Assessment category[b]	1	1	n.a.	n.a.	1	1	2	n.r.
Road construction and maintenance	Area (hectares)	n.r.	n.r.	n.a.	n.r.	n.r.	n.r.	n.r.	n.r.
	Assessed for risk to soil properties (%)	n.a.	100	n.a.	n.a.	100	100	60	100
	Assessment category[b]	n.a.	1	n.a.	n.a.	3	1–2	2	3
Fire management	Area (hectares)	n.r.	20,000–40,000	n.a.	n.r.	n.r.	n.r.	n.r.	n.r.
	Assessed for risk to soil properties (%)	n.a.	100	n.a.	n.a.	100	100	90	n.r.
	Assessment category[b]	n.a.	1	n.a	n.a.	3	1-2	2	n.r.

n.a., not applicable; n.r., not reported

[a] South Australia & ACT do not harvest native forest; there is no multiple-use forest in the NT.

[b] The extent to which soil physical properties are addressed during planning processes varies between 1 (highest rating) and 4 (lowest rating): see Table 4.11. Each rating is an assessment by the relevant jurisdiction.

Note: Data for 2011–16 except that data for Tas., Vic. and WA are from SOFR 2013. NSW figures are the range of annual areas across the five-year reporting period. Areas harvested are reported in indicator 2.1a.

Source: State and territory agencies.

This table, together with other data for Indicator 4.1c, is available in Microsoft Excel via www.doi.org/10.25814/5bda9272d76d7

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Knowledge base on soil physical properties

Improving soil data for plantation planning and management is a priority outlined in the 2010 Research, Development and Extension (RD&E) Strategy for the forest and wood products sector (FWPA 2010). This priority aligns with Australia's first National Soil Research, Development and Extension Strategy (Commonwealth of Australia 2014) which also sets a priority to 'provide improved data for land use planning'.

The coverage and level of detail of mapping of soils in forested areas varies across states and territories. For example, major areas of state forest in northern Tasmania have been mapped at 1:250,000 scale, and 95 soil types with differing properties and erosion risks have been identified throughout the state, mostly in state forests. New maps of soil texture at a regional scale were developed for the whole of Victoria by the Victorian Department of Economic Development, Jobs, Transport and Resources in 2014. A new edition of *Soil groups of Western Australia* was released in 2013 (Schoknecht and Pathan 2013). Areas containing acid sulphate soils have been mapped for the entire NSW coastline at a scale of 1:25,000 (NSW OEH 2016a).

In South Australia, regional natural resource management plans include a summary of threats and issues relating to soil physical conditions in multiple-use forest, nature conservation reserves and other crown land. The Soil and Land Program of the Department of Environment, Water and Natural Resources has developed models that assess the potential of land for specific uses including forestry, using soil and land attribute spatial datasets. Comprehensive soil and land mapping information for South Australia was delivered through the State Land and Soil Mapping Program (1986–2012)[202].

In Western Australia, the knowledge base on the potential impacts on soil physical properties of various forest activities, including machinery disturbance, improved during the reporting period. Heavy machinery used in timber harvesting can cause severe soil rutting and compaction, with the impact exacerbated in wet conditions (Whitford 2011). In the forests of south-western Western Australia, soil compaction on log extraction tracks is related to log load, initial soil bulk density, and gravel content. Compaction increases as the total load of logs hauled over the tracks increases. Soils with a high initial bulk density and high gravel content were less compacted during timber harvesting (Whitford 2012). Primary and secondary extraction tracks were more compacted than tertiary extraction tracks, and significantly more compacted than the general harvested area; soil compaction is known to persist for decades after timber harvesting unless treated. Limits for soil disturbance, and criteria for harvesting operations on moist soil in jarrah forest in south-west WA, were revised based on these findings and incorporated into the *Forest Management Plan 2014–2023* (CCWA 2013) and associated guidelines.

Practices to protect soil during wood harvesting and other operations have changed considerably during the past decade in the forests of south-western Western Australia (CCWA 2013). Cording or corduroy[203] is used to disperse the load of heavy machinery over a larger area, and to significantly reduce compaction, rutting and associated soil mixing (Whitford 2011). Focusing all traffic onto as few tracks as possible, and reusing compacted extraction tracks that remain from any previous harvesting, are the most effective means of reducing the impact of timber harvesting on soils (Whitford 2012).

High-severity fires can induce important changes in soil structure and aggregate stability, due to loss of organic matter, and changes in water repellency and other physico-chemical properties. During wildfire, organic compounds vaporise and move downwards through the soil profile, then condense to form a hydrophobic layer or coating around soil particles (Tulau 2015). A recent study by Heath et al. (2015) in two catchments in the Blue Mountains, New South Wales, found that burn severity had a significant effect on soil carbon levels and topsoil water repellency. Total soil carbon and water repellency were highest in areas affected by burns of low severity, decreased with burns of moderate and high severities, and increased again with burns of very high severity.

Knowledge of risks to soil properties is progressively incorporated into state and territory instruments, and disseminated to the industry in various ways. For example, in Tasmania dissemination of knowledge occurs through the Forest Practices Authority, which provides landowners and managers with access to soil management resource materials, including manuals and fact sheets. Combined with ongoing research and training and the experience of forest managers, these resources help to identify and map soils, and enable assessment and management of risks arising from the interactions of factors such as slope, climate, soil type, rainfall, stream management and vegetation cover.

202 www.environment.sa.gov.au/Knowledge_Bank/Information_data/soil-and-land/mapping-soil-and-land

203 Corduroy is round or split log material that is laid across extraction tracks (snig tracks) in a close and continuous layer, or placed across landings, so as to distribute machine loads over a larger area.

Indicator 4.1d

Management of the risk to water quantity from forests

Rationale

This indicator measures the extent to which the risk to water quantity has been explicitly identified and addressed in forest management. Water quantity is important for ecosystem health and water supply for human use.

Key points

- All jurisdictions where native forest harvesting is permitted have regulatory instruments, such as codes of practice or management guidelines, to manage activities related to harvesting that could affect water yields from forests.
- Practices such as selecting the location of forest to be harvested, limiting the proportion of catchments to be harvested in a year, and thinning to increase water yield, are implemented to manage potential impacts of forestry operations on water quantity.
- Understanding of the impacts of forest type, age, growth rate and tree density on water yield continues to improve, but the ability to predict changes in water yield in specific circumstances is less well developed.
- Water use by tree plantations was considered a significant concern when substantial areas of new plantations were being established at a time that coincided with the ‘millennium drought’ (1996–2010 in eastern Australia). That concern waned in most jurisdictions when plantation expansion ceased in 2008 and more typical rainfall patterns returned.

Large areas of forested land are used to provide reliable and clean supplies of drinking water for human consumption, as well as for irrigation and industrial uses. The quantity of water available in streams and rivers flowing from forested catchments depends on the combination of rainfall, water interception and use by the forest vegetation, run-off, and entry to groundwater systems. Rainfall varies seasonally and across longer periods, while the amount of water used by a forest stand depends on its age, tree density, species mix and growth rate. In general, forested catchments provide higher quality water supplies with a lower risk of variation in water quantity and quality than do catchments with other (non-forest) land uses.

Management practices likely to affect water yields in forested catchments include the timing, scale and spacing of wood harvesting; thinning of regrowth forest; fire management; control of woody weeds; modifications to rotation lengths of growing forests or plantations; and land-use change (e.g. forest clearing for agriculture, or reforestation of former agricultural land). Harvesting wood over a short period from a large proportion of a catchment would change the forest age-class structure significantly, and where a large proportion of the catchment water yield is utilised could affect water supply. However, most water supply catchments are sufficiently large, and the proportion affected from year to year by forest disturbance such as wood harvesting is relatively small, that effects on water supply are typically not significant.

Major bushfire events can influence water yields by changing the age-class structure of native forests, as stand age and leaf area are major determinants of forest water use. Run-off can be high immediately after bushfire as regeneration develops, and low from the subsequent regrowth forest stands, before increasing again as stands mature. The magnitude of these changes depends on the proportion of a catchment that is forested, soil types, the proportion of forest that is burnt, and the intensity of the fire; much smaller effects are likely in mixed-species catchments subject to non-stand-replacing fires.

Instruments in place that address the risk to water quantity

Regulatory instruments specify measures to be implemented to maintain stream flows and water quantity in particular locations. These instruments also provide benchmarks against which the management of water quantity can be assessed. Legally binding instruments include Acts and licences, whereas non-legally binding instruments include codes of practice, guidelines and forest management plans.

The extent to which a regulatory framework aims to maintain water quantity after disturbances associated with forest management is rated according to the five categories used in previous SOFRs. These categories are detailed in Table 4.13, and range from Category 1 (for regulatory instruments that take into account a variety of risks to water quantity) to Category 5 (for instruments that do not mention the need to address risks to water quantity). The extent to which the risks to water quantity posed by forest management activities in multiple-use public forests are addressed by a state or territory's legally binding instruments and non-legally binding instruments is assessed against these categories in Table 4.14.

Compared with protection of water quality, which is a major concern and focus of legislative and regulatory instruments in all jurisdictions and for all tenures (see Indicator 4.1a), protection of water quantity is only of concern where forest establishment or management might affect water supply. Table 4.14 accordingly shows lower ratings for most jurisdictions than Table 4.16, which deals with water quality instruments. The ratings shown for New South Wales and South Australia have been refined since being reported in SOFR 2013, based on further assessment of the regulatory instruments. Ratings have not changed or were not reported in SOFR 2013 for other jurisdictions.

In the Australian Capital Territory, the *Planning and Development Act 2007* requires development proposals likely to have a significant adverse impact on domestic water supply catchments, which are forested and managed under a reserve management plan, to have environmental impact statements.

Table 4.13: Categories of the extent to which regulatory frameworks aim to maintain water quantity after disturbances associated with forest management

Category	Category description
1	The instruments require the following components to be taken into account in addressing the risk to water quantity posed by forest management-related disturbance activities: • local and regional requirements relating to water yield, and the sensitivity of the water supply system to changes in water yield • age structure of stands in forested catchments • the conversion of mature stands to regrowth • rotation lengths • stand density.
2	The instruments address most of the components listed in category 1, and those not addressed are associated with a low risk to water quantity for the particular disturbance activity and geographical setting.
3	The instruments address most of the components listed in category 1 but do not specify all aspects or are limited in their application.
4	The instruments mention the need to address risks to water quantity when conducting disturbance activities but do not specify the components listed in category 1.
5	The instruments do not mention the need to address risks to water quantity.

Source: SOFR 2008.

Table 4.14: Assessed extent to which legally binding and non-legally binding instruments address the risk to water quantity from forest management activities in multiple-use public forests

Type of instrument	ACT	NSW	NT	Qld	SA	Tas.	Vic.	WA
Legally binding	n.a.	4	n.a.	5	1,5[a]	1	2	4
Non-legally binding	n.a.	3	n.a.	5	4,5[b]	1	2	5

n.a., data not available

[a] Rating 1 for plantation operations; 5 for other activities.

[b] Rating 4 for plantation operations; 5 for other activities.

Note: The assessed extent to which instruments address the risk to water quality varies between 1 (highest rating) and 5 (lowest rating): see Table 4.13. Each rating is an assessment by the relevant jurisdiction.

Sources: Data for Tas. from FPA (2017a), and for Qld and SA are for 2016. Data for Vic. and WA are from SOFR 2013. Data for NSW from Forestry Corporation NSW.

This table, together with other data for Indicator 4.1d, is available in Microsoft Excel via www.doi.org/10.25814/5bda9272d76d7

Maintaining appropriate levels of water yield and flow duration in catchments is one of the aims of NSW Regional Forest Agreements (State of NSW 1999; 2000; 2001). In New South Wales, Integrated Forestry Operations Approvals (IFOAs)[204] apply to anyone carrying out forestry operations on State forests and other Crown-timber lands. Under the conditions of IFOAs, wood harvesting operations in public multiple-use native forests are required to be dispersed in space and time; this mitigates environmental impacts, including potential effects on water quantity. Of a total of 2.0 million hectares of multiple-use public forests in New South Wales, approximately 30 thousand hectares (1.5%) are harvested annually, in a mosaic across the estate (FCNSW 2016d); that small proportion distributed across the estate is unlikely to have a significant effect on water quantity in any one catchment.

Water supply from forested catchments is generally not a limiting factor in Queensland. The *Forestry Act 1959* and native forest codes of practice[205] refer to protection of watershed values. Native forest practices address relevant catchment goals during preparation of Operational Harvesting Plans. Forest products operations are dispersed in nature and occur over only a small proportion of any regulated catchment. Selective harvesting has only a limited impact on canopy cover, and thus on water use by the forest. As a result, forest operations do not have significant impacts on water flows at the catchment scale.

With respect to water quantity, water resources in South Australia are protected and managed by being 'prescribed' under the *Natural Resources Management Act 2004* (NRM Act). The NRM Act was amended by the *Natural Resources Management (Commercial Forests) Amendment Act 2011* to give South Australia state-wide forest water legislation. Furthermore, the *Natural Resources Management (Review) Amendment Act 2013* permits South Australian watercourse water and surface water to be treated as one entity, and interconnected water resources to be managed together in appropriate cases.

Regional Natural Resources Management (NRM) boards in South Australia develop a Water Allocation Plan (WAP) for each prescribed water resource. WAPs require forest plantations to be formally assessed for risk to water quantity. WAPs for the Eastern Mount Lofty Ranges, Western Mount Lofty Ranges and Lower Limestone Coast were implemented in 2013. The Lower Limestone Coast Prescribed Wells Area WAP includes a forest water licensing system. Around 165 commercial forestry licences were issued when that plan was implemented. The plan also provides for water allocations to be reduced where unacceptable impacts are occurring, including impacts of commercial forest management. Some of these allocation reductions have already begun in two water management areas, requiring 51% and 44% allocation reductions over eight years. Activities affecting water in the Eastern Mount Lofty Ranges and Western Mount Lofty Ranges are managed under a permit system, however the policies regarding harvesting and replanting differ. The *Forestry Regulations 2013* allow ForestrySA to protect water resources in state forest reserves for the benefit of local communities.

In Tasmania, both the previous *Forest Practices Code 2000* and the current *Forest Practices Code 2015*[206] restrict wood harvesting to no more than 5% of the area of any town water supply catchment in any given year.

In Victoria, Melbourne's water supply catchments include large areas of national parks and some State forests. Harvesting currently takes place in a very small proportion (0.14%) of the area of Melbourne's water supply catchments, and Melbourne Water does not collect water from tributaries of the Yarra River when timber harvesting occurs in upstream catchments; this harvesting also has a minimal impact on overall water yield[207]. Across Victoria, and as set out in the *Timber Allocation (Amendment) Order 2014*, within a five-year period VicForests only harvests 6% of the area of ash forests and 4% of the area of mixed forests available for harvesting, which also minimises the impact on the volume of water generated from the forest.

In Western Australia, the *Forest Management Plan 2014–2023*[208] has been adopted for the south-west forest region. This Forest Management Plan (FMP) continues the approach to protecting water resources of the previous plan. The new FMP includes activities to manage threats of excessive extraction of water by native vegetation and plantations and for human use, and to manage declining rainfall and consequent reductions in groundwater levels and stream flows, damage to stream beds and banks, and changes in the composition, structure and density of riparian vegetation. The new FMP also provides for the preparation of catchment management plans that apply silviculture treatments such as thinning to increase the flow of water to surface and groundwater reservoirs in areas such as over-stocked regrowth forests.

The Northern Territory also contains a number of stream-gauging stations that collect data on water flow rates.

Changes to the water quantity knowledge base

Native forests

Knowledge of the effects of forest operations on water quantity is well developed, particularly in New South Wales, South Australia, Victoria and Western Australia. Capacity to model the effects of wood harvesting, bushfires, forest type, forest age, and climatic variation on catchment water yield improved during the reporting period, and continues to be a key area of research.

204 www.epa.nsw.gov.au/your-environment/native-forestry/integrated-forestry-operations-approvals/

205 publications.qld.gov.au/dataset/self-assessable-vegetation-clearing-codes/resource/a73f5b44-008c-4f92-8644-f92e6caf6592

206 publications.qld.gov.au/dataset/self-assessable-vegetation-clearing-codes/resource/a73f5b44-008c-4f92-8644-f92e6caf6592

207 www.vicforests.com.au/static/uploads/files/fs-water-web-wfrouxwzendz.pdf

208 www.dpaw.wa.gov.au/images/documents/conservation-management/forests/FMP/20130282_WEB_FOREST_MGT_PLAN_WEB.pdf

The Black Saturday bushfires of February 2009 burnt nine catchments north and east of Melbourne, Victoria. A total of 28% of the area of the forested catchments that supply water to the city of Melbourne was affected, with 11% of the area of these catchments severely burnt by intense fire. Feikema et al. (2013) predicted, under average rainfall conditions, a maximum annual reduction in long-term streamflow in the fire-affected water supply catchments of 3.0–6.1%, and a total reduction in post-fire streamflow after 100 years of 1.4–2.8%. These values are low due to the relatively small proportion of the catchments affected by severe fire, and the relatively low tree mortality within these fire areas. Benyon and Lane (2013) found that long-term water yields were expected to decrease in catchments where densities of regenerating seedlings were high, but that there might be long-term increases in water yields in areas with little or no eucalypt regeneration. Removal of the understorey, or suppression of understorey regrowth by an intact overstorey, might result in water yield increases that persist for a decade or more. Thinning of regenerating native forest is another option for increasing water yields after fire (Case Study 4.2).

New South Wales has a well-developed knowledge-base on forest water yields, based on long-term catchment hydrology research. Webb and Jarrett (2013) detected an increase in total streamflow following bushfire and/or integrated harvesting at various intervals in five catchments containing mixed-species eucalypt forest in south-eastern NSW, with a minor reduction in streamflow observed in only two catchments. Catchment-scale hydrological responses in mixed-species eucalypt forests differ from those in ash forests, which have a longer recovery period through seedling regeneration.

The severe 2001–02 bushfires in drinking-water catchments in the outer Sydney Basin led to little or no substantial medium-term impact on water yield in the subsequent 10 years (Heath et al. 2014). These catchments are dominated by vegetation communities that regenerate by resprouting, and that therefore have greater hydrological resilience to severe bushfire than communities dominated by vegetation that only regenerates from seed. On the other hand, Nolan et al. (2015) found different hydrological responses in similar forests following bushfires in 2006 and 2009 in south-eastern Australia, with streamflow reduction over 1–4 years post-fire, due both to climate and to fire effects on vegetation. The reduction in mean annual stream flow was much less in a very wet year, and streamflow recovered to the pre-fire level within 8–12 years after the fire. Finally, long-term hydrological studies in three types of mixed-species eucalypt forest in New South Wales found an increase in water yield after harvesting, dependent on the proportion of the catchment area harvested (Webb et al. 2012a). The increase persisted for at least three years, after which water yield returned to pre-harvest levels, before progressively declining in regenerating forest in some catchments by up to 20% of the pre-harvest water yield; this reduction was generally temporary and was related to changes in forest species composition, basal area and stocking rates. Overall, this research supports the conclusion of Bren et al. (2013) for the Murray–Darling Basin catchments, that it is possible to manage native forests to achieve an optimal level of wood and water production through a combination of carefully scheduled harvesting and fire management.

Declining rainfall in Western Australia is leading to a disconnection between groundwater and surface water systems in some jarrah forest catchments (Kinal and Stoneman 2012). Kinal and Stoneman (2011) found that vegetation thinning may be an appropriate management action to reduce the decline in, or increase the amount of, streamflow within the jarrah catchments. New provisions ‘silviculture for ecosystem health’ and ‘silviculture for water production’ were therefore incorporated into the *Forest Management Plan 2014–2023* (CCWA 2013), with the effectiveness of silviculture for water production to be measured as a key performance indicator.

In Queensland, there is a reasonable knowledge of impacts of activities on water quantity. However, the need for improved knowledge to assist managers with some risk factors has been identified. Clearing of woody vegetation (including forest) in Queensland increased from less than 100 thousand hectares in 2012–13 to 395 thousand hectares in 2015–16 (DSITI 2017). Queensland’s *State of the Environment report 2016*[209] reported no significant or widespread hydrological (water quantity) impacts, potentially because this clearing is dispersed across the state or does not occur in urban drinking-water catchments.

In South Australia, the water-quantity knowledge base is well-developed. Water Allocation Plans are developed and reviewed. A mid-term review of the condition of the water resources managed by the Lower Limestone Coast Prescribed Wells Area WAP is due in 2019. Groundwater levels are monitored by a network of observation wells, and an annual report on the condition of the resource is published by SA’s WaterConnect[210]. A project is underway to validate existing forest water models, review groundwater models, and undertake management scenarios for the Wattle Range in the Lower Limestone Coast area.

Plantations

Water use by forest plantations was considered a significant concern when substantial areas of new plantations were being established, which coincided with the ‘millennium drought’ (1997–2009; Ryan 2013). That concern decreased when plantation expansion ceased in 2008 and more typical rainfall patterns returned. Some of the relevant research is summarised here.

Development of large-scale plantation forestry was included as one of the land-use changes to be considered by the Intergovernmental Agreement on a National Water Initiative[211] (NWI), which provided a framework for considering the impacts of activities that could intercept water. As each jurisdiction in Australia attempts to implement the ‘interception’ requirements of the NWI, water balance models will be required to allow accurate assessments of plantation water use at a catchment scale (see Webb 2009).

209 www.ehp.qld.gov.au/state-of-the-environment/

210 www.waterconnect.sa.gov.au/Pages/Home.aspx

211 www.agriculture.gov.au/SiteCollectionDocuments/water/Intergovernmental-Agreement-on-a-national-water-initiative.pdf

Case study 4.2: The impact of strip thinning on water yield in Crotty Creek catchment, Central Highlands of Victoria

During the drought years of 1997 to 2009, inflows to catchments located high in the Yarra Ranges to the north-east of Melbourne decreased by 60% compared to historic values. In addition, bushfires reduced mean forest age in some catchments, potentially increasing forest water use for a period of time. The bushfires of 2003 and 2006–07 are expected to lead to a reduction in streamflow of 81 gigalitres per year from the pre-fire condition, due to the large-scale regeneration of alpine ash (*Eucalyptus delegatensis*) forests in some catchments. In addition, extrapolating across the catchments predicts that the 2009 bushfires will lead to a 3% reduction in water inflows to reservoirs over the next 50 years.

This situation has led to a need for changes in land-use or forest management aimed at reducing vegetation water use. One of many options to increase water supply is thinning the regenerating forests, which is a feasible approach for producing both water and wood (Ryan 2013). Thinning of regrowth forests from the age of 20–50 years can generally be undertaken at low cost, and sometimes even with a positive financial return, while simultaneously achieving water production objectives by increasing water yields. A low level of regeneration in the thinned areas will assist in maintaining on-going water yields.

This scenario was tested in a case study conducted in 1939 mountain ash (*E. regnans*) regrowth forests in the Crotty Creek catchment, in the Central Highlands of Victoria. Fifty percent of trees were removed in strips 35 metres wide.

Water yield within the thinned catchment is expected to be 40% greater than that from unthinned catchments, with the gain dropping to 16% within 11–15 years as the remaining trees begin to occupy the openings, and the understorey colonises the thinned sites.

Source: Ryan (2013).

Michael Ryan

Strip thinning trial, Crotty Creek, Central Highlands, Victoria.

CRITERION 4

4.1d

Accurate assessments of plantation water use at a catchment scale are required to develop water-balance models in plantations. Roberts et al. (2015) measured all components of plantation water use (canopy interception, soil evaporation, and transpiration) over a period of 3 years in a range of shining gum (*Eucalyptus nitens*) plantation sites in Tasmania, and developed a system to predict water use by plantations of this species from simple plantation inventory measurements. Plantation water use ranged between 500 and 1100 mm per year. Similar values were reported by Benyon and Doody (2014) for blue gum (*E. globulus*) plantations in South Australia. The impact on water availability of projected new plantations across the central north and north-east of Tasmania was modelled by Post et al. (2012). They found that runoff decreased in proportion to the increase in forest cover, but that, while decreases could be significant locally, decreases across the whole of the state would be less than 1%, both annually and for each season.

Zhang et al. (2011, 2012) evaluated plantation impacts on streamflow in 15 catchments across southern Australia using 20–35 years of continuous daily streamflow data and records of plantation management practices. There was a negative relationship between streamflow and plantation area in a catchment; an increase in catchment area occupied by plantations is likely to result in a reduction in streamflow compared to unforested controls. However, in Australia, forest plantations occupy only a small percentage of the catchments in which they occur (Downham and Gavran 2017). Because rainfall and hydrological factors are highly variable, it is difficult to detect the impact of plantations on water yields if the plantations occupy less than 15–20% of a catchment, and those proportions are only likely to be reached in small headwater catchments (Parsons et al. 2007). Zhang et al. (2011, 2012) also found that reductions in streamflow with plantation expansion were relatively uniform in catchments with perennial streamflow, and larger in catchments with ephemeral streamflow.

Barlow et al. (2013) used plantation data for the period 1975–2008 to model the impacts of forest plantations on streamflow in catchments in south-west Victoria, where significant expansion in plantation forestry has taken place. Introduction of plantation history into the model reduced predicted streamflow, but the impact of future plantation expansion on streamflow was predicted to vary across the landscape due to the variable effects of climate, soil properties, slope, and local hydrology.

O'Grady et al. (2012) modelled the impact on catchment water balance of the expansion of African mahogany (*Khaya senegalensis*) plantations in the Daly region of the Northern Territory. The model predicted that the projected plantation expansion would have a small impact on catchment water resources, mainly because the plantations have similar water use to the local native woodlands.


Greg Brave

Lake Eildon, Victoria.

Indicator 4.1e

Management of the risks to water quality in forests

Rationale

This indicator measures the extent to which the risk to water quality has been explicitly identified and addressed in forest management. Water quality is important for forest ecosystem health and water supply for human use.

Key points

- The risks that forest management activities pose to water quality are well understood, as are ways to mitigate those risks. The knowledge base about how to mitigate those risks improved during the reporting period.
- All states and territories have legislation, licences, codes of forest practice or best management practice manuals that mandate or guide practices to be carried out to maintain water quality. These instruments specify a range of factors that must be taken into account.
- These instruments also contain comprehensive requirements to assess the risk to water quality when planning wood harvesting operations. This reflects water quality being a major concern and focus of legislative and regulatory instruments.
- Compliance with mitigation measures to protect water quality is assessed in all states and territories, and is generally high for wood harvesting operations.

This indicator reports on the mitigation measures that are in place to protect water quality during forest management activities. The focus of reporting is on multiple-use public forest and public nature conservation reserves, with data generally not available for other tenures in most states and territories.

Water quality

Large areas of forest land supply water for human consumption, irrigated agriculture and industrial uses, with the forest soil and litter acting as a water store and filter that improves water quality. In general, forested catchments maintain water quantity and quality better than do catchments with other (non-forest) land uses. However, forest management activities and other disturbances such as fire can affect water quality unless planned, managed or mitigated appropriately, for example through measures such as road and track drainage, and maintaining vegetated streamside (riparian) buffer zones to reduce sediment movement into streams. Buffer zones also provide habitats and corridors for wildlife.

The four main types of disturbance that can affect water quality in forested areas are roading (road and track construction, maintenance and use), fire, wood harvesting, and recreation. The most common impact associated with forest management activities is the generation and movement of sediment into drainage lines and water bodies. However, a number of other factors can also reduce water quality. These include pollution from application of fertilisers and herbicides, elevated water temperature where streamside vegetation is cleared, and an increase in biological oxygen demand (the oxygen required for breakdown of organic matter by microorganisms).

Planned and unplanned fires have the potential to affect water quality through increased erosion risk coupled with more intense run-off after rain, which increases flows of sediment, nutrients and other determinants of water quality, such as trace elements. On the other hand, reforestation of land not carrying trees can reduce the adverse impacts of erosion, dryland salinity and waterlogging, by stabilising soils, lowering groundwater levels and decreasing the volume of saline groundwater entering streams or drainage lines.

Planning that aims to reduce the impact of recreation infrastructure and activities (such as roading and traffic) on water quality in reserves is implemented under regulations and under various pieces of state and territory legislation. Although recreation activities are often permitted in reserved forests, a relatively small proportion of the total area is used for access and other visitor infrastructure. Hence, most of the area of nature conservation reserves is not subject to such disturbance activities that might affect soil and water values. Bushfire is the major threat to water quality in reserved forests.

Instruments that address the risks to water quality

Legally binding instruments (such as Acts and licences) and non-legally binding regulatory instruments (such as codes of practice, guidelines and forest management plans) that include measures to protect water quality in catchments where forest management activities are undertaken are in place in all jurisdictions. Key mitigation measures include providing adequate and appropriate drainage for roads, trails and tracks, and protecting streamsides and drainage lines with vegetation buffers or filter strips that minimise soil movement into streams. However, the degree to which measures are prescribed in detail varies across jurisdictions.

The extent to which a regulatory framework requires the maintenance of water quality is rated according to the five categories used in previous SOFRs. These categories are detailed in Table 4.15, and range from Category 1 (for regulatory instruments that take into account many specified types of risk to water quality) to Category 5 (for instruments that do not mention the need to address risks to water quality). The extent to which the risks to water quality are addressed by a state or territory's legally binding and non-legally binding instruments is assessed against these categories in Table 4.16.

The data in Table 4.16 show that there are regulatory instruments in place to protect water quality in all jurisdictions and for all tenures for which this was reported. Most of these instruments rate highly for the number of factors that must be taken into account. This reflects water quality being a major concern and focus of legislative and regulatory instruments. The ratings shown for South Australia have been refined since those reported in SOFR 2013 based on further assessment of the regulatory instruments. Ratings have not changed or were not reported in SOFR 2013 for other jurisdictions.

The Australian Capital Territory has non-legally binding instruments for its public plantation estate (wood harvesting from native forests is not allowed in the Australian Capital Territory). These instruments seek to minimise the risk to water quality by considering streams, drainage lines, water bodies and slope, and by specifying appropriate management practices and streamside buffers. Plantation forestry in the Australian Capital Territory is based on *ACT Code of Forest Practice 2005* (Environment ACT 2005), which focuses

Box Creek falls, Kanangra Boyd Wilderness, NSW.

Table 4.15: Categories of the extent to which the regulatory framework requires the maintenance of water quality

Category	Category description
1	The regulatory instruments require the following components to be taken into account in addressing the risk to water quality from disturbance activities: • stream and drainage lines (e.g. including exclusion zones) • road drainage and stream crossings (e.g. cross-draining of log extraction tracks) • slope • sensitive aquatic habitat.
2	The instruments address most of the components listed in category 1, and those not addressed are associated with low risks to quality for the particular disturbance activity and geographic setting.
3	The instruments address most of the components listed in category 1 but do not specify all aspects or are limited in their application.
4	The instruments mention the need to address risks to water quality when conducting disturbance activities but do not specify the components listed in category 1.
5	The instruments do not mention the need to address risks to water quality.

Source: SOFR 2008.

Table 4.16: Assessed extent to which legally and non-legally binding regulatory instruments address the risk to water quality from forest operations, road and trail works, fire management and recreation

Instruments	Tenure	ACT	NSW	NT	QLD	SA	Tas.	Vic.	WA
Legally binding	Multiple-use public forests	3*	1	n.r.	2	4	1	1	4
	Public nature conservation reserves	n.r.	1	n.r.	n.r.	4	1–2	1	4
	Leasehold land	3*	n.r.	n.r.	2	4	n.r.	n.r.	n.r.
Non-legally binding	Multiple-use public forests	1	1	n.r.	2	1,4[a]	1	2	1,3[b]
	Public nature conservation reserves	1	1	n.r.	n.r.	n.a.	1–2	2	4
	Leasehold land	1	n.r.	n.r.	n.r.	1,4[a]	n.r.	n.r.	n.r.

n.r., not reported; n.a., not applicable

[a] Rating 1 for plantation operations; 4 for other activities.

[b] Rating 1 for native forest operations; 3 for plantation activities.

*, assessed by ABARES.

Note: The extent to which instruments address the risk to water quality varies between 1 (highest rating) and 5 (lowest rating): see Table 4.15. Each rating is an assessment by the relevant jurisdiction except where indicated.

Source: Data for Tas. from FPA (2017a). Data for NSW, Vic. and WA are from SOFR 2013 except that NSW multiple-use public forest data are from Forestry Corporation of NSW. ACT data from ACT Environment, Planning & Sustainable Development Directorate.

This table, together with other data for Indicator 4.1e, is available in Microsoft Excel via www.doi.org/10.25814/5bda9272d76d7

on protecting water quality during plantation activities. Minimum widths for riparian management zones are prescribed, and restrictions are in place for wet weather, and machinery use in drainage lines or depressions, steep slopes and erodible soils. A review of the code concluded that it provides a comprehensive approach to protecting water quality in the Australian Capital Territory (Smethurst et al. 2012). The *ACT Strategic Bushfire Management Plan 2014–2019*[212] (ESA 2014) considers impacts of high-intensity unplanned landscape-scale fires and suppression activities on the water quality of water catchments. Under the *Nature Conservation Act 2014*, management plans are prepared in the Australian Capital Territory for nature conservation reserves; these plans address the risk to water quality from disturbance activities.

New South Wales has legally binding instruments that address risks to water quality for operations in both the native forest and plantation estates. In the New South Wales public native forest estate, Integrated Forestry Operations Approvals contain requirements for assessing and managing risks to soil erosion and water pollution. The approvals contain the terms of a licence under the *Protection of the Environment Operations Act 1997* (NSW) (the 'environment protection licence'). The purpose of the environment protection licence is to control the carrying out of forest operations, including harvesting, thinning and ancillary road construction, for the purpose of regulating water pollution resulting from any such operation.

For the private native forest estate in New South Wales, the *Private Native Forestry Code of Practice 2013* contains provisions for protecting catchment water values. Mitigation measures include establishing riparian exclusion and buffer zones, snig tracks and extraction tracks, appropriate drainage systems and stream crossings, and complying with wet-weather limitations for snigging, log landing and portable mill operations.

Softwood and hardwood plantations in New South Wales are authorised under the *Plantation and Reafforestation (Code) Regulation 2001*, which prescribes standards and regulations relating to the protection of soil and water. Prescriptions

[212] esa.act.gov.au/wp-content/uploads/The-ACT-Strategic-Bushfire-Management-Plan.pdf

cover buffer zones, slope limits, wet weather provisions, and road, track and stream crossing and drainage location, design and construction, maintenance and management during operations.

The *Bush Fire Environmental Assessment Code for New South Wales 2006*[213] provides standards to prevent soil erosion and instability, and standards for the protection of riparian buffers, for bushfire hazard reduction works.

In the Northern Territory, the *Codes of Practice for Forestry Plantations 2004* (DRPI 2004) specifies goals related to the protection of water quality. This code is being reviewed. Management plans for conservation reserves in the Northern Territory also include provisions to protect water values. The Northern Territory also contains a number of stream-gauging stations that collect data on water quality.

In Queensland, the *Forestry Act 1959* requires State forests to be used and managed in a manner to protect water of sufficient quality; the *Environmental Protection Act 1994* and the *Water Act 2000* are the main pieces of legislation under which waters are protected while supporting ecologically sustainable development, but they make no special reference to forestry. Risks to water quality from wood production are managed largely through codes of practice. In 2013, the Queensland Government introduced self-assessable vegetation clearing codes (renamed in 2017 as 'accepted development vegetation clearing codes') in accordance with the *Vegetation Management Act 1999*. For freehold land, *Managing a native forest practice – A self-assessable vegetation clearing code 2014*[214] (DNRM 2014) requires harvesting or removal of vegetation to be carried out in a way that maintains water quality values. The code specifies buffer and filter zone requirements for wetlands and different stream orders.

The Code of Practice for Native Forest Timber Production on the Queensland Parks and Wildlife Service (QPWS) Forest Estate 2014[215] (DNPRSR 2014) is the other legally binding code protecting water quality in Queensland. It prescribes operational standards for timber harvesting, so as to achieve a high level of protection of environmental values, including water quality. Water quality risks from wood production plantations on private land are managed by requirements of the *Timber Plantation Operations Code of Practice for Queensland 2015*[216] (Timber Queensland 2015). Water quality values are maintained in plantations by minimising disturbance to waterways, planning and designing fill disposal areas and embankments, and restricting heavy vehicle traffic during persistent wet or dry weather. With only minor exceptions, all native forest wood production managed by Queensland is certified to the Australian Standard for Sustainable Forest Management[217], which requires management of risks to water quality.

South Australia has legally and non-legally binding instruments for its plantation estate. Non-legally binding 'Industry Best Practice' described in the *Guidelines for Plantation Forestry in South Australia 2009*[218] seeks to minimise the risk to water quality by considering streams, drainage lines, water bodies and slope, and by specifying appropriate management practices and streamside buffers. Following a fire, consideration of water quality protection is necessary in regards to subsequent rain events. *The Environment Protection (Water Quality) Policy 2015* under the *Environment Protection Act 1993*, provides the structure for legally binding regulation and management of water quality in South Australian inland surface waters, marine waters and ground waters. The *Forestry Regulations 2013* made under the *Forestry Act 1950* place controls on activities in reserves to protect water values.

In Tasmania, the risk to water quality is assessed for forest management activities under the *Forest Practices Act 1985*, irrespective of the land tenure or forest type. The *Forest Practices Code 2015*[219] (FPA 2015b) provides guidelines and standards to conduct forest practices for the protection of all watercourses, by minimising disturbance to watercourse channels and riparian (streamside) zones, and by reducing soil disturbance in and near watercourses. The code also meets statutory objectives for water management and water quality standards for human use, by minimising the risk of sedimentation and pollution from forest management activities. The code allows harvesting of plantations that are in streamside reserves and that are within 10 metres of Class 4 watercourses on low to moderate-high erodibility class soils, but does not permit harvesting within 10 metres of a Class 1, 2 or 3 watercourse in plantations established after 1 January 2001. There are supporting manuals such as the *Guidelines for the Protection of Class 4 Streams* (FPA 2011a)[220].

In Victoria, the *Victorian Waterway Management Strategy 2013*[221] (DEPI 2013) sets regional planning arrangements for water quality management and objectives for water quality monitoring in relation to forestry, catchment development, recreational activities, and extreme events such as bushfire and flood.

The *Code of Practice for Timber Production 2014*[222] (DEPI 2014b) applies to all timber production on state forests, private native forests and plantations in Victoria. It outlines specific requirements to maintain or improve water quality and river health by protecting waterways and aquatic and riparian habitat from disturbance, and to prevent soil sediments and other pollutants from entering waterways. Mitigation measures outlined in the code include the establishment of buffer and filter strips, the installation

213 www.rfs.nsw.gov.au/__data/assets/pdf_file/0014/24332/Bush-Fire-Environmental-Assessment-Code.pdf

214 publications.qld.gov.au/dataset/self-assessable-vegetation-clearing-codes/resource/a73f5b44-008c-4f92-8644-f92e6caf6592

215 www.npsr.qld.gov.au/managing/pdf/timber-production-qpws-estate.pdf

216 www.timberqueensland.com.au/Docs/Growing-Processing/Timber-Plantation-Operations-Code-of-Practice-Version-1.pdf

217 www.responsiblewood.org.au/

218 www.pir.sa.gov.au/__data/assets/pdf_file/0011/254765/guidelines_for_plantation_forestry_in_sa_web.pdf

219 www.fpa.tas.gov.au/fpa_services/planning_assistance/forest_practices_code

220 www.fpa.tas.gov.au/__data/assets/pdf_file/0014/110246/Guidelines_for_the_protection_of_Class_4_streams.pdf

221 www.water.vic.gov.au/__data/assets/pdf_file/0019/52543/VWMS-Summary_FINAL_WEB-ready.pdf

222 www.forestsandreserves.vic.gov.au/__data/assets/pdf_file/0016/29311/Code-of-Practice-for-Timber-Production-2014.pdf

of appropriate drainage systems and stream crossings, restrictions on disturbances on steep slopes, the use of silt traps alongside roads, and road closures in wet weather. The *Code of Practice for Bushfire Management on Public Land 2012*[223] (DSE 2012) addresses the potential impacts of fire on water quality, and prescribes measures that minimize the impact of bushfire management activities on the physical, chemical and biological qualities of streams and wetlands.

In Western Australia, the *Forest Management Plan 2014–2023* (CCWA 2013) covers all the main wood production areas in the state's south-west, and emphasises the protection of water values. The plan includes activities to manage the risk of stream salinity as a result of rising groundwater tables, and to manage the risk of surface water turbidity of as a result of erosion or contamination with bacteria, hydrocarbons or pesticides. The *Guidelines for Protection of the Values of Informal Reserves and Fauna Habitat Zones*[224] (DEC 2009a) exclude timber harvesting from informal reserves along streams and rivers to protect water quality. The *Code of Practice for Fire Management 2008* (DEC 2008)[225] guides land managers to balance the impacts of fire management actions on water quality. Risks to water quality through erosion, waterlogging, sedimentation and contamination are managed according to the *Soil and Water Conservation Guidelines 2009* (DEC 2009c). Design, construction and maintenance of unsealed roads to minimise sediments are carried out according to the *Unsealed Roads Manual* of the Australian Road Research Board[226]. Use of certain products, practices or activities is limited or controlled in 'Reservoir Protection Zones'. Drinking water sources are protected by restricting the type of recreational activities allowed, and by controlling pesticide use in these areas.

Assessment of the risk to water quality

Water quality is monitored at many sites across the states and territories to determine whether water for different uses, including drinking water, meets the required standards, but not all these sites are located in forests. It is also not always possible to identify the causes of changes in water quality at a monitoring point, because of the need to consider all activities, land-uses and vegetation types (forest and non-forest) in the catchment above that point, and because it is difficult to measure the many factors that determine the spatial and temporal impacts of forest activities. Assessment of the risk of forest management activities to water quality is generally based on field monitoring of water at a limited number of locations, and comparing water quality parameters against recommended thresholds set out in various guidelines and standards.

The extent to which risks to water quality are assessed in planning processes is rated according to the four categories used in previous SOFRs. These categories are detailed in Table 4.17, and range from Category 1 (for a risk assessment system that takes account of many specific types of risk to water quality) to Category 4 (for a risk assessment system that is ad hoc or does not take into account any of the above risks to water quality).

Table 4.18 shows the proportion of disturbance activities planned in multiple-use public forest in 2011–16, assessed for risks to water quality against these categories, by jurisdiction. In the Australian Capital Territory, New South Wales, Queensland, South Australia, Tasmania, Victoria and Western Australia, assessments of the potential risks to water quality are conducted for forest activities and roading operations in multiple-use public native forests and plantations. However, the assessments have varying levels of robustness. In the states and territories for which data were available, almost all the proposed activities were assessed for risks to water quality.

Table 4.17: Categories of the extent to which risks to water quality are assessed in planning processes

Category	Category description
1	The water quality risk assessment system comprehensively takes account of all the following factors: • stream and drainage lines (e.g. including exclusion zones) • road drainage and stream crossings (e.g. cross-draining of log extraction tracks) • slope • sensitive aquatic habitat.
2	The water quality risk assessment system takes into account most of the components listed in category 1, and those not addressed are associated with low risks to water quality for the particular disturbance activity and geographic setting.
3	The water quality risk assessment system takes into account some of the factors listed in category 1 or only partially accounts for these factors.
4	The water quality risk assessment system is ad hoc and/or does not take into account any of the factors listed in category 1.

Source: SOFR 2008.

[223] www.ffm.vic.gov.au/__data/assets/pdf_file/0006/21300/Code-of-Practice-for-Bushfire-Management-on-Public-Land.pdf

[224] library.dbca.wa.gov.au/static/FullTextFiles/069674.pdf

[225] www.dpaw.wa.gov.au/images/documents/fire/fms-code-of-practice.pdf

[226] www.arrb.com.au/manual-guides

Table 4.18: Proportion of disturbance activities in multiple-use public forest assessed for risk to water quality, and assessed category

Disturbance activity	Metric	ACT	NSW	NT	Qld	SA	Tas.	Vic.	WA
Native forest harvesting and silviculture	Assessed for risk to water quality (%)	n.a.	100	n.a.	100	n.a.	100	n.r.	100
	Assessed category[a]	n.a.	1	n.a.	2	n.a.	1	1	2
Plantation operations	Assessed for risk to water quality (%)	100	100	n.a.	n.r.	100	100	n.r.	100
	Assessed category[a]	1	1	n.a.	n.r.	1	1	1	3
Road construction and maintenance	Assessed for risk to water quality (%)	100	100	n.a.	n.r.	100	100	n.r.	100
	Assessed category[a]	2	2	n.a.	n.r.	2	1 (MUF) 2 (NCR, OCL, Pv[b])	1	2
Fire management	Assessed for risk to water quality (%)	100	100	n.a.	n.r.	100	100	n.r.	n.r.
	Assessed category[a]	2	2	n.a.	n.r.	2	1 (MUF) 2 (NCR, OCL, Pv[b])	1	n.r.

n.r., not reported; n.a., not applicable. MUF, multiple-use public forest; NCR, nature conservation reserve; OCL, other Crown lands; Pv, private.

[a] The extent to which risks to water quality are assessed in planning processes varies between 1 (highest rating) and 4 (lowest rating): see Table 4.17. Areas harvested are reported in Indicator 2.1a and areas burned in Indicator 3.1b.

[b] Additional information for other tenures provided by Tasmanian agencies.

Source: Data for ACT, Queensland, Tasmania and Western Australia are from SOFR 2013. Data for NSW are from Forestry Corporation of NSW and the Department of Primary Industries Plantation Assessment Unit. NT has no multiple-use public forests.

This table, together with other data for Indicator 4.1e, is available in Microsoft Excel via www.doi.org/10.25814/5bda9272d76d7

The data in Table 4.18 show that there are regulatory instruments in place to protect water quality in all jurisdictions and for all activities for which this was reported. These instruments rate highly for the number of factors that must be taken into account. This reflects water quality being a major concern and focus of legislative and regulatory instruments.

Water quality knowledge base

The knowledge base relating to forest management activities and water quality is reasonably strong in all jurisdictions, and is particularly strong in regards to soil erosion and related mitigation measures. Research continues on suspended sediment export, and implications of bushfires for the quality of water available to downstream users.

The Forestry Corporation of New South Wales monitors water quality in native forests and plantations, across various intensities of harvesting and road activities, and across soil types, to investigate the potential impacts of forest activities on stream sediment and downstream water quality. For example, a replicated catchment experiment in native eucalypt forest in Kangaroo River State Forest, near Coffs Harbour, showed that selective harvesting using best management practices did not affect suspended sediment yields in two of three treated catchments; in the third catchment, an increase in event sediment loads and concentration, at the time of harvesting, subsided within 12 months (Webb et al. 2012b; see also Case study 4.1). Walsh (2017) assessed the impact of harvesting in small head-water (zero-order) catchments and in 10-metre buffer strips on water turbidity and sediments in the Brooman State Forest, near Batemans Bay. Harvesting increased runoff and sediment levels but not mean turbidity or sediment concentration, and sediment levels dissipated over 18 months where there was no harvesting in the buffers.

Webb and Hanson (2013), working in coastal catchments on the mid-north coast of NSW, showed that preventing or reducing road-to-stream drainage connectivity is essential for reducing the impacts of roads on water quality.

In Victoria, knowledge of the risk posed by post-fire debris flows and other hydro-geomorphic changes in different locations in the landscape has improved following the 2009 bushfires in Victoria (Jones et al. 2014; Nyman et al. 2015; Langhans et al. 2016). Post-fire debris flows are major sources of fine suspended sediment, and a risk to water quality in forest catchments, as sediment flow rates can be 2–3 orders of magnitude higher than annual background erosion rates (Cawson et al. 2012; McInnes-Clarke et al. 2014; Nyman et al. 2011, 2015; Sheridan et al. 2015). Susceptibility to debris flow varied with slope, burn severity and aridity (Nyman et al. 2015). The effects of prescribed burning on surface runoff, erosion and water quality, however, were shown to be minimal and to last only for a short period (3 months to 1 year) (Cawson et al. 2012), due to the general low fire intensity and burn patchiness. The most significant runoff, erosion and water quality impacts of prescribed burns occurred when these were followed by an intense storm. Sheridan et al. (2015) showed that higher aridity (a function of long-term mean precipitation and net radiation) is associated with lower post-fire infiltration capacities, increasing the chance of surface runoff and debris flows.

In South Australia, there is reasonable knowledge on the impacts of forest management activities on water quality. The Environment Protection Authority (EPA) monitors the water quality of waterways, with the data used to produce annual Aquatic Ecosystem Condition Reports.

One of 17 monthly sampling sites established in 1998 for long-term monitoring of water quality at the Warra Long-term Ecological Research site, southern Tasmania.

Western Australia has long-term datasets on the response of streamflow, stream salinity and groundwater to wood harvesting in the south-west region. These datasets underpin silvicultural specifications, stream zone dimensions, and rehabilitation practices. The risk to water quality due to salinity has reduced due to significant declines in annual rainfall and dropping groundwater levels. In the *Forest Management Plan 2014–2023* (CCWA 2013), the Swan and South West regions and parts of the Warren Region[227] have therefore been reclassified as 'low salt sensitivity', with phased harvesting now only required in those parts of the Warren Region classified as 'moderate salt sensitivity' (DPaW 2016a).

Tasmania has well-developed knowledge on water quality in multiple-use public forests and some private forest areas. The Department of Primary Industries, Parks, Water and Environment manages the Water Quality Database, with water quality routinely monitored at 86 stream gauging sites, with spot sampling of turbidity, dissolved oxygen, pH, electrical conductivity and water temperature (FPA 2017a). Streams within catchments with a history of forest management operations showed no significant impacts on stream health, and possessed similar macroinvertebrate communities to those without forest management operations. There were no records of triazine contamination of streams from forest plantations in the reporting period (FPA 2017a). In 2015, a review of the Giant Freshwater Lobster Recovery Plan noted sedimentation arising from clearing in headwater streams as a key threat to juvenile lobsters, and recommended research on optimal headwater streamside buffers to reduce downstream sediment flows (DoEE 2015). Magierowski et al. (2012) showed that freshwater macroinvertebrate biodiversity was most significantly affected by grazing land use in catchments and by riparian vegetation condition, with minimal impacts from upstream production forest management. Case study 4.3 describes research into this issue.

[227] Administrative regions within the South-West Forest Region covered by the FMP 2014–2023.

Table 4.19: Compliance with environmental protection requirements on Crown and private land, NSW, 2011–12 to 2015–16

	2011–12	2012–13	2013–14	2014–15	2015–16
Number of EPA audits and investigations undertaken on Crown land	39	94	66	55	37
Number of non-compliances with EPL detected on Crown land	414	127	15	10	29
Number of EPA audits and inspections undertaken on private land	n.r.	258	148	32	n.a.
Number of corrective action requests issues for private land	n.r.	59	37	5	n.a.

n.r., not reported; n.a., not applicable

Notes: EPL, environment protection licences. Non-compliances include administrative errors, as well as matters relating to soil erosion and water quality. Corrective action requests include 'show cause' notices, 'clean-up' notices, and official cautions.

Source: Annual reports, Implementation of NSW Forest Agreements and Integrated Forestry Operations Approvals, EPA NSW[228].

This table, together with other data for Indicator 4.1e, is available in Microsoft Excel via www.doi.org/10.25814/5bda9272d76d7

Compliance with water quality measures

Assessing compliance with requirements for the protection of water quality is related to the process of assessing compliance with measures to prevent soil erosion (see Indicator 4.1b). All states and territories audit compliance with requirements for the protection of water quality.

In New South Wales, the Environment Protection Authority (EPA) has developed risk-based compliance strategies to guide regulation of forest management operations in native forests on both private and public lands. The EPA audits and assesses compliance against the compliance priorities, which for example in 2015–16 were protection of water quality and in-stream habitat degradation resulting from inadequate road and snig track crossing location, design, construction, operation and maintenance, and protection of vegetation adjoining streams and drainage features to maintain water quality and riparian habitat (EPA 2016)[229]. The results of audits and investigations of compliance with environmental protection requirements on Crown and private land in New South Wales are shown in Table 4.19. The data show performance improvements across the reporting period.

In Queensland, the Australian Standard for Sustainable Forest Management certification audits are conducted for native forest harvesting authorised under the *Forestry Act 1959* as a component of Department of Agriculture and Fisheries (DAF) forest management certification. DAF and the Department of National Parks, Sport and Recreation also audit native forest harvesting operations. No significant non-compliance or breach for native forest activities authorised under the *Forestry Act 1959* was reported during the 2011–16 reporting period.

In South Australia, there were no reported completed prosecutions or civil penalties under the *Environment Protection Act* relating to forest management during the 2011–16 reporting period[230]. The *Natural Resources Management Act 2004* and the *Environment Protection (Water Quality) Policy 2015* also contain penalty provisions for regulatory breaches. The majority of forest plantation managers in South Australia have independently audited systems for sustainable forest and land management. Short-term and long-term water monitoring by ForestrySA in the Mount Lofty Ranges provided no significant detections of any herbicide used by ForestrySA for its forest management operations; herbicides not used by ForestrySA were found in some samples at low levels and are believed to have originated from upstream sites not managed by ForestrySA (ForestrySA/PIRSA 2015).

In Tasmania, forest operations managed by Forestry Tasmania[231] are regulated by the Forest Practices Authority, with independent annual audits. During 2015–16, the Forest Practices Authority audit examined 19 Forest Practices Plans developed by Forestry Tasmania; compliance was rated at the highest level obtainable on all 11 criteria examined. No breaches were recorded related to protecting water values (Forestry Tasmania 2016a). Furthermore, in 2014–15 none of the water samples taken from streams after chemical application within production forests contained detectable chemicals (Forestry Tasmania 2016b), consistent with adherence to guidelines and Codes of Practice requirements during aerial and ground-based chemical applications.

A case study from northern Tasmania showed that harvesting a 20-year-old shining gum (*Eucalyptus nitens*) pulpwood plantation from a streamside management zone using management practices from the Code of Forest Practice did not affect water quality or stream turbidity (Neary et al. 2010).

In Victoria, river health is monitored at eight-year intervals through the Index of Stream Condition (ISC), which measures 1,200 river reaches representing 29,000 kilometres of major rivers and tributaries. ISC data from 2013 showed that 23% of the total river length in Victoria was in good to excellent condition, but 45% of the river length within forested catchments was in good to excellent condition. River condition was better in eastern Victoria than in western Victoria, and better in public forests than private forests, with results corresponding closely with the extent of forest cover in each catchment (DEPI 2014a[232]).

[228] www.epa.nsw.gov.au/your-environment/native-forestry/native-forestry-nsw-overview/regulating-native-forestry/native-forestry-compliance-update

[229] www.epa.nsw.gov.au/your-environment/native-forestry/integrated-forestry-operations-approvals/annual-reports

[230] www.epa.sa.gov.au/data_and_publications/completed_prosecutions_and_civil_penalties

[231] From July 2017, Sustainable Timbers Tasmania.

[232] www.forestsandreserves.vic.gov.au/__data/assets/pdf_file/0019/52705/VIC_SFR2013_lowres.pdf

Case study 4.3: Effect of upstream forest management on stream ecosystem condition in middle catchment reaches in Tasmania

Davies et al. (2016) studied the impact of upstream forestry operations on downstream mid-catchment stream reaches in Tasmania. Downstream study sites were situated in fourth-order stream reaches[234] with no adjacent forestry activity, and changes in stream ecosystem condition were taken to represent the accumulated effect of management activity in the upstream catchment. Harvesting operations occurred from before 1987 to 2007, but mostly occurred before 1991; sites harvested before 1987 were harvested before formal adoption of the Tasmanian Forest Practices Code under the *Tasmanian Forest Practices Act (1985)*. Plantations were either hardwood (generally shining gum, *Eucalyptus nitens*) or softwood (generally radiata pine, *Pinus radiata*), established on former native forest sites.

Impacts of upper-catchment forestry operations were detected in mid-catchment river reaches up to 10 km downstream (Table 4.20). Macroinvertebrate community composition, measured as the proportion of three aquatic insect families, was affected by unsealed roads and/or (in four out of seven catchments) by clearfell, burn and sow harvesting operations in native forests. Variation in the area proportion of unsealed roads explained 75% of the variance in the responses of these aquatic insect taxa. Based on a combination of field evidence and independent experimental evidence, the mechanism was deduced to involve deposition of fine sediments. Populations of juvenile giant freshwater crayfish (*Astacopsis gouldi*) declined marginally with an increasing proportion of upstream land subject to clearfell operations.

Plantation forestry operations had less effect on sediment levels and no impact on downstream macroinvertebrates. This may be because catchments containing plantations had a smaller area of unsealed roads, and were generally on less erodible (basaltic) soils compared to the more erodible soils in catchments containing native forest harvested by clearfell techniques.

The Forest Practices Code protects streams of order 2–4 by requiring riparian buffer zones of at least 20 metres in width. Additionally, operational guidelines adopted since 2004 include buffer zones around headwater streams where there is significant erosion risk. Other management prescriptions to reduce impacts include increased engineering and maintenance standards for unsealed roads to reduce sediment movement into streams, including for roads outside the specific areas covered by forest practices plans; measures to increase interception of sediment following rainfall and runoff after broad-scale burning; and area limits for clearfell operations. These could be provided in a catchment-level or estate-level approach to forest management, using long-term forest practices plans that vary with geological and soil context and that complement established coupe-scale prescriptions.

Adapted from Davies et al. (2016)

Table 4.20: Response of stream conditions parameters to forest harvesting, roading and plantation area

Stream condition parameter	Response of parameter to forestry operations: Response to proportion of catchment area subject to clearfell operations	Response to proportion of area under unsealed roads in catchments with clearfell operations	Response to proportion of area under plantation
Proportion of aquatic EPT insect taxa[a]	In four of seven catchments, declines as area proportion of CBS increases above 40%	Declines when area of unsealed roads is above 2%	Not affected
Benthic algal cover or biomass	Not affected	No data	Not affected
Organic detritus	Increases as area proportion of CBS increases above 40%	No data	Not affected
Silt	Increases as area proportion of CBS increases above 40%	No data	Increases when area proportion of plantations is above 80%
Sand	Increases as area proportion of CBS increases above 40%	No data	Not affected
Fine sediment	Increases as area proportion of CBS increases	Increases when area of unsealed roads above 2%	Not affected
Giant freshwater crayfish (*Astacopsis gouldi*)	Declines marginally as increasing area proportion of clearfell increases	No data	No data
Stream channel and bank condition[b]	Not affected	No data	Not affected

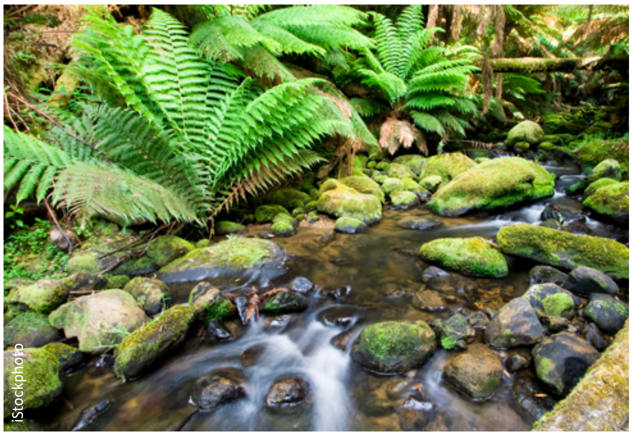
Note: 'CBS' – clearfell, burn and sow.

[a] EPT taxa: the aquatic insect orders Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies), which have a high species diversity in Tasmania and are sensitive to anthropogenic impacts.

[b] Dominant bed material type, bank shape, area of bank erosion and quantity of large wood.

[234] First-order streams are headwater streams in Tasmania.

In Western Australia, the Department of Parks and Wildlife[233] oversees approvals, monitoring and compliance of disturbance activities in state forests and timber reserves, with audits of forest management activities against the requirements of the *Forest Management Plan 2014–2023* (CCWA 2013). In 2015, the then Department of Parks and Wildlife issued 13 notification reports and 3 works improvement notices related to soil and water (DPaW 2016c). Informal river and stream reserve zones for water protection are of width 60–400 metres depending on stream order; assessment of these zones in harvesting coupes showed 99.9% compliance, with a single minor incident involving machine activity across a reserve boundary.



Great Otway National Park, Victoria.

[233] From July 2017, the Department of Biodiversity, Conservation and Attractions.

Criterion 5

Maintenance of forest contribution to global carbon cycles

Radiata pine plantation.

Criterion 5 Maintenance of forest contribution to global carbon cycles

This criterion, which comprises only one indicator, Indicator 5.1a, reports on the amount of carbon stored in Australia's forests, and the effects of natural disturbance, forest management and forest land-use change on forest carbon dynamics. The indicator also reports the amount of carbon stored in wood products. Taken together, these parameters comprise the role of Australia's forests in the carbon cycle.

Internationally, concern about the effects of increased atmospheric concentrations of greenhouse gases, most importantly carbon dioxide (CO_2), on the climate has focused attention on the carbon cycle and human-induced changes to it. Forests are a major component of the global carbon cycle because of the large amounts of carbon stored in forests, the sequestration of carbon by growing forests, the storage of carbon in wood and wood products in service and (at the end of service life) in landfill, and the potential reduction in emissions when wood is used instead of fossil fuels as an energy source or to replace more energy-intensive structural materials.

The role of forests and forest management in the carbon cycle is determined by their net effect across the landscape and the economy over long time periods, rather than by short-term, local changes at individual forest sites. National forest carbon dynamics thus need to be considered over long time frames (more than a decade) to properly assess the contribution of Australia's forests and forest management to the global carbon cycle, and sustainable management of forest carbon stocks.

The indicator presents data from the carbon stock account for Australia's forests for the period 2001 to 2016. These data are derived from the land use, land-use change and forestry component of Australia's National Greenhouse Gas Inventory, and cover native forests not used for wood production, native forests used for wood production, commercial plantations, trees planted for environmental purposes, and carbon stored in timber and wood-based products. The data also cover the range of activities and events, including wildfire, regrowth, and the harvest and growth of plantations, that cause changes in carbon stocks over time.

This icon indicates data, maps or graphics from *Australia's State of the Forests Report 2018* that are available for electronic download. Data used in figures and tables in this criterion, together with higher resolution versions of maps, are available via www.doi.org/10.25814/5bda94dad76d8 and www.doi.org/10.25814/5be3bc4321162.

Tuan State Forest, Queensland.

Indicator 5.1a

Contribution of forest ecosystems and forest industries to the global greenhouse gas balance

Rationale

This indicator assesses the contribution of Australian forests to the global carbon cycle. Forest management can have a significant positive or negative impact on the global carbon cycle.

Key points

- A total stock of 21,949 million tonnes of carbon (Mt C) was stored in Australia's forests at the end of June 2016.
  - Of this, 85% was stored in non-production native forests, 14% in production native forests and 1.2% in plantations.
  - An additional 94 Mt C was present in wood and wood products in use, and 50 Mt C in wood and wood products in landfill.
  - In total, 22,093 Mt C was held in Australia's forests plus harvested wood products at the end of June 2016.
- Over the period 2011–16, forest carbon stocks increased by 129 Mt C.
  - This increase in carbon stocks was due to a combination of recovery from past clearing, additional growth of plantations, reduced clearing of native forest, expansion of the area of native forests, and recovery from bushfire and drought.
  - Over the period 2001–16, carbon stocks in forests have varied by no more than 0.7% of the total stock.
- Of the 21,949 Mt C stored in forests in 2016, 7,838 Mt C (36%) was in above-ground biomass and 14,110 Mt C (64%) was in below-ground biomass.
  - Above-ground forest biomass comprises living organisms, deadwood and litter, while below-ground forest biomass comprises living roots and soil.
- In the period 2001–16, transfers of carbon from Australian forests to harvested wood products were approximately 104 Mt C.
  - After including changes due to imports and exports, disposal and decay, carbon stocks in the pool of wood and wood products in use in Australia showed a net increase of 17 Mt C in the period 2001–16, while carbon stocks in the pool of wood and wood products in landfill in Australia showed a net increase of 9 Mt C.
  - The 25 Mt increase in carbon stocks in wood products over the period 2001–16 was greater than the 12 Mt decrease in carbon stocks in forests over this period.
- Overall, during the period 2011–16 Australia's land sector contributed net sequestration of an amount that offset 3.5% of total human-induced greenhouse gas emissions for this period from all sectors. This was primarily due to the gains through forest growth and forest management practices exceeding the losses from activities such as land clearing.
- Carbon stocks and stock changes presented in this indicator were calculated from Australia's National Greenhouse Accounts as reported in Australia's *National Inventory Report 2016*. They relate to the 139 million hectares of forest used for Australia's greenhouse gas accounting.
  - The forest carbon stock reported for various time-periods in SOFR 2018 is substantially higher than the forest carbon stock reported for these time-periods in SOFR 2013. This results from a reassessment of the forest area used for Australia's National Greenhouse Accounts, an increase in the model parameter for maximum biomass per hectare, and an increase in modelled carbon stocks in non-production forests.

International concern about the effects on climate of increased atmospheric concentrations of greenhouse gases such as carbon dioxide (CO_2) has focused attention on the global carbon cycle[235]. Forests are an important component of the global carbon cycle, and maintenance of forest carbon stocks is a key indicator of sustainable forest management. This indicator quantifies and reports on the carbon balance of Australia's forests, and how this is affected by their stewardship, management and use. The indicator also considers how the forestry sector contributes to the global carbon cycle through storage of carbon in wood and wood products in use and, at the end of useful service life, in landfill[236].

Forests absorb CO_2 from the atmosphere during photosynthesis and store carbon in biomass, which following tree death and decay is converted into deadwood, litter and soil organic matter. In turn, CO_2 is released from forests by respiration, and by the decay and combustion of forest material. The rate at which carbon is sequestered into woody tissue is highest in the early-age to mid-age growth phases of trees (regenerating and regrowth forests). In mature and older forests, net exchange of CO_2 with the atmosphere is usually low, as slower growth is balanced by death and decay. Bushfires[237], like any natural event, will generally have a transient impact on forest ecosystems as standing trees and forest debris are burned and subsequently recover, with recovery periods varying from a few years to many decades depending on the forest type and fire intensity. The non-CO_2 gases released in these events are out of the scope of this indicator.

The amount of carbon stored on Australia's forested lands can change over time because of:

- the natural developmental or successional dynamics of forests
- bushfire, drought, dieback and regrowth
- human activities such as wood harvesting
- increases in forest area due to forest expansion, reforestation[238], or establishment of commercial plantations and environmental plantings
- decreases in forest area due to clearing for agriculture, urban expansion or other land uses
- variation in climatic factors such as temperature and rainfall.

The role of forests in the carbon cycle is best interpreted at a macro-scale. This is because the atmosphere is influenced by the net effect of forest biology and forest management across landscapes, the nation and the economy, rather than local changes at individual forest sites.

Once wood has left the forest, its role in the carbon cycle is determined by factors such as:

- energy used and emissions produced during wood processing and transport
- change in the stocks of wood and wood products in use and in landfill
- reductions in net greenhouse gas emissions due to the use of wood for local energy generation displacing the use of fossil fuels, and due to the use of wood for structural purposes in place of more energy-intensive structural materials.

Forest carbon accounting

Australia's National Greenhouse Accounts during the SOFR 2018 reporting period have been maintained by the Department of the Environment and Energy[239] (DoEE) and are available online[240]; they are published annually in Australia's *National Inventory Reports*[241]. National inventory reports are annual reports of anthropogenic emissions by sources, and removals by sinks, of greenhouse gases not otherwise managed through the Montreal Protocol[242]. These accounts constitute Australia's National Greenhouse Gas Inventory, and are prepared according to the rules specified under the United Nations Framework Convention on Climate Change and the Kyoto Protocol.

In Australia, the National Greenhouse Gas Inventory (DoEE 2018a) has been developed to provide emissions estimates covering the entire nation, including Australia's extensive land sector. The land use, land-use change and forestry (LULUCF) component of Australia's National Greenhouse Gas Inventory includes 139 million hectares of forests, as assessed by DoEE as at the end of June 2016[243] (see Figure 5.1). During the period 2011–16, this forest area contributed to the net sequestration by the land sector of an amount that offsets 3.5% of total human-induced greenhouse gas emissions for this period from all sectors (DoEE 2018a,b), primarily due to the gains from regrowth and forest management practices exceeding the losses from activities such as land clearing.

DoEE has monitored forest cover using national coverages of Landsat satellite data over 25 time periods from 1972 to (most recently) 2016, including annually from 2004, for the National Greenhouse Gas Inventory. The Landsat data include the Landsat MSS, ETM+ and OLI data products[244]. The imagery is assembled as maps, and used to detect fine-scale changes in forest cover at a resolution of 25 metres by 25 metres. The changes are analysed to identify whether they

235 While greenhouse gases other than CO_2 are included in national greenhouse accounts, the interest for this indicator is the changing stores of carbon in forests and forest products, the gains and losses of which result in sequestration and emission of CO_2.

236 The National Greenhouse Gas Inventory, published by the Department of the Environment and Energy, became consistent with this scope in 2016.

237 Bushfire, wildfire and unplanned fire are used interchangeably in this report: see Indicator 3.1b.

238 Reforestation is re-establishment of native forest through human intervention on non-forest land that previously carried forest, whereas forest expansion is establishment or re-establishment of native forest on non-forest land without human intervention.

239 Until July 2016, the Department of the Environment.

240 See ageis.climatechange.gov.au/

241 www.environment.gov.au/climate-change/climate-science-data/greenhouse-gas-measurement/publications#national

242 The Montreal Protocol on Substances that Deplete the Ozone Layer (a protocol to the Vienna Convention for the Protection of the Ozone Layer) is an international treaty designed to protect the ozone layer by phasing out the production of numerous substances believed to be responsible for ozone depletion.

243 For methodological and measurement reasons, this forest area used for Australia's national inventory system for greenhouse gas accounting differs from the forest area (134 million hectares) presented in Indicator 1.1a and used elsewhere in this report (see Indicator 1.1a).

244 landsat.gsfc.nasa. gov/

Harvested plantation pine logs.

are due to human activity (e.g. wood harvesting, forest clearing, plantation establishment) or natural events (e.g. periods of dieback, drought or bushfire and subsequent regrowth, and expansion of forests onto previously non-forest land). Since 2013, only permanent changes in land use are incorporated in these forest area figures, with transient changes in canopy cover due to natural events being excluded. This resultant forest area coverage underpins the carbon accounts for Australia's National Greenhouse Gas Inventory system.

Changes in the carbon stock in Australia's forest area are then estimated using the Full Carbon Accounting Model (FullCAM), a modelling methodology consistent with international requirements[245], with spatial simulations where relevant. FullCAM is an ecosystem model that uses a mass-balance approach to carbon cycling for each of the following carbon pools:

- living biomass
  - above-ground biomass (stem or bole, branches, bark, leaves)
  - below-ground biomass (roots)
- dead organic matter
  - dead wood
  - litter
- soil organic matter.

Emissions of CO_2 related to harvested wood products (HWPs) are also reported in the LULUCF component of Australia's National Greenhouse Gas Inventory. Emissions over time depend on the useful life of wood-based products, the method of their disposal, and their eventual storage and decay in landfill.

The carbon stocks in forests and wood products reported in this indicator are thus derived from the same carbon stock data as are used to calculate emissions from the LULUCF sector for Australia's National Greenhouse Gas Inventory.

Emissions values are determined according to the accounting rules specified under the United Nations Framework Convention on Climate Change or the Kyoto Protocol, and do not simply represent differences in carbon stocks over time.

Revisions since *Australia's State of the Forests Report 2013*

Carbon stock figures for this indicator are taken from the National Greenhouse Gas Inventory systems maintained by the Department of the Environment and Energy. Under methodological rules established under guidance from the Intergovernmental Panel on Climate Change, historical estimates of emissions are revised when improvements to data sources and compilation methods are made.

Since SOFR 2013, significant improvements to satellite observation technology have allowed a re-assessment of the forest areas used for carbon stock calculations. These changes led to increased detection of forest across the continent, primarily in drier regions. In addition, land simulation applications have been further developed to include native forest that is expanding into previous non-forest areas. The forest area figure for June 2016 used for this indicator (139 million hectares; DoEE 2018a) is similar to the forest area figure derived in Indicator 1.1a (134 million hectares) and used for all other indicators in SOFR 2018.

Improvements have also been made to the understanding of carbon dynamics, model parameters, source information for and modelling of soil carbon levels, and the maximum carbon content of different types of forest (Paul et al. 2017; Roxburgh et al. 2017).

The carbon data are now presented by financial year rather than calendar year, with reporting now occurring across 5-year periods ending on 30 June 2006, 2011 and 2016, consistent with other indicators.

Together, these changes led to revisions of figures presented in SOFR 2013, with total carbon stocks reported in SOFR 2018 being approximately 8,900 Mt C larger than those reported in SOFR 2013 across all time periods.

[245] The UNFCCC subjects its Annex 1 parties (including Australia) to annual reviews of their methodology by panels of expert reviewers made up of other compilers and experts in the international community, so as to assure ongoing compliance with guidelines issued by the Intergovernmental Panel on Climate Change (IPCC).

Carbon stock account for Australia's forests, 2001–16

In 2016, the stock of carbon in Australia's forests was 21,949 million tonnes of carbon (Mt C) (Table 5.1). The stock of carbon in forests decreased by 13 Mt C (0.1%) between 2001 and 2016. This occurred through a reduction of 148 Mt in carbon stocks in 2001–06, followed by a small gain of 7 Mt C in 2006–11, and a more substantial gain of 129 Mt C in 2011–16 (Table 5.1). Over the period 2001–16, carbon stocks in forests have varied by no more than 0.7% of the total stock.

The decline of carbon stocks in Australia's forests over the period 2001–06 was driven by clearing and conversion of forest land to other land uses, mainly agriculture, but was also influenced by temporary losses of forest carbon to bushfire (especially in 2003) and drought. However, the extent of the decline from 2001 to 2006 was only 0.67% of the total forest carbon stock at 2001. The recovery of carbon stocks over the periods 2006 to 2011 then 2011 to 2016 was due to a combination of recovery from past clearing, additional growth of plantations, reduced clearing of native forest, expansion of the area of native forests, and recovery from bushfire and drought.

In 2016, the majority of the carbon in forests (18,668 Mt C, 85%) was held in the category 'Non-production native forests', which includes all areas of native forest not available for wood harvesting (Table 5.1). Most of the balance (3,009 Mt C, 14%) was held in 'production native forests'. A relatively small amount of carbon (258 Mt C, 1.2%) was held in plantations, and an even smaller amount (15 Mt C, 0.1%) was held in environmental plantings.

The distribution of carbon in Australia's forests is shown in Figure 5.1. Forests with higher biomass densities are found in the wetter areas of the south-west, south-east and east of Australia; the northern and inland forests have lower biomass densities.

For 2016, carbon stock figures for forests by state and territory are shown in Table 5.2. New South Wales has the largest forest carbon stocks (6,682 Mt, 30% of Australia's total), followed by Queensland (5,766 Mt, 26% of Australia's total). This principally reflects the larger areas of forest in these two states. The Australian Capital Territory has the least forest carbon (83 Mt, 0.4%), consistent with the small area of forest in the territory, followed by South Australia (614 Mt, 2.8%), a reflection of the comparatively drier landscape in that state.

Table 5.1: Carbon stored in forests and harvested wood products, 2001 to 2016

	2001	2006	2011	2016	2016
Forest category		Mt C			**Proportion of total forest carbon**
Non-production native forests[a]	18,813	18,627	18,586	18,668	85.1%
Production native forests[b]	2,951	2,956	2,971	3,009	13.7%
Total native forests	**21,765**	**21,583**	**21,557**	**21,676**	**98.8%**
Post-1990 environmental plantings[c]	6	8	11	15	0.1%
Total other forests	**6**	**8**	**11**	**15**	**0.1%**
Softwood plantations	148	152	151	147	0.7%
Hardwood plantations	42	70	101	110	0.5%
Total plantations	**190**	**222**	**252**	**258**	**1.2%**
Forests total	**21,961**	**21,813**	**21,820**	**21,949**	**100.0%**
Wood products in use	77	83	89	94	
Wood products in landfill	42	46	49	50	
Harvested wood products total	**119**	**129**	**138**	**144**	
Total forests and harvested wood products	**22,080**	**21,943**	**21,958**	**22,093**	

Mt C, million tonnes of carbon.

All years are financial years.

[a] 'Non-production forests' are native forests not available for or subject to forestry industry activity. They are generally assumed to be in a state of equilibrium with the atmosphere unless exposed to disturbances, naturally dying, or regrowing from seed. They include forests of all species, including mangroves.

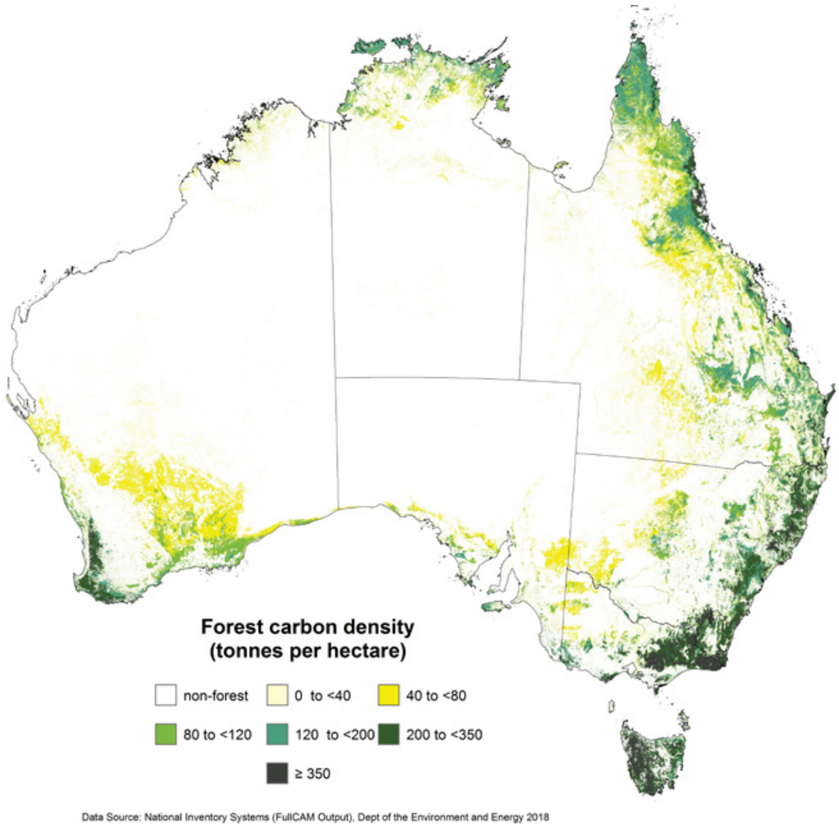
[b] Under the National Greenhouse Accounts definition of *forest management lands*, 'Production native forests' are both multiple-use public native forests and private native forests managed for wood production.

[c] Environmental plantings are forest that has been planted with native species, and without the intent of being eventually harvested for wood. They are part of the 'Other forests' category described in Indicator 1.1a.

Source: Department of the Environment and Energy.

This table, together with other data for Indicator 5.1a, is available in Microsoft Excel via www.doi.org/10.25814/5bda94dad76d8

Figure 5.1: Carbon density of Australia's forests, 2016



Note: Forest extent (139 million hectares) as determined for Australia's National Greenhouse Gas Inventory as at June 2016. This spatial coverage differs from that used in other SOFR 2018 indicators because of methodological and measurement reasons: see Indicator 1.1a.

A higher resolution version of this map is available via www.doi.org/10.25814/5be3bc4321162

Table 5.2: Carbon stored in forests and wood products by state and territory, 2016 (Mt C)

Forest category	ACT	NSW	NT	Qld	SA	Tas.	Vic.	WA	Australia
Non-production native forests	81	5,301	877	5,440	573	1,582	1,661	3,151	18,668
Production native forests[a]	0	1,335	0	306	0	808	279	281	3,009
Total native forests	**81**	**6,636**	**877**	**5,746**	**573**	**2,390**	**1,940**	**3,433**	**21,676**
Post-1990 environmental plantings	0	4	0.3	2	1	3	2	2	15
Total other forests	**0**	**4**	**0.3**	**2**	**1**	**3**	**2**	**2**	**15**
Softwood plantations	1	31	0	17	32	19	33	14	147
Hardwood plantations	0	11	1	1	8	12	33	45	110
Total plantations	**1**	**42**	**1**	**18**	**40**	**31**	**66**	**59**	**258**
Forests total	**83**	**6,682**	**878**	**5,766**	**614**	**2,424**	**2,008**	**3,494**	**21,949**
Wood products in use	0.4	29	0.1	13	8	12	23	9	94
Wood products in landfill	0.8	21	0.2	7	4	1	11	6	50
Harvested wood products total	**1.2**	**50**	**0.3**	**20**	**11**	**13**	**34**	**15**	**144**
Total forests and harvested wood products	**84**	**6,731**	**878**	**5,787**	**626**	**2,437**	**2,042**	**3,508**	**22,093**

Mt C, million tonnes of carbon.

Note: See footnotes to Table 5.1. NSW figures include figures for the Commonwealth territory of Jervis Bay.

[a] The category 'production native forests' includes both multiple-use public forests and private native forests managed for wood production.

Totals may not tally due to rounding.

Source: Department of the Environment and Energy

This table, together with other data for Indicator 5.1a, is available in Microsoft Excel via www.doi.org/10.25814/5bda94dad76d8

CRITERION 5

5.1a

Changes in carbon stocks over time

The carbon accounts for Australia's forests over three periods from 2001 to 2016 are presented in Table 5.3.

Major events causing reductions in forest carbon stocks include forest clearing for agriculture, urban or industrial development. Transient reductions in carbon stocks are caused by wood harvesting from production forests, prescribed burning, and natural events such as bushfire, drought, wind and outbreaks of pests or diseases.

Major increases in carbon stocks occur in forests following planting events, afforestation and reforestation; and during regeneration and regrowth from past events such as fires and wood harvesting. Regrowth may take 100 years for new trees to approach maturity (see Indicator 1.1b).

The national assessment of carbon stocks excludes transient changes in canopy cover arising from natural climatic cycles or events such as droughts and floods. The analysis takes a long-term view of carbon cycles, in the interests of accurately representing the long-range impacts of events on carbon stocks.

While bushfire does cause measurable changes in carbon stocks, as for the significant bushfire events of 2003 (Figure 5.4), these events have a lesser impact on the long-term trend in carbon stocks (Figure 5.2), because in the long-term carbon losses due to bushfires are typically recovered as the forests regrow. The turnaround in carbon stocks since 2007 is more broadly attributable to changes in land management and management practices, and expansion of native forest onto non-forest land.

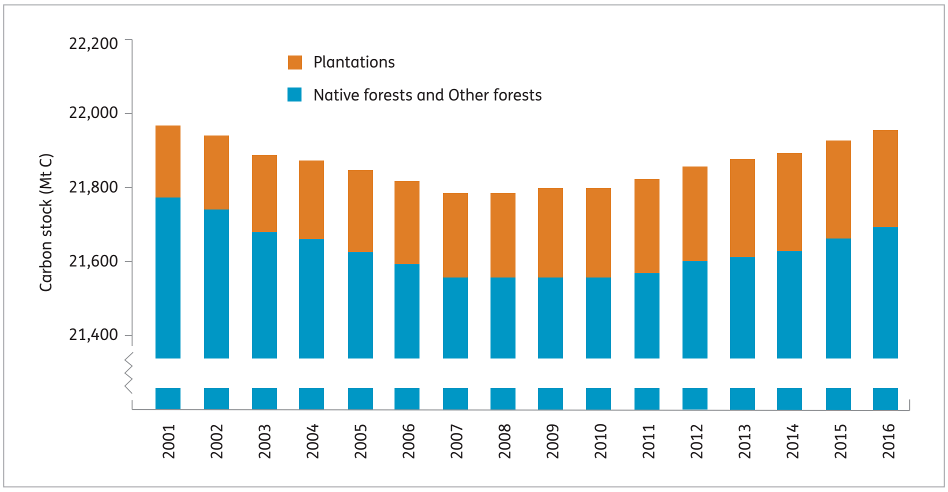
Reclassifications to/from forest

Forest clearing is associated with the conversion of forested land to agricultural, urban or other land uses. When forest land is cleared it is reclassified as non-forest land, and all carbon stocks on that land immediately before the clearing event are reclassified to other land types. Similarly, when a grassland becomes a forest through plantation establishment, regrowth of native forest on previously cleared land, or natural regeneration or expansion of native forest[246], the carbon stocks on that land before the planting or regeneration event are reclassified as forest carbon stocks. Table 5.3 shows the net amount of carbon subtracted from or added to the forest carbon accounts due to reclassification of forest land of various categories to or from non-forest land.

In the period 2001–06, there was a net loss of 194 Mt C from the forest carbon accounts due to reclassification to/from non-production native forests, mostly due to land clearing (Table 5.3). However, in 2011–16 the area of clearing was less than the area of regeneration and regrowth of non-production forests on previously non-forest land, leading to a net gain from land reclassification to/from non-production native forests of 53 Mt C in the forest carbon accounts (Table 5.3).

There has been a shift over time in the categories of forest being cleared. Over the period 2011–16, there has been a

Figure 5.2: Carbon stocks in Australian forests, 2001–2016



Mt C, million tonnes of carbon.
Note: The carbon stock in 'Other forests' is very small and would not be visible if shown separately on this histogram.
Source: Department of the Environment and Energy.

The data used to create this figure, together with other data for Indicator 5.1a, are available in Microsoft Excel www.doi.org/10.25814/5bda94dad76d8

246 For the purposes of Australia's national carbon accounts, conversion from non-forest to forest occurs when the woody vegetation reaches over 2 metres in height and attains a canopy cover of at least 20%.

Table 5.3: Carbon accounts for Australia's forests, 2001 to 2016 (Mt C)

	2001–06	2006–11	2011–16	2001–16
Opening stock	21,961	21,813	21,820	21,961
Reclassifications to/from[a]				
Non-production native forests	–194.5	–56.7	53.0	–198.2
Production native forests	0.0	0.0	0.0	0.0
Post-1990 environmental plantings	1.2	2.0	2.1	5.3
Softwood plantations	2.5	1.9	–1.3	3.0
Hardwood plantations	12.8	5.8	–18.2	0.3
Total reclassification	**–177.9**	**–47.1**	**35.5**	**–189.5**
Net growth/loss in[b]				
Non-production native forests	21.9	18.3	25.5	65.8
Production native forests	21.1	27.7	44.5	93.4
Post-1990 environmental plantings	0.8	1.0	1.3	3.2
Softwood plantations	17.0	14.1	13.7	44.8
Hardwood plantations	18.9	32.3	39.4	90.6
Total net growth	**79.8**	**93.5**	**124.5**	**297.7**
Fire and regrowth from fire[c]				
Non-production native forests	–13.6	–3.0	3.4	–13.2
Production native forests	–1.2	–1.1	–0.5	–2.8
Post-1990 environmental plantings	0.0	–0.2	–0.2	–0.4
Softwood plantations	0.0	0.0	0.0	–0.1
Hardwood plantations	–0.1	–0.2	–0.4	–0.6
Total fire and regrowth from fire	**–14.9**	**–4.4**	**2.4**	**–17.0**
Transfers to wood products[d]				
Native forests	–15.2	–11.9	–6.2	–33.3
Softwood plantations	–16.0	–16.4	–16.5	–48.9
Hardwood plantations	–3.5	–7.1	–11.1	–21.7
Total transfers to wood products	**–34.7**	**–35.4**	**–33.8**	**–103.9**
Closing stock	**21,813**	**21,820**	**21,949**	**21,949**

Mt C, million tonnes of carbon.

[a] Reclassifications means the net conversions of land to or from a forest type. This includes the first-time clearing of forest, the re-clearing of regrowth forest, the establishment and removal of plantations, and the growth of native forest from seed on non-forest land.

[b] Net growth/loss accounts for the carbon stock changes within a forest category over time. This includes the growth of trees (but not in non-production native forests that have been continuously forest since 1972, where growth is presumed to be balanced with decay), and losses of woody material left on site during harvesting events.

[c] Net impacts of fire include the immediate losses of carbon in deadwood and litter due to a fire event, and the subsequent recoveries within the forest. Contributions of recovery are counted in the year where the regrowth occurs rather than in the year where the fire occurred.

[d] Transfers to wood products (Table 5.5) and domestic accumulation of wood products in use (Tables 5.1 and 5.5) are not equal and opposite. Transfers to wood products is equated to logs removed from a harvesting site. Domestic accumulation of wood products in use includes imported material, excludes exported material, excludes waste lost during manufacturing, and includes losses due to the disposal of wood products in the waste system.

Source: Department of the Environment and Energy.

This table, together with other data for Indicator 5.1a, is available in Microsoft Excel via www.doi.org/10.25814/5bda94dad76d8

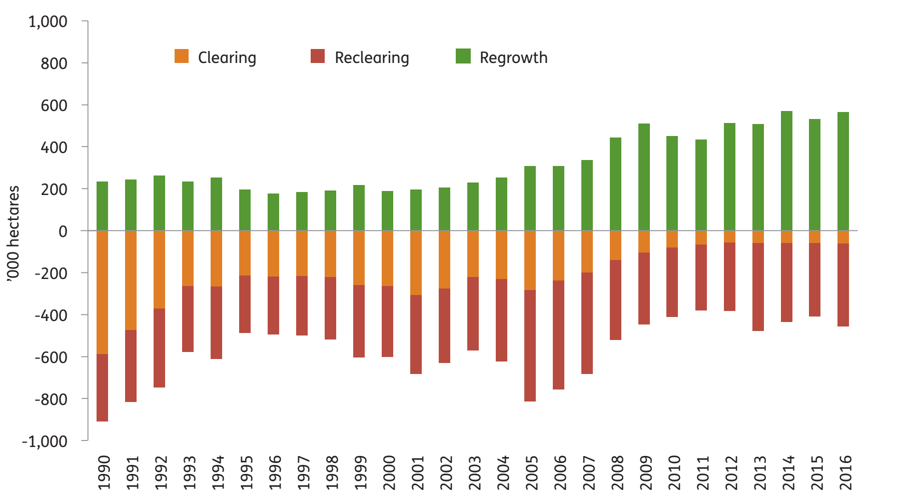
continued reduction of the proportion of forest clearing that is first-time clearing of that land. Most forest clearing is now the re-clearing of regrowth on previously cleared land (Figure 5.3). In addition, the annual area of forest regrowing on cleared land has increased progressively over the last 15 years.

Over the period 2011–16, the NGGI data show first-time clearing was recorded for 0.29 million hectares of forest, 2.69 million hectares of forest regrew on land that had been cleared after 1972, and reclearing of 1.86 million hectares of regrowth forest was recorded (Figure 5.3). The total area of forest cleared over this period was 2.16 million hectares, and the net increase of forest area as a result of clearing, regrowth and reclearing was 0.53 million hectares.

In the year 2015–16, the NGGI data show first-time clearing was recorded for 60 thousand hectares of forest, 564 thousand hectares of forest regrew on land that had been cleared after 1972, and reclearing of 395 thousand hectares of regrowth forest was recorded (Figure 5.3). The total area of forest cleared in this year was 455 thousand hectares, and the net increase of forest area as a result of clearing, regrowth and reclearing was 108 thousand hectares.

Both regulatory constraints and farmers' terms of trade can be useful predictors of land clearing. Historically, economic considerations have been an important driver of land clearing for farmers and other land managers. When the prices of agricultural products have been high (reflected in farmers'

Figure 5.3: Annual areas of forest cleared, regrown, and recleared



Source: Department of the Environment and Energy. Clearing and reclearing data are annual area data from Figure 6.5a of *National Inventory Report 2016 Volume 2* (DoEE 2018a). Regrowth data are gross annual area of regrowth on land cleared since 1972 (Figure 6.5b of National Inventory Report 2016 Volume 2 shows the cumulative regrowth area after accounting for reclearing, and those area data are therefore different to the gross regrowth areas presented here). The year '2016' refers to the financial year.

The data used to create this figure, together with other data for Indicator 5.1a, are available in Microsoft Excel www.doi.org/10.25814/5bda94dad76d8

terms of trade[247]), landowners have had a stronger incentive to clear land and expand production. Typically, an increase in farmers' terms of trade has been followed by an increase in forest clearing about one year later, while a decrease in farmers' terms of trade has been followed by a decrease in forest clearing about one year later (DCCEE 2012).

In recent decades, state governments have passed legislation to restrict land clearing. The Queensland Government substantially restricted clearing from 2007 onwards and reinforced the restrictions in 2009. This policy change is reflected in the sharp drop in national land clearing figures since 2007 (Figure 5.3). Other recent reductions in rates of land clearing, deriving from legislation rather than economic conditions, were not accompanied by significant changes in farmers' terms of trade.

The reclassification of non-forest land to commercial plantations and environmental plantings was associated with additional forest carbon stocks in 2001–06 and 2006–11. However, in 2011–16, there was a small loss of 1.3 Mt in carbon stocks from plantings and removals of softwood plantations, while 18 Mt carbon was removed from the forest accounts due to the net reclassification of hardwood plantations to non-forest lands (Table 5.3). Additional carbon stocks resulted from a small amount of reclassification of land to environmental plantings in all time periods.

[247] 'Farmers' terms of trade' is the ratio of an index of prices received by farmers to an index of prices paid by farmers.

Net growth/loss

Figures for net growth/loss are dominated by natural growth of replanted or regenerating forest, or regrowth following wood harvest. Over the period 2001–16, this added 298 Mt C to the forest carbon accounts (Table 5.3), with growth of production native forests and plantations together accounting for 76% of this figure.

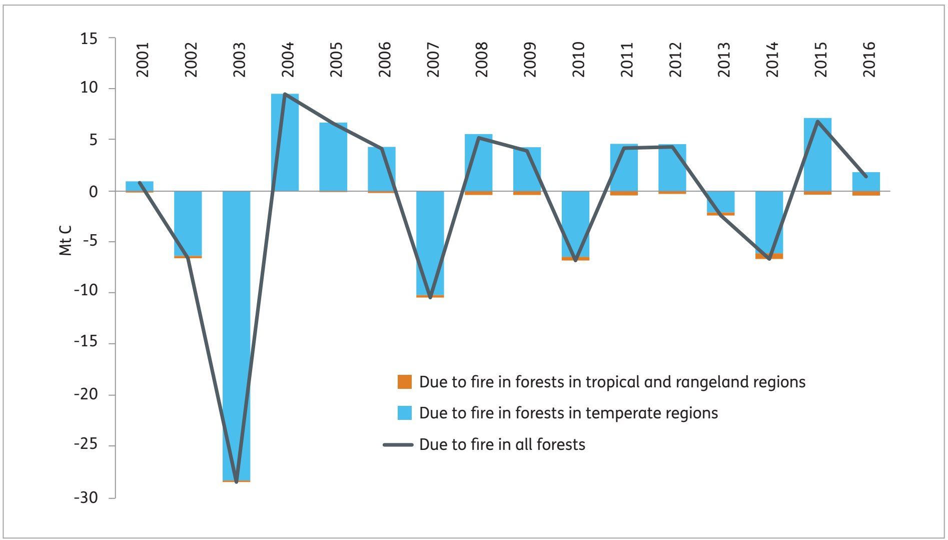
Net growth in production native forests increased their carbon stock by 28 Mt C in 2006–11 and 45 Mt C in 2011–16 (Table 5.3), with this forest category reaching a stock of 3,009 Mt C in 2016 (Table 5.1). The carbon stock in hardwood plantations reached 110 Mt C in 2016 (Table 5.1). By contrast, the increase in carbon stocks of the softwood estate through growth (44.8 Mt C over the period 2001–16) was exceeded by the amount of carbon transferred to wood products or emitted as CO_2 through the oxidation of harvesting debris and changes to soils (48.9 Mt C over this period) (Table 5.3).

Fire and regrowth from fire

Bushfires occur every year in Australia's forests (see Indicator 3.1b). The fire regime in forests varies with climatic zone, soil type and vegetation type. In particular, climatic variability contributes large year-to-year variations in the extent of fires. In general, forests in northern Australia burn more frequently but at lower severity than do forests in southern Australia.

Bushfires generally have transient impacts on Australia's forests, but the loss of carbon stocks from forest lands can be very high in years in which substantial bushfires occur in temperate forests (Figure 5.4). In the period 2001–16, bushfires across

Figure 5.4: Carbon stock changes due to fire and regrowth from fire, by region, 2001–16



Mt C, million tonnes of carbon.

Note: Years represent fire seasons ending in June for temperate regions, and July for tropical and rangeland regions (for which the fire season runs from the beginning of the late dry season in August to the end of the subsequent early dry season in July).

Source: Department of the Environment and Energy. Carbon losses in fire are from litter and debris pools only.

The data used to create this figure, together with other data for Indicator 5.1a, are available in Microsoft Excel www.doi.org/10.25814/5bda94dad76d8

Australia burned 82 million hectares of forest, and resulted in net losses of 17 Mt C over this period. Of this, bushfires in temperate regions burnt a total of approximately 12 million hectares of forest, and resulted in losses of 132 Mt C from forest deadwood and litter stocks; this loss will be mostly mitigated through continuing recovery in future years.

Losses of carbon caused by fire are determined by the size of the areas burnt and the amount of biomass burnt per unit area. The rates of recovery of forest carbon stocks after fire vary with climate, ecosystem type, previous fire history and site conditions. Many Australian tree species are fire-tolerant; fire of moderate intensity often primarily burns fine debris and leaves and stimulates growth, without killing trees. Because of this ecology, the carbon accounts assume that most forest impacted by bushfire will reach effectively full recovery within a period of 11 years, with recovery times depending on the location of the fire, unless the area in question is impacted by another fire event.

Figure 5.4 shows the impact of fire on year-to-year carbon stock changes. In 2001–06 there was a net loss from fire of 15 Mt of carbon across all forest categories (Table 5.3). This includes 28 Mt of net carbon loss from forests during the significant temperate-region bushfires in 2003. The majority of the recovery in carbon stocks following these fires was modelled to also occur within the 2001–06 period (Figure 5.4). Similarly, the temperate-region forest fires of 2007 caused a net loss of 10 Mt of carbon, with recovery being reflected in the net carbon gains over the period 2011–16 (Figure 5.4, Table 5.3).

Recovery of carbon stocks from forest fires in tropical and rangeland regions is modelled to occur over a shorter time-period, which, when combined with the more frequent occurrence of fires in these regions, leads to tropical and rangeland fires having a much smaller net effect on carbon stocks within any one year. For example, in 2003, the large areas of forest fire in tropical and rangeland regions emitted 2.4 Mt C in that year, but these forests also sequestered 2.3 Mt C in recovery from previous fires.

Transfers to wood products

The amount of carbon removed from forests in the form of sawlogs, pulplogs and other log types (that is, transferred to wood products) was similar across all three time periods (2001–06, 2006–11 and 2011–16; Table 5.3), and totalled 104 Mt for the combined period 2001–2016. However, there was a progressive change in the sources of harvested wood, leading to changes over time in the pattern of carbon stock change. The amount of carbon in wood transferred from native forests to wood products declined over this period, while the amount of carbon in wood transferred from hardwood plantations to wood products increased. These figures reflect changing harvest volumes in different forest categories reported in other SOFR indicators. The amount of carbon in wood transferred from softwood plantations to wood product remained relatively constant over this period.

Distribution of carbon across pools

Table 5.4 shows the breakdown of carbon in Australia's forests between above-ground living biomass, deadwood, litter, below-ground living biomass and soil. Soil carbon is the largest pool of carbon in forests, and accounts for 52% of carbon stored on forest lands. Living biomass is the other significant pool, comprising tree stems, branches, bark and foliage as above-ground components, and roots as below-ground components. Living biomass accounts for 38% of carbon stored on forest lands, with the larger proportion of living biomass being above-ground. The remaining carbon is found in litter and deadwood above-ground; these two debris pools, especially litter, serve as the main fuel in bushfires (Sullivan et al. 2012) and are thus the main source of bushfire CO_2 emissions.

Above-ground living biomass will, upon death, become deadwood, either on the ground or first standing then on the ground, and litter. As these debris pools decay, a proportion will become soil carbon while the remainder will enter the atmosphere as CO_2. Below-ground living biomass, upon death, will decay directly to soil carbon. Soil carbon will also gradually oxidise to CO_2 and enter the atmosphere if disturbed, such as by the loss of stabilising forest cover.

In 2011–16, forest carbon stocks increased in all pools except deadwood, with the largest increases being in soil (82 Mt C) and above-ground living biomass (33 Mt C). Similarly, in 2001–06 when forest carbon stocks were decreasing, the largest losses of carbon were in soil (66 Mt C) and above-ground living biomass (43 Mt C). The differences between carbon pools in the amounts of carbon gained and lost reflect the sizes of the different carbon pools. In addition, more gradual gains of carbon in growing forests balance the modelled instantaneous losses of all carbon pools from the forest carbon accounts when land is reclassified to non-forest after, for example, land clearing.

Both the rate of input to the soil carbon pool and the rate of output from the soil carbon pool are affected by management activities, particularly forest clearing, soil cultivation or wood harvesting, as well as by bushfire (Page et al. 2011). Changes in total soil carbon stocks in response to management activities depend on initial soil carbon levels and past management practices. For example, soil carbon stocks generally decline under pine plantations established on land that had previously carried pastures, associated with a large loss of nitrogen from the soil and soil acidification, but do not decline on land that was formerly under native forest (Paul et al. 2002).

In most Australian native forests, the above-ground carbon pools (living trees, deadwood and litter) are most vulnerable to rapid loss through management events or bushfires. The temporal pattern of change in soil carbon stocks is slower than rates of change in above-ground carbon pools (Page et al. 2011), and the mass ratio of above-ground to below-ground carbon can vary markedly across the landscape.

The quality of soil carbon data is likely to improve over time, especially in native forests. The high spatial and temporal variability of soil carbon stocks and fluxes means that intensive sampling and measurement of soil carbon stocks and their change is required over large land areas, which is difficult to undertake. While advances have been made in the understanding of agricultural soils (and by extension the soils of lands newly converted to forest), overall understanding of the dynamics of soil carbon in Australian forests remains low, especially in native forests.

Table 5.4: Carbon pools in forests

	2001	2006	2011	2016	2016
Pool	**Mt C**	**Mt C**	**Mt C**	**Mt C**	**Proportion of total**
Living biomass	5,639	5,596	5,594	5,627	26%
Deadwood	1,629	1,620	1,618	1,618	7.4%
Litter	596	590	590	593	2.7%
Above-ground total	**7,864**	**7,806**	**7,802**	**7,838**	36%
Living biomass	2,682	2,658	2,654	2,665	12%
Soil[a]	11,416	11,349	11,363	11,445	52%
Below-ground total	**14,097**	**14,007**	**14,018**	**14,110**	64%
Total forest	**21,961**	**21,813**	**21,820**	**21,949**	100%

Mt C, million tonnes of carbon.

[a] Soil carbon is reported to a depth of 1 m for mangrove forests, but to 30 cm for all other forests.

This table, together with other data for Indicator 5.1a, is available in Microsoft Excel via www.doi.org/10.25814/5bda94dad76d8

Box 5.1: The Emissions Reduction Fund

The Emissions Reduction Fund (ERF) is a voluntary offsets scheme that allows farmers and land managers to create carbon credits either by reducing greenhouse gas emissions or by storing carbon in vegetation or soils.

The ERF commenced in 2014. It builds on the preceding Carbon Farming Initiative (CFI), expanding coverage to encourage emissions reductions across the economy. Existing CFI projects were automatically transitioned to the ERF.

ERF methodologies set out the rules and instructions for undertaking projects, estimating abatement, and reporting to the Clean Energy Regulator. Each ERF project must use an approved ERF methodology to ensure that abatement is measurable and verifiable.

Sequestration projects remove CO_2 from the atmosphere by sequestering carbon in plants as they grow and as they increase soil organic matter. Examples are revegetation, establishing commercial plantations, and increasing soil carbon. Projects that avoid losses of vegetation, such as protecting native vegetation at imminent risk of clearing for agricultural purposes, are also treated as sequestration projects.

ERF participants can bid in an auction for a contract to sell carbon credits generated by their projects to the Clean Energy Regulator. Participants can also choose to sell credits from their projects to businesses to offset emissions from those businesses, as well as other ERF projects looking to fulfil their contracts with the Australian Government.

In 2017, projects protecting or establishing native vegetation on agricultural land represented more than half the total contracted abatement under the ERF.

In addition to boosting farmers' and landholders' incomes through the sale of carbon credits, the ERF provides other benefits. For example, the environmental plantings methodology could be used by landholders who want to establish plantings to provide shelter for stock, minimise erosion, reduce salinity, improve water quality or provide habitat for wildlife.

Carbon stored in vegetation and soils can be released to the atmosphere, reversing the environmental benefit of the sequestration project. For this reason, all sequestration projects are subject to permanence obligations. The ERF permanence rules recognise the realities of Australia's natural environment and climatic conditions. Owners of environmental planting projects will not be penalised for the project areas losing carbon because of bushfire, drought, pests or disease. In most cases, vegetation and other carbon stores will recover naturally after these events; if not, landowners must take reasonable action to re-establish carbon stores.

Participants can use the Australian Government's publicly available FullCAM modelling software to calculate carbon stocks. Additional information about the ERF and the supporting tools is available at environment.gov.au/climate-change.

Carbon stored in wood products in use and in landfill

Harvesting of forests for wood products results in the loss of carbon to the atmosphere during and after the harvesting event, sequestration of carbon from the atmosphere during subsequent regeneration and regrowth, and a transfer of carbon to the wood products pool. The lifecycle of wood products in use is modelled to vary from short-term (e.g. paper products) to long-term (e.g. structural timber). Wood products that are not recycled are disposed to landfill, where a proportion of their carbon will gradually decay into carbon dioxide or methane, while the remainder (including carbon from some paper products) remains stable in the landfill.

Changes in the carbon stock of harvested wood products are quantified using a model-based method, which employs decay rates for each wood product category (DoEE 2018a). A national database of domestic wood production, including import and export, has been maintained in Australia since the 1930s (most recently reported in ABARES 2017b). This consistent and detailed collection of time-series data was an input to development of a national wood products model. The model links intake of raw materials, through various processing options, to outputs of products and by-products, including to export, recycling, entry to and decomposition in landfill, use for bioenergy, and loss to atmosphere. A detailed description of the harvest wood products model is given in Section 6.15 of the *National Inventory Report 2016, Volume 2* (DoEE 2018a).

A total of 22,093 Mt C was present in Australia's forests and harvested wood products at the end of 2016 (Table 5.1), of which 144 Mt C (0.7%) is in harvested wood products in use and in landfill. After including changes due to imports and exports, disposal and decay, carbon stocks in the pool of wood and wood products in use in Australia showed a net increase of 17 Mt C in the period 2001–16, and carbon stocks in the pool of wood and wood products in landfill showed a net increase of 9 Mt C (Tables 5.1 and 5.5). The increase in carbon stocks of harvested wood and wood products in use and in landfill over this period was larger than the decrease in forest carbon stocks over this period, leading to a net gain of 13 Mt C in forest plus wood and wood products over this period (from 22,080 Mt C to 22,093 Mt C) (Table 5.1).

Handling bulk waste at a paper recycling plant.

Trends in wood products in use, for disposal and in landfill

On average, carbon accumulated in harvested wood products in use by 1.5% per year over the period from 2001 to 2016. The bulk of this was stored in relatively long-lived products such as timber used for construction. In 2016, 94 Mt C was stored in wood products in use (Table 5.5).

The amount of waste generated in the disposal of wood products to landfill depends on how much material at the end of its useful life is diverted to other disposal paths or uses, including combustion for energy, recycling, or disposal to aerobic treatment processes.

In the period 2001–16, 13.6 Mt C in wood and paper products was transferred to landfill (Table 5.5). The total mass of carbon in wood products stored in landfill in 2016 was 51 Mt C (Table 5.1).

Both paper and wood in landfill decay relatively slowly, although at different rates. In one reported study, 10% of the carbon in wood transferred to a well-managed landfill decayed over a span of some decades, with the remainder being present for longer periods (Wang et al. 2011). Consequently, with the current quantities of wood being disposed of to landfill, the total stock of carbon stored in landfills will continue to increase.

Trends in waste paper generation and disposal

The amount of carbon in annual paper usage (consumption, calculated as production plus imports minus exports) rose from 147 thousand tonnes in 1945 to 1,845 thousand tonnes in 2016 (Figure 5.5), reflecting both an increasing population, and that the per capita consumption of paper increased almost four-fold between 1945 and 2016 (from an estimated annual 20 kg C per person in 1945, to an annual 76 kg C per person in 2016).

The amount of carbon in waste paper transferred annually to landfill increased from 188 thousand tonnes C in 1945 to a maximum of 927 thousand tonnes in 1995, then declined to 210 thousand tonnes C by 2016 as a result of a shift from disposal in landfill to recycling since the late 1980s (Figure 5.5). The proportion of waste paper recycled increased from 28% in 1990 to 85% in 2016, while the proportion of paper disposed in landfill has declined since the mid-2000s (Figure 5.5). The increase in the proportion of product recycled partly reflects the effectiveness of a number of state government waste management initiatives.

Energy from woody biomass

In 2015–16, the burning of wood and wood waste combusted 2,500 tonnes of carbon, with a gross calorific value[248] of 95.6 petajoules (PJ[249]) of energy. The majority of this wood was consumed in the residential sector (1,300 tonnes carbon, with a gross calorific value of 49.2 PJ); the manufacturing sectors (700 tonnes carbon, with a gross calorific value of 29.2 PJ) are also significant consumers. The electricity generation sector is a relatively small user of wood and wood waste to produce energy, combusting only 400 tonnes of wood and wood waste in 2015–16 with a gross calorific value of 16.9 PJ (DoEE 2017b).

[248] The gross calorific value of a fuel is the amount of heat released during its combustion under standard conditions

[249] 1 petajoule = 10^{15} joules

Table 5.5: Carbon input to, and output from, the harvested wood products pool in Australia (Mt C)

	2001–06	2006–11	2011–16	2001–16
Wood products in use – opening stock	**76.7**	**83.2**	**88.8**	**76.7**
Domestic production	24.1	24.2	23.5	71.8
Imports	5.4	5.9	6.0	17.4
Exports	–10.8	–11.4	–12.5	–34.8
Disposal to landfill	–6.1	–4.5	–3.0	–13.6
Other losses from use	–6.1	–8.5	–8.8	–23.4
Wood products in use – closing stock[a]	**83.2**	**88.8**	**94.1**	**94.1**
Wood products in landfill – opening stock	**41.9**	**46.2**	**49.0**	**41.9**
Disposal into landfill	6.1	4.5	3.0	13.6
Decay in landfill	–1.8	–1.7	–1.5	–5.1
Wood products in landfill – closing stock[b]	**46.2**	**49.0**	**50.4**	**50.4**

Mt C, million tonnes of carbon.

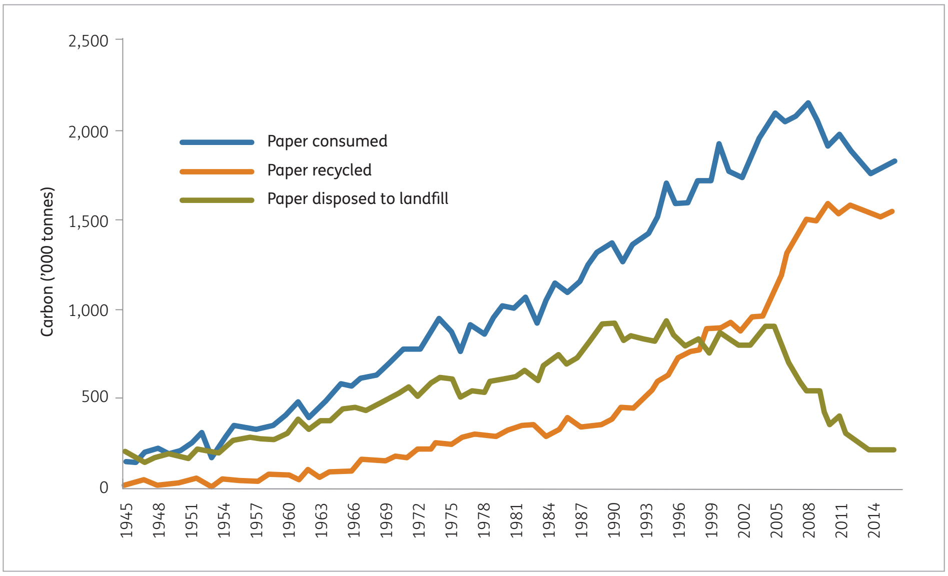
[a] 'Wood products in use – closing stock' is calculated as 'Wood products in use – opening stock', plus 'Domestic production', plus 'Imports', less 'Exports', less 'Disposal to landfill', less 'Other losses from use'.

[b] 'Wood products in landfill – closing stock' is calculated as 'Wood products in landfill – opening stock', plus 'Disposal into landfill', less 'Decay in landfill'.

Source: Department of the Environment and Energy

This table, together with other data for Indicator 5.1a, is available in Microsoft Excel via www.doi.org/10.25814/5bda94dad76d8

Figure 5.5: Carbon in paper consumed, recycled and disposed to landfill annually, 1945–2016



Note: Consumption is calculated as production plus imports minus exports.

Source: DoEE (2018a), based on ABARES (2017b), Wilson (1969), and Australian Paper Industry Council (APIC) statistics (unpublished).

The data used to create this figure, together with other data for Indicator 5.1a, are available in Microsoft Excel www.doi.org/10.25814/5bda94dad76d8

CRITERION 5

5.1a

Case study 5.1: Carbon stocks in the Great Barrier Reef catchment zone

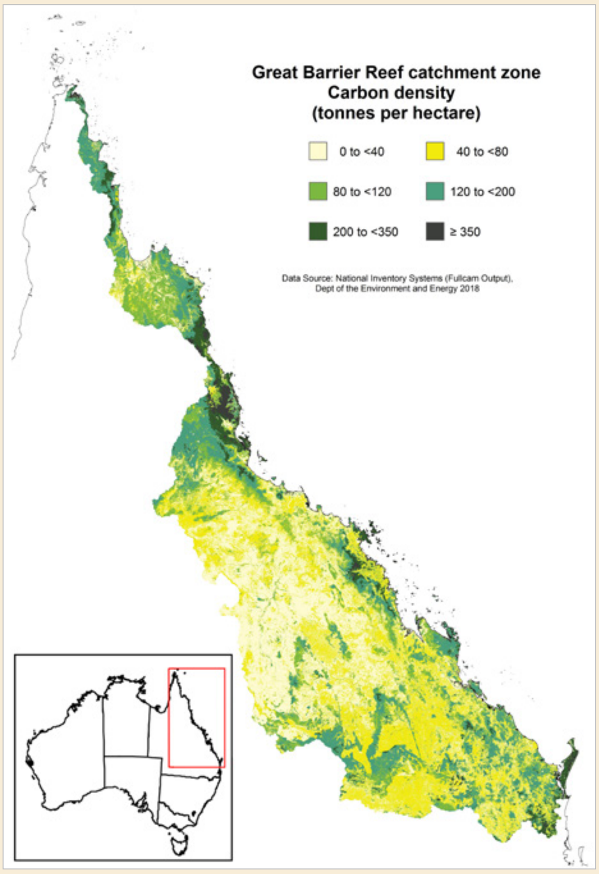
The capability to produce carbon stock accounts for any ecosystem in Australia is under development by the Department of the Environment and Energy. The Great Barrier Reef (GBR) catchment zone is of particular interest as an ecosystem due to its relationship with the Great Barrier Reef. The health or management of a set of catchments will be directly related to the health of a coastal reef through changes to runoff and coastal stability. The GBR catchment area is one of a range of ecosystems of interest to parties participating in pilot projects to develop accounts under the new System of Environmental-Economic Accounting.

A total of 4,018 Mt C was present in the land in the GBR catchments in 2016 (Table 5.6). Of this, 79% was present on forest land, including 3.7% on land carrying mangroves. Figure 5.6 shows the spatial distribution of those carbon stocks. The highest carbon densities are in areas of coastal and montane rainforest and in mangrove forests, while the lowest carbon densities are in grassland and agricultural land.

Over the period from 2001 to 2016, the total carbon stocks of the GBR catchments declined progressively from 4,078 Mt C to 4,018 Mt C (a 1.5% decline). However, the carbon stocks in forests declined initially, but have increased slowly since 2009. Forest carbon stocks changed in line with changes in the area of forest in the GBR catchments, with the initial decline being due to clearing, followed by a rise due to reforestation as well as subsequent regrowth of forests. Carbon in non-forest land initially increased due to addition to the accounts of stocks of below-ground carbon on land that had been cleared and reclassified from forest land, then decreased through loss of this carbon by oxidation over the subsequent decade. It is projected that, if forest recovery continues, the total carbon stocks in the GBR catchments will begin to rise.

Of particular interest to the GBR catchment region are the coastal mangrove forest communities. Mangroves comprise only 0.9% by area of the forest in this region, but contain 4.7% of the total forest carbon (Table 5.6), as the carbon density (mass per unit area) of carbon in mangroves is high (Table 5.7). A large proportion of the carbon in mangrove forests (83%) is below-ground, which reflects the large amounts of carbon stored in mud in tidal ecosystems. Accordingly, excavation activities in mangroves can be a more significant source of carbon emissions than the clearing of other types of forest.

Figure 5.6: Carbon density of land in the Great Barrier Reef catchments, 2016



Note: Map includes carbon stored on non-forest land.

A higher resolution version of this map, together with other data and maps for Indicator 5.1a, is available via www.doi.org/10.25814/5be3bc4321162

Oliver Creek, Daintree forest, Queensland.

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Table 5.6: Carbon stocks of the Great Barrier Reef catchments, 2001-16

Vegetation type	2001	2006	2011	2016	2016 Proportion of total carbon stock
	Mt C				
Mangrove forest	149	149	149	149	3.7%
Non-mangrove forest	3,070	3,013	3,007	3,017	75%
Total forest	**3,219**	**3,162**	**3,156**	**3,165**	**79%**
Non-forest	**855**	**881**	**867**	**848**	**21%**
Total GBR catchments	**4,074**	**4,043**	**4,023**	**4,013**	**100%**

Mt C, million tonnes of carbon.
Total may not tally due to rounding.

This table, together with other data for Indicator 5.1a, is available in Microsoft Excel via www.doi.org/10.25814/5bda94dad76d8

Table 5.7: Carbon stocks of the Great Barrier Reef catchments, by carbon pool, 2016

Vegetation type	Area ('000 ha)	Above-ground carbon (Mt C)	Below-ground carbon (Mt C)	Total carbon (Mt C)	Carbon density (t C/ha)	Proportion of total carbon that is below-ground
Mangrove forest	217	26	123	149	686	83%
Non-mangrove forest	23,252	1,082	1,935	3,017	130	64%
Total forest	**23,469**	**1,108**	**2,058**	**3,165**	**135**	**65%**
Non-forest	**19,554**	**21**	**827**	**848**	**43**	**98%**
Total GBR catchment	**43,024**	**1,128**	**2,885**	**4,013**	**93**	**72%**

Mt C, million tonnes of carbon.

This table, together with other data for Indicator 5.1a, is available in Microsoft Excel via www.doi.org/10.25814/5bda94dad76d8

Case study 5.2: Carbon dynamics of managed native forests in Australia

Forestry and forest management can play many roles in mitigating climate change. These roles include maintaining or increasing existing carbon stores in forest biomass, in soil and in harvested wood products, both in plantations and native forests, and assisting in reducing greenhouse gas emissions through use of wood instead of other, more energy-intensive products.

A collaborative project between the NSW Department of Primary Industries, CSIRO and state forest agencies in New South Wales and Victoria measured or modelled all key carbon stocks in, and flows from, three forest types and regions, including into harvested wood products. The project took a life cycle assessment (LCA) approach, which incorporates all relevant emissions to the atmosphere and removals from the atmosphere, as needed to determine the climate impacts of an industry sector. Over 500 mature native forests trees were weighed (Figure 5.7), and the impact of disturbances (harvest and fire) on carbon pools were considered along with the dynamics of carbon in harvested wood products in use and in landfill. The study also considered the fossil fuel displacement benefits arising from using biomass for bioenergy, the impacts of product substitution, and the socioeconomic implications of native forest management for the case-study regions.

Study sites were paired within three species/region combinations (each site containing either forest managed for production or forest managed for conservation), and had a known history of disturbances (harvest, thinning and bushfire events). Forest management and forest product scenarios were modelled using the software tool "ForestHWP" (Figure 5.8), including baseline options (business as usual, BAU) for production or conservation, scenarios with increased incidence of fire, alternative management options for biomass (e.g. increasing bioenergy production), and end-of-life use options for forest products.

The greenhouse gas impact of different forest management and forest product scenarios (long-term carbon storage and reduced emissions) was expressed in similar terms. For the conservation scenario, this is the long-term forest carbon store (tonnes carbon per hectare, tC/ha). For the production scenario, this is

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the long-term forest carbon store in 1 hectare of forest *plus* the store of carbon in harvested wood products from 1 hectare of forest, in use and in landfill, *plus* the reduced carbon emissions associated with use of harvested wood products from 1 hectare of forest instead of other products. The emission footprint of the harvested wood products was also expressed as tonnes carbon emitted per tonnes carbon in harvested wood products, which allowed comparison with the emissions associated with production of alternative materials.

Key findings of the study include:

- Total above-ground carbon was high, but not as high as previously reported for some forests in Australia.
  - Studies of mature forest stands that do not weigh biomass directly can significantly overestimate biomass values, and caution is required when interpreting their results in terms of optimum forest management regimes or the contribution of mature forest stands to the global carbon balance.
- The long-term average greenhouse gas benefits (reduction of net greenhouse-gas emissions) of the production and conservation scenarios (excluding below-ground carbon dynamics) were determined for the study sites (Figure 5.9).
  - For the mountain ash (*Eucalyptus regnans*) forest in the Central Highlands, Vic., production scenarios resulted in greater greenhouse gas benefits compared to conservation scenarios (60% greater for the BAU production scenario, increasing to 67% greater in other production scenarios).
  - For the silvertop ash (*E. sieberi*) forest on the south coast of NSW, the BAU production scenario had slightly (4.3%) greater greenhouse gas benefits than the conservation scenario, increasing to 15% greater in other production scenarios.
  - For the blackbutt (*E. pilularis*) forest in northern coastal NSW, the conservation scenario gave 12% greater greenhouse gas benefit than the BAU production scenario. However, production scenarios where a fraction of the harvest residue biomass was used for bioenergy or pulp production gave greenhouse gas benefits up to 30% greater than under the conservation scenario.

Figure 5.7: A mountain ash (*Eucalyptus regnans*) log from a production site being weighed

- Large volumes of harvest residues and mill residues are currently under-utilised, and could be utilised for applications such as bioenergy generation, with beneficial impacts on net emissions.
- Using harvested wood products as substitutes for other materials mitigates greenhouse gas emissions, in the same way as does the use of sustainably sourced (renewable) forest biomass for bioenergy generation instead of fossil fuels.
  - Expressed on the basis of their life-cycle impact on emissions, domestic native harvested wood products have an emission footprint of approximately 0.2 tonne carbon per tonne of carbon in the product, which is 20-fold less than the emissions footprint of imported hardwood for decking and flooring or fibre-cement cladding, and 10-fold less that the emissions footprint of concrete slabs and steel or concrete transmission poles.
- Use of Australian native forest pulpwood for paper production also reduces greenhouse gas emissions compared to use of pulpwood from native forests in SE Asia.
  - This is due to the large emissions caused by forest harvesting in SE Asia and associated forest degradation and loss, especially on peatlands.
- The overall greenhouse gas benefits of wood use are maintained regardless of the fate of wood at the disposal stage, that is, whether it is recycled, used for energy production, or disposed in landfill.

The overall conclusion of this study is that, across the three regions studied, halting native forest management for wood production would not reduce overall greenhouse gas emissions. In addition, there is considerable room for improvement in the greenhouse gas outcomes of production forestry for all the three case study regions included in this study. These improvements could be achieved primarily by a combination of reduced wastage, increased recovery, increased physical carbon storage in hardwood forest products, and increased use of wood biomass instead of fossil fuels to produce energy.

A full account of this study, together with the modelled economic impacts of different forest management scenarios, is available in Ximenes et al. (2016).

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Figure 5.8: The ForestHWP software interface

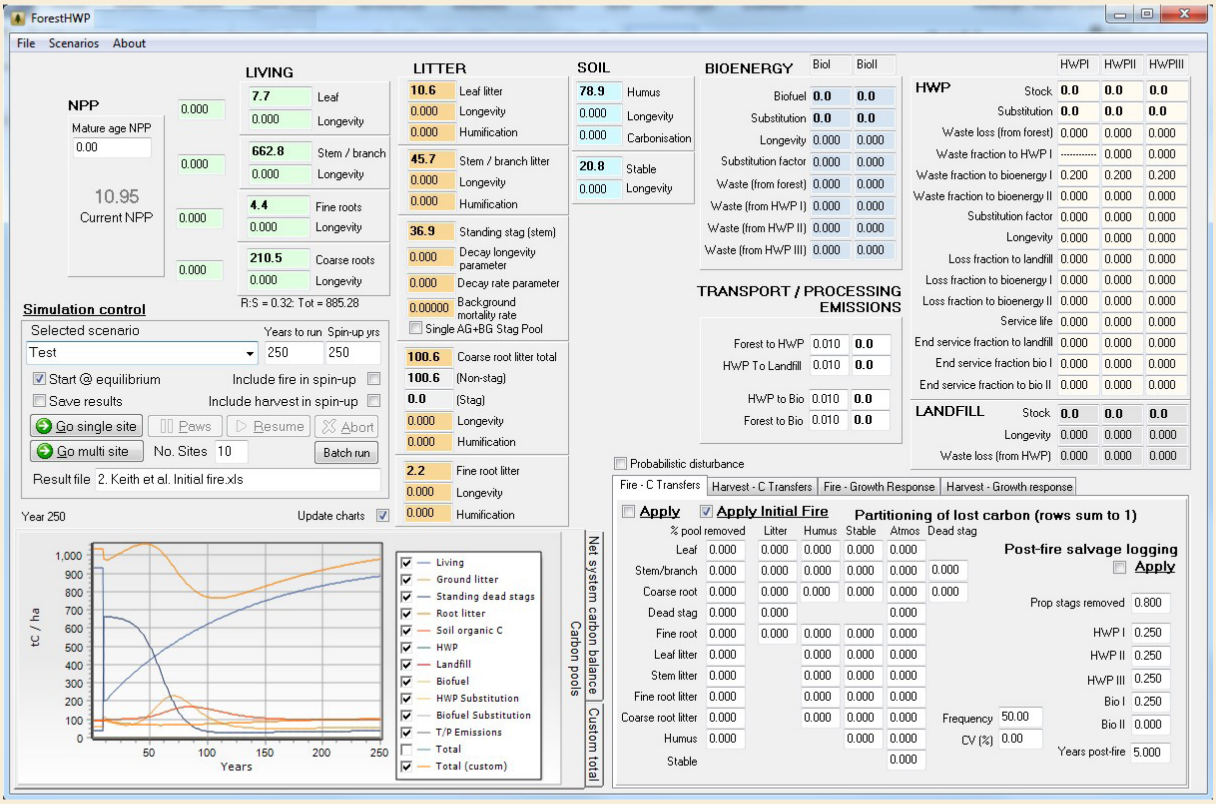
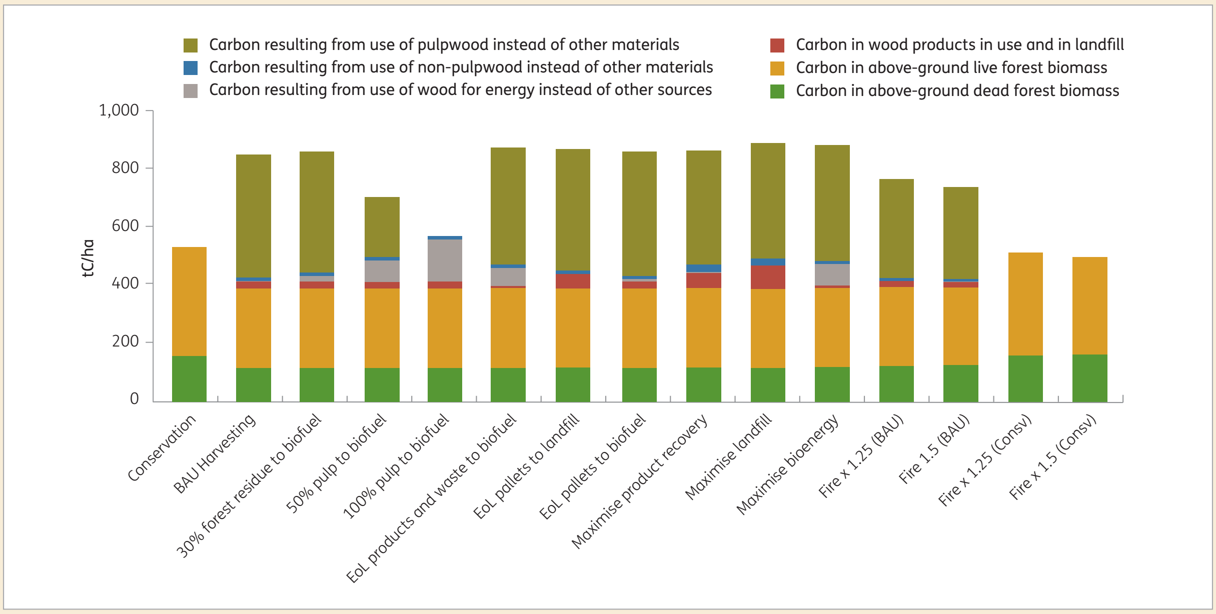


Image courtesy of Stephen Roxburgh, CSIRO

Figure 5.9: Long-term average results for mountain ash forest and forest products at the Victorian Central Highlands site, for each of the major carbon balance components, and alternative forest management and forest product scenarios



BAU, business as usual; EoL, end-of-life; HWP, harvested wood products.

Notes:

Six carbon pools are reported across 15 forest management scenarios.

Carbon in biomass is expressed as tonnes C per hectare of forest. Carbon in wood products is expressed as tonnes C deriving from one hectare of forest. Carbon resulting from use of wood instead of other materials or sources is expressed as the reduction in tonnes C added to the atmosphere due to use of wood from one hectare of forest.

Details of scenarios are given in Table 6.2 of Ximenes et al. (2016).

Source: redrawn from Ximenes et al. (2016).

Case study 5.3: Western Arnhem Land Fire Abatement (WALFA) project

Australia's vast northern tropical savannas[250] are extremely flammable. Fire has always been one of the most important tools utilised by Aboriginal people for managing their country. Following European settlement and the displacement of Aboriginal people from their clan estates, Aboriginal fire management began to break down across much of northern Australia. Fire regimes became dominated by bushfires in the late dry season. Large and environmentally destructive, these wildfires also contribute significantly to Australia's greenhouse gas emissions. In 2018, the *National Inventory Report 2016* stated that these grassland and woodland fires accounted for 9.5 million tonnes of CO_2 e, and are the main source of emissions in Grazing Land Management[251] (Table 11.36 of DoEE 2018b; see also Maraseni et al. 2016). However, initiatives by Indigenous fire managers and partner agencies to reinstate traditional early-dry-season burning practices have demonstrated that a significant reduction in carbon emissions is possible, along with highly valued social, cultural, environmental and economic benefits for Aboriginal landowners.

Western Arnhem Land in the Northern Territory of Australia is one such region which had a recent history of severe late-dry-season wildfires covering many thousands of square kilometres annually. In the late 1990s, Aboriginal landowners from Western and Central Arnhem Land and a small group of non-Aboriginal scientists began talking about fire in the landscape. Aboriginal elders – among the last to be born in the bush outside missions and settlements – spoke of "orphaned country", which had become unhealthy through being devoid of people undertaking customary fire management. These discussions led to the development of a vision of people living on healthy country, and ultimately to the program of fire management now known as the Western Arnhem Land Fire Abatement (WALFA) project (Russell-Smith et al. 2009).

Figure 5.10: Aboriginal rangers in Arnhem Land undertake ground burning in the early dry season

Continued

[250] A savanna is a tropical or subtropical, woodland/grassland ecosystem with trees sufficiently widely spaced that the canopy does not close. Areas of savanna where the canopy cover reaches or exceeds 20% are classified as woodland forest. Rainfall is seasonal, and dry-season fires are frequent.

[251] CO_2-e is 'carbon dioxide equivalent': one tonne of CO_2-e is one tonne of CO_2 or an amount of another greenhouse gas that has the same greenhouse capacity as one tonne of CO_2.

Continues

In 2006, the WALFA project commenced formal operation, with the goal of reinstating Indigenous fire management over the remote Arnhem Plateau. WALFA is a partnership between the five Aboriginal ranger groups with responsibility for that part of Western Arnhem Land, the Northern Territory Government, the Northern Land Council, the Darwin Centre for Bushfires Research, and ConocoPhillips (a global oil and natural gas company). With the advent of the Commonwealth Government Carbon Farming Initiative (CFI) and subsequent Emissions Reduction Fund (ERF) legislation, the WALFA project became the landscape-scale model upon which the approved Savanna Burning Methodology[252] was based, enabling registered fire projects to earn Australian Carbon Credit Units (ACCUs[253]).

To support their engagement with the Emissions Reduction Fund, and their production of ACCUs, the Aboriginal ranger groups with responsibility for the WALFA project in Arnhem Land formed Arnhem Land Fire Abatement (NT) Limited (ALFA; formerly WALFA Ltd). ALFA is a not-for-profit company limited by guarantee and owned exclusively by Aboriginal people with custodial responsibility for those parts of Arnhem Land under active bushfire management. ALFA registered the WALFA project as an eligible offsets project in 2014. Since then, ALFA has expanded to register and support five fire projects in central, north-east and south-east Arnhem Land.

The Arnhem Land fire abatement projects use strategic fire management activities (including early-dry-season burning and late-dry-season firefighting) to reduce the extent and severity of destructive late-dry-season bushfires and in doing so reduce the fire-generated emissions of greenhouse gases. One main activity is for Aboriginal ranger groups within the project areas to undertake aerial and ground burning in the early dry season to reduce fuel loads, protect important environmental and cultural sites, and to establish a mosaic of low-intensity burns around and within the project area (Figure 5.10). This reduces the intrusion of fires from neighbouring lands and contains other fires within the project area, thus reducing the total area that is burnt each year and shifting the seasonality of burning from late dry season to early dry season. This in turn reduces emissions because the resultant fires are less intense and overall less country is burnt each year. The five fire projects are operated by nine Aboriginal ranger groups, consisting of traditional custodians and their families. These ranger groups manage and implement all of the fire project operations in Arnhem Land including fire planning, consultations, early-dry-season burning, late-dry-season firefighting, data recording and fire monitoring.

The five registered fire projects in Arnhem Land cover an area of almost 80,000 km^2, which is an area larger than the area of Tasmania. To date, the projects have been issued with 1.8 million ACCUs representing an abatement of 1.8 million tonnes of CO_2-e. The fire projects in Arnhem Land account for 4 % of the 45.4 million ACCUs issued by the Clean Energy Regulator in Australia across all approved methodologies to date. The fire projects in Arnhem Land therefore make a very real contribution to reducing Australia's greenhouse gas emissions.

[252] Updated in April 2018: see www.environment.gov.au/climate-change/government/emissions-reduction-fund/methods/savanna-fire-management-2018-emissions-avoidance

[253] An ACCU represents one tonne CO_2-e stored by a project or the emission of one tonne CO_2-e which is avoided by a project.

Criterion 6

Maintenance and enhancement of long term multiple socio-economic benefits to meet the needs of societies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Use of timber in the construction industry.

Criterion 6 Maintenance and enhancement of long term multiple socio-economic benefits to meet the needs of societies

The 17 indicators in this criterion aim to show the extent to which Australia's forests contribute to national and regional economies, benefit personal and community wellbeing, and support cultural values.

Socio-economic data are important measures of the monetary and non-monetary value and benefits of forests to society. In addition, Australian communities, including Aboriginal and Torres Strait Islander communities (referred to in SOFR 2018 as Indigenous communities), have strong social, spiritual and cultural attachments to forests, whether for traditional needs, provision of wood and non-wood forest products and other benefits, direct and indirect employment, or active and passive recreation.

The indicators in this criterion are grouped into five sub-criteria.

Production and consumption

The first group of indicators, Indicators 6.1a to 6.1e, focusses on wood and non-wood forest products. As well as providing material used in everyday lives, wood from forests provides employment for workers in harvesting and processing, incomes to landholders and businesses, and revenues to governments. Many Australian non-wood forest products from Australian forests are also harvested and sold commercially, including for emerging export markets, while some industries are based on wild harvesting and hunting. Trends over time in the values and volumes of wood products are covered in Indicator 6.1a, while trends over time in the values and volumes of non-wood forest products are covered in Indicator 6.1b. Together, these indicators provide one assessment of the socio-economic benefits derived from forests.

The range of other services provided by Australia's forests, such as carbon sequestration, soil conservation, protection of catchments for water production, ecotourism, and biodiversity conservation, are the subject matter of Indicator 6.1c. There are markets or other economic mechanisms for capturing the value of some of these services, and for ascribing a monetary value to them. In addition, these services can provide social and environmental benefits to which monetary value cannot be ascribed.

Trends over time in production and consumption, presented in Indicator 6.1d, indicate the capacity of the forest and wood-processing industries, through domestic production and importation, to meet Australian society's demand for wood products, and are a measure of the industry's contribution to the national economy.

Rising global and national demands for forest products, with consequent increased demands on forest resources, have led to greater reuse and recycling of forest products. Considerable quantities of wood-based forest products, such as structural timbers, pulp, paper, and sawmill residue, are recycled in Australia. These are reported in Indicator 6.1e.

Investment

Indicator 6.2a reports data on investment in forest management, that is, expenditure in developing, maintaining and obtaining goods and services from forests, as a measure of the economic commitment to forest utilisation and management.

Both state and territory forest management agencies and private sector entities undertake many activities that constitute forest management. However, differences in the classification of activities, accounting arrangements and reporting timelines, and the commercial-in-confidence nature of some of this information, mean that it is not possible to calculate a national figure for expenditure on forest management. Expenditure on the management of forests in nature conservation reserves is also generally unavailable in a consistent form. Data on establishment of new plantations and re-establishment of harvested plantations are presented as an indication of investment in future wood availability.

Investment in research, development and adoption of new or improved technologies can lead to improvements in forest management and industry practices. This is reported in Indicator 6.2b across the forestry and wood products industry sector, by subsector.

Recreation and tourism

Australia's forests are highly valued for recreation and tourism. Indicators 6.3a and 6.3b assess the area of forest available for recreation and tourism, and the range and use of activities available.

An area of forest is considered to be available for recreation and tourism if there is no legal or other prohibition on public access to the forest. This includes most publicly owned forested lands designated as nature conservation reserves or for multiple use, as well as some private forest areas. Some activities are only permitted in some areas to ensure visitor safety, or to protect specific scientific, natural, cultural or water-supply values; difficulties of access may also restrict public use of some areas of forests.

Indicator 6.3b describes the wide range of forest-based recreation and tourism facilities available. Some facilities, such as walking and riding tracks, picnic sites and campgrounds, are provided specifically to meet the needs of recreational visitors and tourists. Other facilities, such as roads and vehicular tracks, are provided for a range of management purposes but are also available for use for recreation and tourism. Indicator 6.3b also presents available data on visitor numbers, but this is often not specific to forest areas, and the dispersed nature of forest tourism and recreation means that data on use are limited across jurisdictions and tenures, and difficult to compile nationally.

Cultural, social and spiritual needs and values

Forests are highly valued by the community for their wide range of cultural, social and spiritual values. These values are addressed in Indicators 6.4a to 6.4d.

Indicator 6.4a reports the area of forest to which Australia's Indigenous peoples have use and rights, as recognised through formal and informal management regimes. Access, management and ownership are key parts of the relationship of Indigenous people with land. The Indigenous estate can be broadly divided into categories based on the degree of Indigenous ownership, management and other rights over the land.

The extent to which Australia's Indigenous communities participate in forest management reflects their connection with the land, and the integration of Indigenous values into forest management practice, policy and decision-making; this is described in Indicator 6.4c. Effective Indigenous participation can occur through a variety of direct or consultative mechanisms, but it is difficult to measure the extent of this participation at the national scale.

Australia's forests include many sites that provide evidence of the interactions between non-Indigenous people and forest landscapes, and the activities that have occurred on the continent since first European settlement. The wide variety of sites, features and structures in forests that are formally managed to protect recorded non-Indigenous cultural values are described in Indicator 6.4b.

Understanding the importance that people place on Australia's forests, as reported in Indicator 6.4d, provides an insight into the level of acceptance and approval by communities of activities related to forest management.

Sawn pine timber, Mount Gambier.

Employment and community needs

The final four indicators in Criterion 6, Indicators 6.5a to 6.5d, deal with employment and wage and injury rates in the forestry and wood products sector of the economy, and with the resilience of forest-dependent Indigenous and non-Indigenous communities to changing social and economic conditions.

Employment levels, reported in Indicator 6.5a, are an important measure of the contribution of forests to viable communities and the national economy. A sustainable industry will maintain wage rates, workforce health and worker safety at levels that are comparable with national averages for similar occupations, and these parameters are reported in Indicator 6.5b.

The Australian forestry and wood products sector has changed substantially in recent years. There have been reductions in the areas of native forest available for harvest and consequently in the volume of wood harvested from native forests. An increasing proportion of wood has been harvested from plantations, although plantation expansion has recently ceased and there has been rationalisation of the ownership of existing plantations. Some older processing facilities have been closed or decommissioned, and some new processing facilities developed.

The capacity of Indigenous and non-Indigenous communities to accommodate and adapt to such changes is influenced by the level of their economic dependence on the forestry industries, and by the resources on which they can draw to assist them in responding to change. Community resilience can be measured in different ways, and is sometimes used interchangeably with adaptive capacity, since increasing adaptive capacity will enhance community resilience. The resilience of forest-dependent communities to economic and social changes is assessed in Indicator 6.5c for non-Indigenous communities, and in Indicator 6.5d for Indigenous communities.

This icon indicates data, maps or graphics from *Australia's State of the Forests Report 2018* that are available for electronic download. Data used in figures and tables in this criterion, together with higher resolution versions of maps, are available via www.doi.org/10.25814/5bda972cd76d9 and www.doi.org/10.25814/5be3bc4321162.

Indicator 6.1a

Value and volume of wood and wood products

Rationale

This indicator measures the size and economic contribution of the wood products sector to Australia's economy. Analysis of trends in the value and volume of wood and wood products enables socio-economic benefits derived from the forest industry to be assessed.

Key points

- The volume of Australia's log harvest in 2015–16 was 30.1 million cubic metres, a 13% increase from 26.5 million cubic metres in 2010–11.
  - Over this five-year period, the volume of logs harvested from native forests declined from 6.5 million cubic metres to 4.1 million cubic metres, a decrease of 37%.
  - In comparison, the volume of logs harvested from commercial hardwood and softwood plantations increased from 20.0 million cubic metres to 26.0 million cubic metres, an increase of 30%.
  - In 2015–16, 86% of the volume of logs harvested in Australia was from commercial plantations.
- The value of logs harvested from native forests and commercial plantations increased by 22% over the reporting period, from $1.9 billion in 2010–11 to $2.3 billion in 2015–16[254].
  - This increase occurred for harvested plantation softwood sawlogs, and for plantation softwood and hardwood export pulplogs, due mostly to the increases in harvest volumes of these log types over the same period.
- The value of production (total industry turnover, or sales and service income) of the wood products industries decreased by 2% between 2010–11 and 2015–16, from $24.0 billion to $23.7 billion.
  - The total volume of sawnwood production increased by 12% between 2010–11 and 2015–16, from 4.6 million cubic metres to 5.1 million cubic metres. The value of sawnwood production decreased by 7% between 2010–11 and 2014-15, from $3.8 billion to $3.5 billion.
  - The total volume of wood-based panel production decreased by 2% between 2010–11 and 2015–16, from 1.73 million cubic metres to 1.70 million cubic metres. The value of wood-based panel production decreased by 3% between 2010–11 and 2015–16, from $1.62 billion to $1.57 billion.
  - The total weight of paper and paperboard production increased by 2% between 2010–11 and 2015–16, from 3.16 million tonnes to 3.22 million tonnes. The value of paper and paperboard production decreased by 4% between 2010–11 and 2015-16, from $10.9 billion to $10.5 billion.
- The value added by the forest and wood products industries in 2010–11 was $8.3 billion, a contribution to Australia's gross domestic product of 0.59%. In 2015–16, the value added was $8.6 billion, representing a contribution to gross domestic product of 0.52%.

This indicator presents information on the value and volume of wood and wood products that are directly generated by the forest and wood products industries. Secondary or flow-on economic activity, such as turnover generated through indirect employment, is not examined.

Estimates of value and volume of wood products are subject to various assumptions; the assumptions for volume estimates may be different from the assumptions for value estimates.

[254] All dollar figures are unadjusted for inflation.

Harvested logs

The volume of Australia's log harvest in 2015–16 was 30.1 million cubic metres, a 13% increase from 26.5 million cubic metres in 2010–11 (Figure 6.1). More than half (54%) of the logs harvested in Australia in 2015–16 were softwood, almost entirely from commercial plantations. The remainder were hardwood logs from commercial plantations (33%) and native forests (13%). Native forest softwoods, mostly from New South Wales and Queensland, represent a very small proportion of the total log harvest.

Australia's native forest resource base available for wood production has changed over the reporting period, as explained in Indicator 2.1a. In 2010–11, the native forest log harvest contributed 25% (6.5 million cubic metres) of the total harvested log volume, and this had declined to 14% (4.1 million cubic metres) by 2015–16, a reduction in volume of 37% (Figure 6.1). The lower native forest log harvest was mostly comprised of a decrease in the volume of pulplogs harvested for woodchip export, which declined from 3.3 million cubic metres to 1.3 million cubic metres over the reporting period, a fall of 61%.

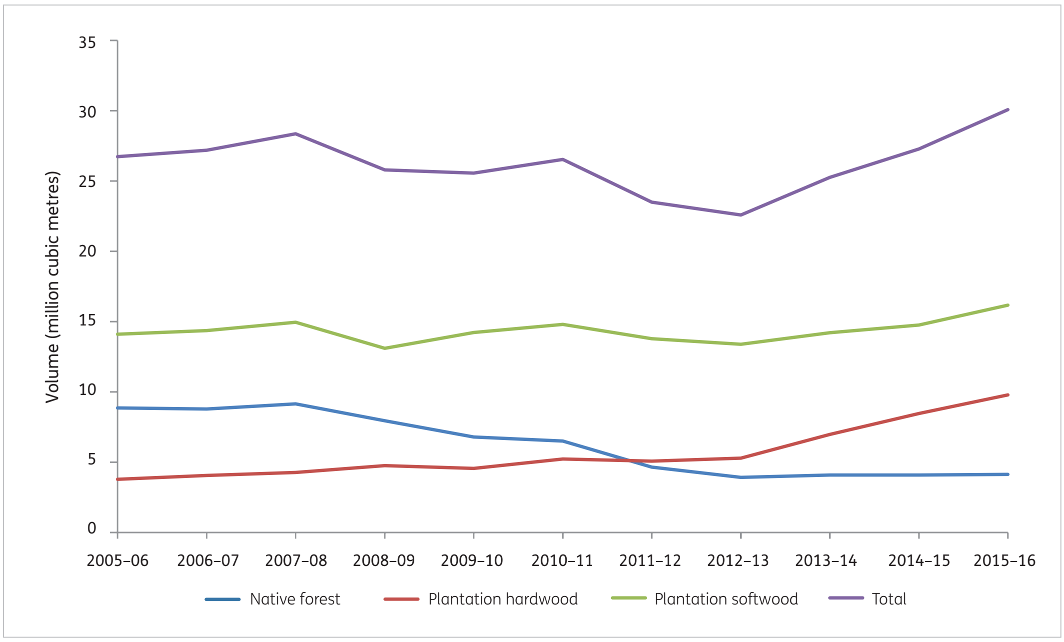
The decline in native forest log harvest has occurred at the same time as increases in log harvest from Australia's commercial hardwood plantation estate. The hardwood plantation log harvest increased by 87% from 5.2 million cubic metres in 2010–11 to 9.8 million cubic metres in 2015–16 (Figure 6.1). The largest change came from a higher harvest of hardwood plantation pulplogs for woodchip export, which almost doubled over this reporting period, from 4.8 million cubic metres to 9.3 million cubic metres. Harvests of softwood logs from commercial plantation forests also increased between 2010–11 and 2015–16, from 14.8 million cubic metres to 16.2 million cubic metres.

Overall, the volume of logs harvested from commercial softwood and hardwood plantations increased by 30% from 20.0 million cubic metres in 2010–11 to 26.0 million cubic metres in 2015 16. In 2015–16, a total of 86% of the volume of logs harvested in Australia were harvested from commercial plantations, compared to 75% in 2010–11[255].

The value (calculated at the mill door) of harvested logs increased by 22% from $1.9 billion to $2.3 billion between 2010–11 and 2015–16 (Figure 6.2). This increase occurred for harvested plantation softwood sawlogs, and for plantation softwood and hardwood export pulplogs, due mostly to the increases in harvest volumes of these log types over the same period. The value of logs harvested from commercial plantations increased from $1.36 billion to $1.88 billion over this period, while the value of logs harvested from native forests decreased from $0.50 billion to $0.39 billion.

In 2015–16, the largest contributors to Australia's total log harvest, for both volume and value, were Victoria and New South Wales (Figures 6.3 and 6.4). Victoria accounted for 8.2 million cubic metres (27%) of total volume and $599 million (26%) of total value. New South Wales contributed 5.6 million cubic metres (19%) to total volume and $458 million (20%) to total value.

Figure 6.1: Volume of logs harvested by log type, 2005–06 to 2015–16



Note: Data for native forest logs include the small volume of native forest softwood (cypress pine) sawlogs.
Source: ABARES (2017b).

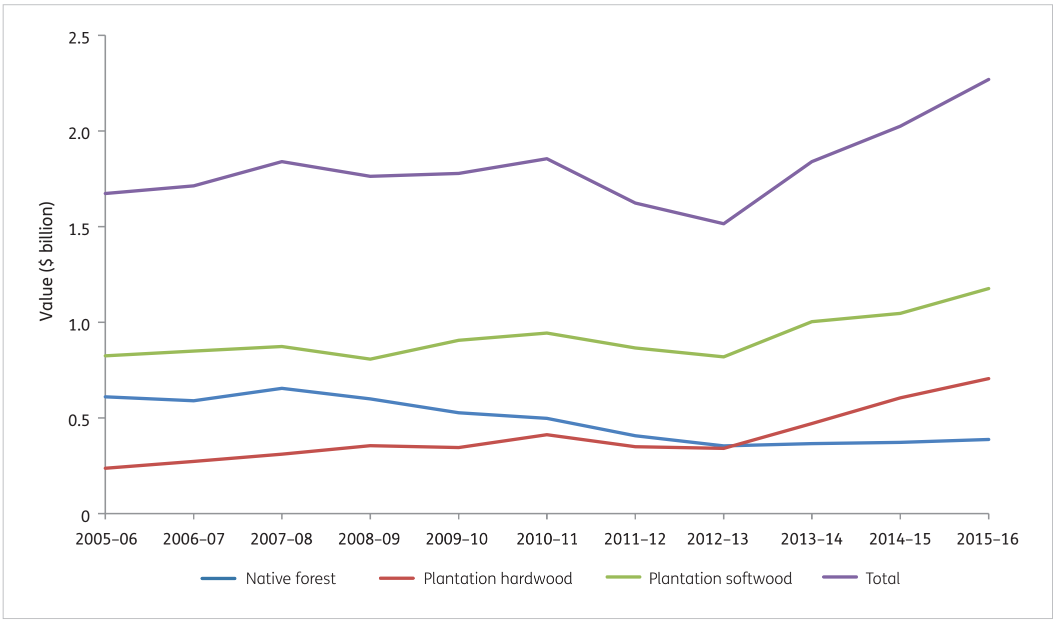
The data used to create this figure, and a copy of the figure, are available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

[255] SOFR 2013 reported that 76% of the volume of logs harvested in 2010–11 was from commercial plantations, but this was a rounding error. The correct figure for 2010–11 is 75%.

CRITERION 6

6.1a

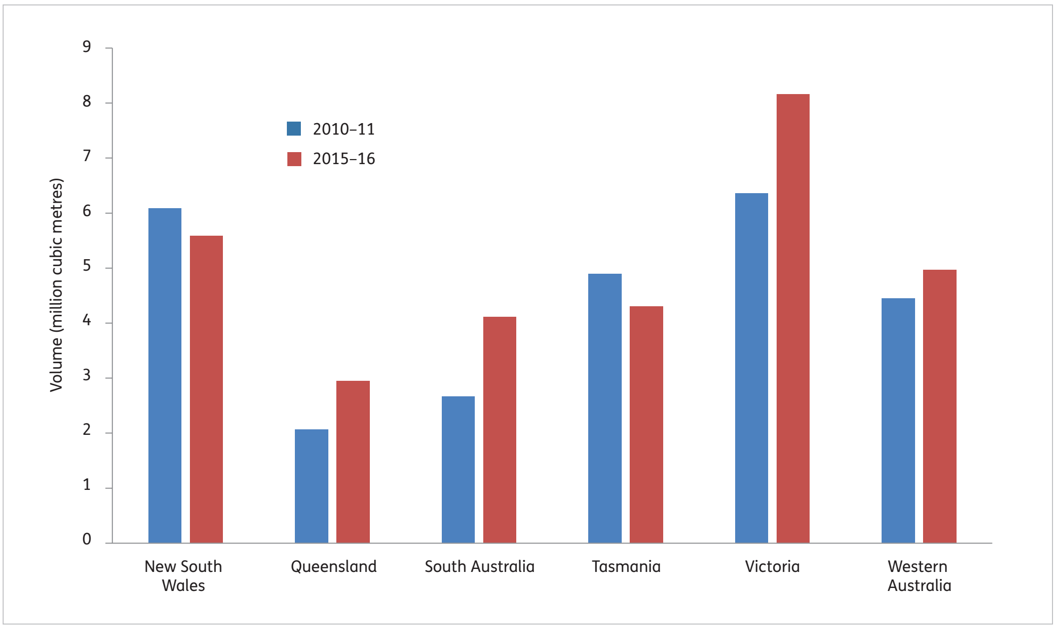
Figure 6.2: Value of logs harvested by log type, 2005–06 to 2015–16



Notes: Value represents estimated gross value of logs delivered to mill door or wharf gate. Data for native forest logs include the small volume of native forest softwood (cypress pine) sawlogs.
Source: ABARES (2017b).

The data used to create this figure, and a copy of the figure, are available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

Figure 6.3: Volume of logs harvested, by jurisdiction, 2010–11 and 2015–16



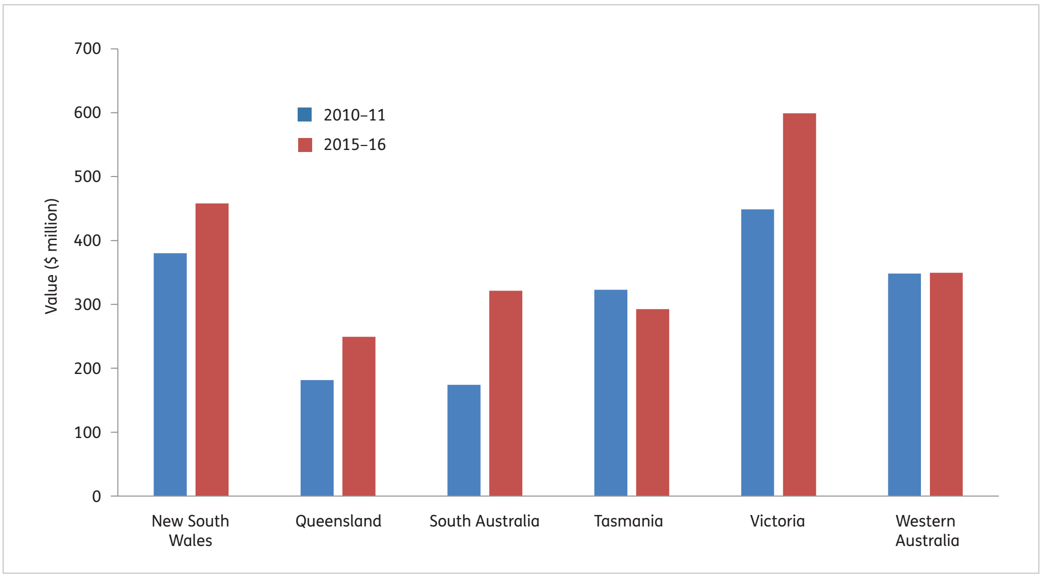
Note: Harvest volume data for ACT and NT are zero or not available for 2010-11 and 2015-16.
Source: ABARES (2017b).

The data used to create this figure, and a copy of the figure, are available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

The most substantial changes in log harvest volumes between 2010–11 and 2015–16 were increases in South Australia (54%) and Queensland (43%). Victoria recorded the largest absolute volume increase (1.8 million cubic metres or 28%), while volumes fell in Tasmania (12%) and New South Wales (8%).

The average unit value of logs (the value per cubic metre) differs between states, mainly due to differences in the type and quality of log harvested (such as softwood or hardwood, and pulplog or sawlog) and wood source (such as native forest or commercial plantation).

Figure 6.4: Value of logs harvested, by jurisdiction, 2010–11 and 2015–16



Note: Harvest volume data for ACT and NT are zero or not available for 2010-11 and 2015-16.

Source: ABARES (2017b).

The data used to create this figure, and a copy of the figure, are available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

Table 6.1: Turnover (sales and service income) in wood products industry, 2010–11 to 2015–16

		2010–11	2011–12	2012–13	2013–14	2014–15	2015–16[a]
Total wood products manufacturing	$ billion	24.0	21.4	20.1	20.0	22.2	23.7
Total manufacturing	$ billion	389.2	399.2	387.5	377.4	373.7	371.5
Contribution of wood product industries to total manufacturing	%	6.2	5.4	5.2	5.3	5.9	6.4

Note: Turnover (sales and service income) is defined as sales of goods whether or not manufactured by the business, exclusive of goods and services tax.

[a] The 2015-16 turnover data for total wood products manufacturing include an estimated turnover figure for the sawnwood industry.

Source: ABARES (2017b).

This table, together with other data for Indicator 6.1a, is available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

Wood products

Australia's wood products industry includes businesses that manufacture sawnwood, wood-based panels, and paper and paperboard products, each of which is discussed below, as well as other sectors. In addition to these products, there is a growing contribution from businesses that manufacture engineered wood products.

The value of production (total industry turnover, or sales and service income) in wood products manufacturing decreased by 2% between 2010–11 and 2015–16, from $24.0 billion to $23.7 billion (Table 6.1). In 2015–16, wood products industries contributed 6.4% of total national turnover of manufacturing, compared to 6.2% in 2010–11. The increased contribution was due to total manufacturing turnover decreasing at a faster rate (4.5% between 2010–11 and 2015–16) than total wood product manufacturing turnover over that period.

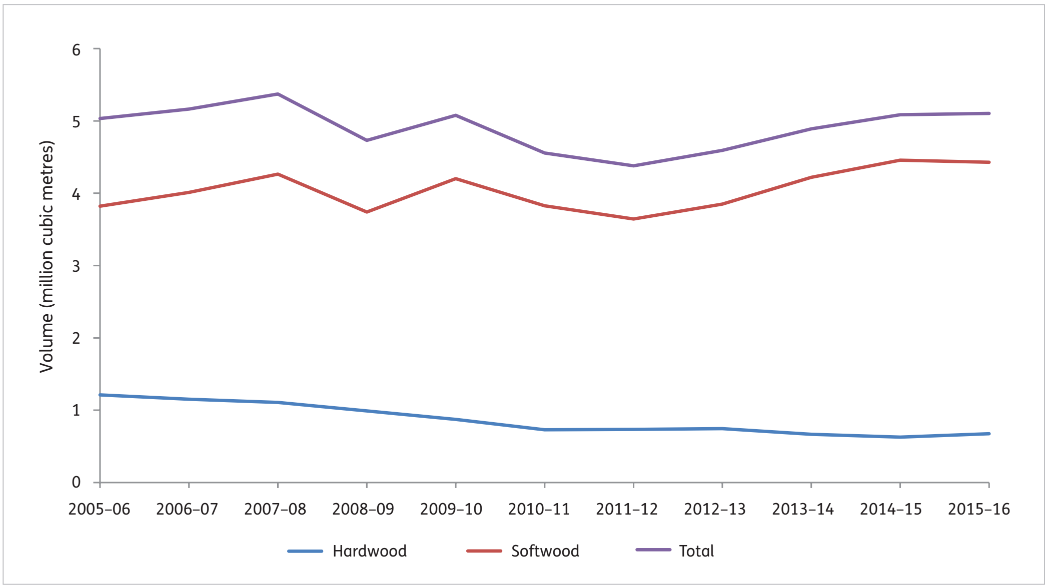
Sawnwood

The total volume of sawnwood production increased by 12% between 2010–11 and 2015–16, from 4.6 to 5.1 million cubic metres (Figure 6.5). This increase was the result of a rise in softwood sawnwood production, which increased by 16% over the same period, from 3.8 million cubic metres to 4.4 million cubic metres. In comparison, hardwood sawnwood production decreased by 8%, from 730 thousand to 675 thousand cubic metres.

Changes in hardwood and softwood sawnwood production over the reporting period reflect the response of the wood products industry to competitive pressures, expectations of future wood product demand and log supply (Gavran et al. 2014), and resource availability. Over the reporting period, ongoing increase in the area of native forest managed for conservation in Australia has reduced access to native forest for wood production, thereby reducing the amount of hardwood sawlogs from native forests available for the wood products industry.

The commercial hardwood plantation estate, which produced 9.8 million cubic metres of hardwood logs in 2015–16, supplied only 0.2 million cubic metres of sawlog. This was because only

Figure 6.5: Volume of sawnwood production, 2005–06 to 2015–16



Source: ABARES (2017b).

The data used to create this figure, and a copy of the figure, are available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

Table 6.2: Turnover (sales and service income) in selected wood products industries, 2010–11 to 2015–16

Product type		2010–11	2011–12	2012–13	2013–14	2014–15	2015–16[a]
Sawnwood	$ billion	3.8	3.4	n.a.	n.a.	3.5	n.a.
Wood-based panels	$ billion	1.62	1.44	1.26	1.33	1.46	1.57
Paper and paperboard products	$ billion	10.9	9.7	9.9	9.8	10.1	10.5

n.a., data not available

[a] An estimated 2015-16 turnover figure for sawnwood is included in the total wood products manufacturing 2015-16 turnover figure in Table 6.1.

Notes: Sawnwood comprises 'log sawmilling' and 'timber resawing and dressing'. Wood-based panels comprises 'veneer and plywood' and 'reconstituted wood product'.

Source: ABARES (2017b).

This table, together with other data for Indicator 6.1a, is available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

a small proportion of hardwood plantations are managed for sawlog production, and those are mostly not of harvestable age; and because there are substantial technical and commercial impediments to growing hardwood sawlogs in plantations. The majority of hardwood plantation production is pulplogs for woodchip export; small proportions are used for domestic paper production, wood-based panels and sawlogs.

The value of sawnwood production (sales and service income, or turnover) decreased by 7% between 2010–11 and 2014–15, from $3.8 billion to $3.5 billion (Table 6.2). No comparison could be made with 2015–16 as data are unavailable.

Wood-based panels

The total volume of wood-based panel production decreased by 2% between 2010–11 and 2015–16, from 1.73 million cubic metres to 1.70 million cubic metres (Figure 6.6). Plywood was the only product that increased in production over the reporting period, by 22% from 140 thousand cubic metres to 171 thousand cubic metres. Both particleboard and medium-density fibreboard production declined, by 3% and 5%, respectively.

The value of Australia's wood-based panel production decreased by 3% between 2010–11 and 2015–16, from $1.62 billion to $1.57 billion (Table 6.2).

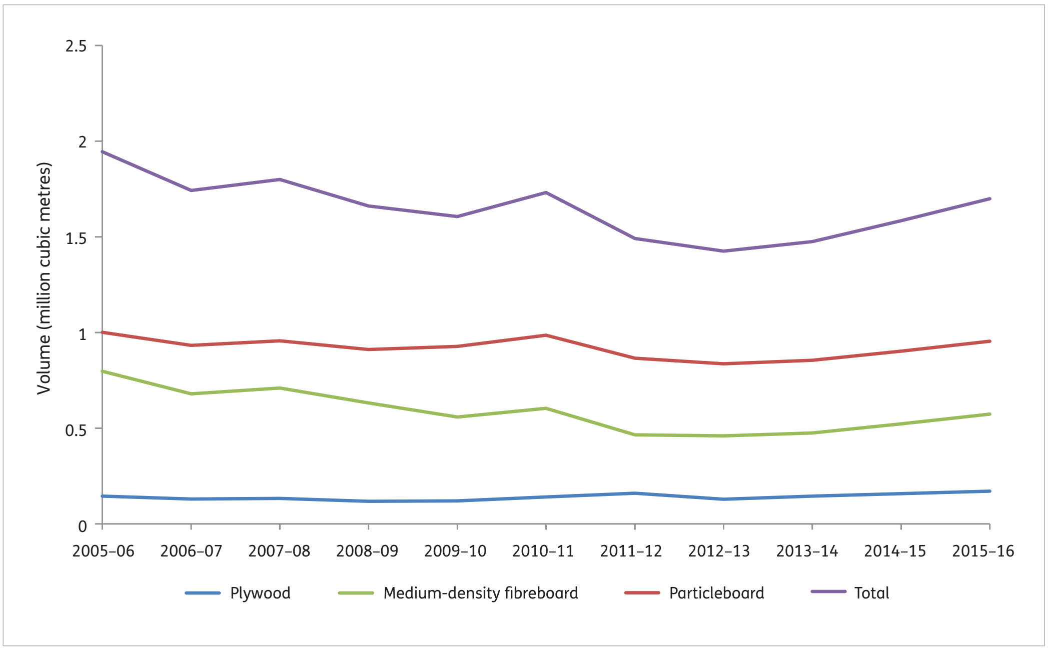
Paper and paperboard products

The total weight of paper and paperboard production increased by 2% between 2010–11 and 2015–16, from 3.16 million tonnes to 3.22 million tonnes (Figure 6.7).

Paper and paperboard products in Australia in 2015–16 comprised newsprint, printing and writing paper, household and sanitary products, and packaging and industrial products. Of these products, the weight of printing and writing paper produced increased the most, by 50% from 342 thousand tonnes in 2010–11 to 513 thousand tonnes in 2015–16. By comparison, newsprint production decreased by 27% over the reporting period, from 439 thousand tonnes to 319 thousand tonnes (Figure 6.7).

The value of Australia's paper and paperboard production decreased by 4% between 2010–11 and 2015–16, from $10.9 billion to $10.5 billion (Table 6.2).

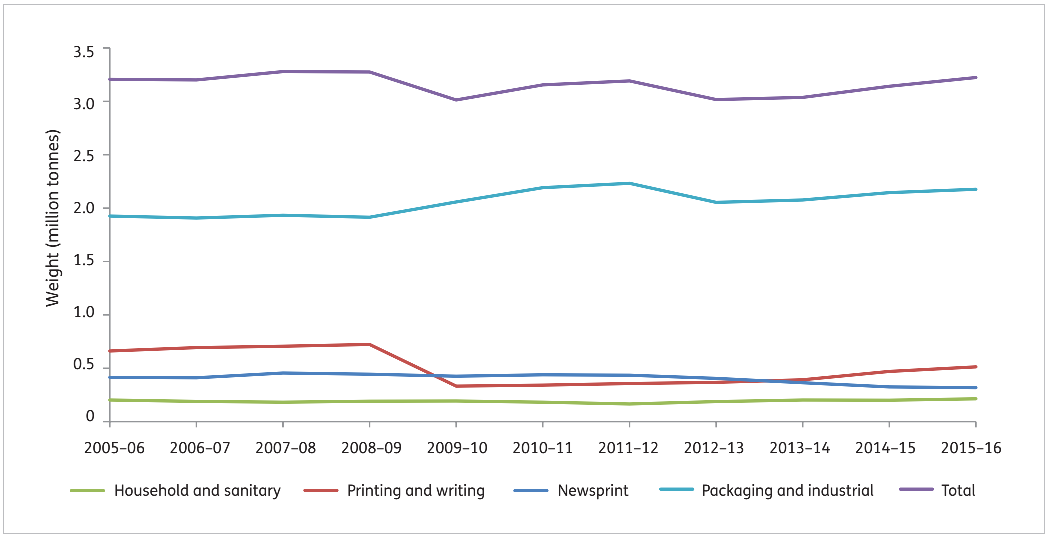
Figure 6.6: Volume of wood-based panel production, 2005–06 to 2015–16



Source: ABARES (2017b).

The data used to create this figure, together with other data for Indicator 6.1a, are available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

Figure 6.7: Weight of paper and paperboard production, 2005–06 to 2015–16



Source: ABARES (2017b).

The data used to create this figure, together with other data for Indicator 6.1a, are available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

CRITERION 6

6.1a

Contribution of the forestry and wood products industries

The value added by the Australian forestry and wood products industries[256], referred to as 'industry value added'[257], was $8.3 billion in 2010–11 and contributed 0.59% of Australia's gross domestic product (GDP) in that year (Table 6.3). By 2012–13, industry value added had decreased to $7.0 billion, and the contribution to GDP had decreased to 0.46%, driven largely by a downturn in the domestic housing market and softening in wood products exports, both of which are important drivers of economic growth in Australia's forestry and wood products industries. By 2015–16, and following a recovery in domestic dwelling construction and wood products exports, industry value added increased to $8.6 billion. The contribution to GDP increased, but only to 0.52%, as national GDP grew faster than industry value added between 2010–11 and 2015–16 (Table 6.3).

Hardwood sawmill, Eden, NSW.

Table 6.3: Forestry and wood products industries value added, 2010–11 to 2015–16

	2010–11	2011–12	2012–13	2013–14	2014–15	2015–16
Forestry and wood products manufacturing ($ billion)	8.29	7.35	7.01	7.71	7.91	8.60
National GDP ($ billion)	1,410	1,492	1,528	1,590	1,617	1,655
Proportion of national GDP (%)	0.59	0.49	0.46	0.49	0.49	0.52

Source: ABARES (2017b).

This table, together with other data for Indicator 6.1a, is available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

[256] These industries are defined according to the Australian and New Zealand Standard Industrial Classification (ANZSIC) 2006. The forestry industry is equivalent to Division A, Subdivision 3 – forestry and logging. The wood products industry consists of Division C, Subdivision 14 – wood product manufacturing; and Division C and Subdivision 15 – pulp, paper and paperboard manufacturing (Trewin and Pink 2006).

[257] 'Industry value added' is a measure of economic activity that represents the value added by an industry to its intermediate inputs (that is, the value added to the goods and services other than capital that are inputs to the production process). It is the measure of the contribution by manufacturing to gross domestic product. In the context of SOFR 2018, 'industry value added' omits some downstream parts of the forestry and wood products industries, particularly wholesaling, retailing and value-adding (and thus omits the manufacturing of some commodities).

Indicator 6.1b

Values, quantities and use of non-wood forest products

Rationale

This indicator measures the quantities, values and use of non-wood products. It enables socio-economic benefits to be monitored by ascertaining trends in quantities, values and use of non-wood products.

Key points

- Many Australian non-wood forest products (NWFPs) are commercialised, and supply domestic and export markets. However, for most NWFPs there are insufficient data to assess production quantities and value.
- Some NWFP industries are based on products derived from native species, including crocodile eggs, mud crabs, and eucalyptus and tea tree oil. Other NWFP industries are based on products derived from animals that are pests, such as wild pigs and deer. For both these categories of NWFP, only some of the production derives from forest.
- Harvest of game pigs and kangaroos for meat declined between 2011–12 and 2015–16, while harvest of deer and goats for meat was variable over time. Production of crocodile hides decreased slightly over this period.
- Over the period 2011–16, an annual average of 21 thousand tonnes of honey was produced, much of which was produced from forested lands. The volume of honey production declined by 17% during this period, while the gross value of production increased by 39% to $110 million in 2015–16.
- In 2011, the gross annual value of production of NWFPs regarded as having high forest dependence was $198 million. A more recent estimate of the gross value of production for these products was not available. However, between 2011 and 2016 the gross annual value of production increased for tea tree, and for honey and beeswax, and varied or decreased for some other products.

Non-wood forest products (NWFPs) are products of biological origin other than wood that are derived from forests. In some countries, people in rural communities depend on NWFPs for everyday necessities and for subsistence income. In Australia, many NWFPs have been commercialised and are traded both domestically and internationally (Bird 2010; Hansda 2009). This indicator provides an overview of selected commercialised NWFPs; there are insufficient data to examine the full range of NWFPs. Some tree-based industries are not discussed in this indicator because they are regarded as horticulture, rather than forest-based industries. Some other forest species (e.g. flowering shrubs) that have been fully commercialised outside forests are also not discussed, because none of their production derives from forest.

Information about the sustainability of harvest of NWFPs is presented in Indicator 2.1d.

Classification of non-wood forest products

Not all products reviewed in this indicator are fully forest-dependent, because the plants and animals on which the sector is based exist both within forests and outside forests. For these products, data on the proportion obtained from forests are generally not available. Lack of data is a major barrier to providing a complete measure of the harvested quantities, market value and usage of NWFPs.

The non-exhaustive list of NWFPs in Table 6.4 features products considered to have high forest dependence or to be derived from forest-based animal and plant stocks. A portion of the harvest of feral buffalo (*Bubalus bubalus*) also derives from forests (Foster 2014), but this industry is not reported here.

The estimated gross value of production of products with a high forest dependence was reported as $126 million in 2006–7, and $198 million in 2011–12 (MIG and NFISC 2013). These figures do not include forest-related production in the goat, kangaroo and wallaby industries. A more recent

Table 6.4: Estimated gross value of production ($'000) of selected non-wood forest products, 2011–12 to 2015–16

Sector	2011–12	2012–13	2013–14	2014–15	2015–16
Crocodile products	51,859	–	–	–	28,100
Mud crabs[b]	22,900	21,400	21,300	19,000	15,900
Deer	1,688[a]	1,818	2,148	2,177	2,245
Game pigs	9,456[a]	1,719	1,490	3,124	5,757
Eucalyptus oil	1,260	–	–	–	–
Tea-tree oil	12,132	–	–	–	28,582
Native bush foods	17,915	–	–	–	–
Sandalwood	14,740	–	–	–	–
Honey and beeswax	79,376[a]	88,374	88,037	100,553	110,241

–, not available

[a] Figures for 2011–12 differ slightly from those in SOFR 2013 due to updated production and or price data.

[b] Queensland only.

Note: Gross value of production (GVP) is the value placed on recorded production at the wholesale prices realised in the marketplace, where the marketplace is at a market point to be consumed locally or exported, or refers to a raw material for a secondary industry, or is at a market point before being value-added by an industry. In many cases, the value of production of an industry will be less than the value of exports because of substantial value-adding through processing before export.

Source: MIG and NFISC (2013); Foster (2014); DAF (2017); ABARES (2018).

This table, together with other data for Indicator 6.1b, is available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

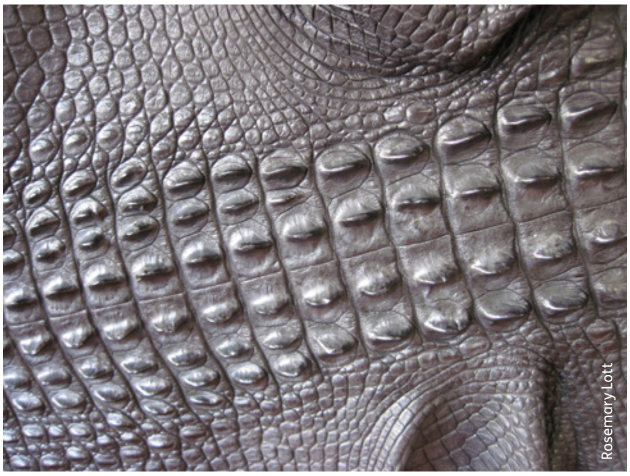
estimate of the gross value of production for products with a high forest dependence was not available, however current data (Table 6.4) show an increase in the gross annual value of production of some products (including tea tree oil, and honey and beeswax) between 2011 and 2016, while some other products decreased in total value.

Crocodiles

The crocodile farming industry depends on the commercial harvesting of eggs from the wild, incubating these eggs, and raising hatchlings, a process known as ranching (CFANT 2015). Crocodile hatchlings are used primarily to raise crocodiles for skin products and meat. Most crocodile farms raise saltwater crocodiles (*Crocodylus porosus*), although a few farms also raise freshwater crocodiles (*C. johnstoni*). The harvesting of wild eggs is often from mangrove forests and forested wetlands (including melaleuca forest), so crocodile eggs are considered a non-wood forest product. Some hatchlings and juveniles are also harvested from the wild.

Production of live crocodile eggs from farms and harvest from the wild in the Northern Territory totalled an average of around 75,000 eggs per year between 2011 and 2016, about twice the level of the previous SOFR reporting period. Most of the eggs were harvested from the wild (Table 6.5). To help prevent over-harvesting, the Northern Territory Government regulates the harvest of wild crocodile eggs by requiring and managing permits for harvest. The management program for the saltwater crocodile (*C. porosus*) in the Northern Territory for 2016–2020 allows an increased harvest ceiling of 90,000 viable eggs per year, representing a potential 40% increase in egg harvest[258].

Crocodile hide production has increased substantially over the long term, but dipped during the five-year reporting period (Table 6.6). Around 80% of production is exported. The major use for Australian crocodile skins is the manufacture of



Crocodile products (considered non-wood forest products because eggs harvested from wetland forests are used to raise crocodiles).

high-quality leather goods. Some pieces of crocodile leather are also exported. Australian crocodile meat production and exports from 2011–12 to 2015–16 are shown in Table 6.7. Other parts of the crocodile (such as teeth, skulls and feet) are used as components in accessories, jewellery, medicine, and the production of oils.

258 The *Northern Territory crocodile farming industry strategic plan 2015–21* (CFANT 2015) states a harvest ceiling of 100,000 (live) eggs, while the *Wildlife Trade Management Plan for the Saltwater Crocodile (*Crocodylus porosus*) in the Northern Territory of Australia, 2016–2020* (DLRM 2015) specifies 90,000 viable eggs. Modelling indicates that a harvest of 120,000 eggs from the wild would equate to 100,000 live eggs (the harvest unit used in previous management programs) or 90,000 viable eggs (the harvest unit used in the *Wildlife Trade Management Plan for the Saltwater Crocodile (*Crocodylus porosus*) in the Northern Territory of Australia, 2016–2020*) (DLRM 2015). Modelling also indicates that this harvest ceiling is less than 50% of the total number of eggs laid each year and, because survival in the wild from egg to later age classes is less than 25%, the egg harvest mostly represents displaced rather than additional mortality (DLRM 2015).

Table 6.5: Crocodile egg harvest from the wild for commercial use, Northern Territory, 2011–12 to 2015–16

Period	2011–12	2012–13	2013–14	2014–15	2015–16
Harvest ceiling	60,000	60,000	70,000	70,000	70,000
Eggs permitted	52,500	58,500	60,750	68,000	70,000
Eggs harvested	42,171	47,610	51,238	50,022	47,194

Source: Saalfeld and Fukuda (2017) and previous saltwater crocodile monitoring reports at denr.nt.gov.au/land-resource-management/saltwater-crocodile-monitoring.

This table, together with other data for Indicator 6.1b, is available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

Table 6.6: Australian crocodile hide production and exports, 2011–12 to 2015–16

Product statistic	Metric	2011–12	2012–13	2013–14	2014–15	2015–16
Production	Number of hides (saltwater and freshwater)	48,532	–	–	–	41,852
Exports	Number of hides (saltwater and freshwater)	36,560	59,518	52,461	37,524	35,111
Exports	Value of hides ($ million)	14.7	28.4	25.2	23.6	22.2

–, not available

Source: MIG and NFISC (2013); ABS (2017d); Northern Territory Department of Primary Industry Fisheries; Queensland Department of Environment and Heritage Protection.

This table, together with other data for Indicator 6.1b, is available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

Table 6.7: Australian crocodile meat production and exports, 2011–12 to 2015–16

Product statistic	Metric	2011–12	2012–13	2013–14	2014–15	2015–16
Production	Tonnes	243.0	–	–	–	132.3
Exports	Tonnes	25.9	29.3	24.0	17.1	26.4
Exports	$ '000	321	369	259	182	317

–, not available

Source: ABS (2017d); ABARES (2018).

This table, together with other data for Indicator 6.1b, is available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

Deer

Wild (feral) deer are common and widespread in parts of Queensland, South Australia, Tasmania and Victoria, and their numbers are increasing in New South Wales; they are less common in the Northern Territory and Western Australia (Davis et al. 2016; NSW DPI[259]). Six species have established wild populations, including fallow deer (*Dama dama*), red deer (*Cervus elaphus*) and sambar (*Rusa unicolor*). Wild deer are a pest species in forests, and are commonly hunted both for recreation and as a method of pest management. Wild and farmed deer are sold for meat through licenced abattoirs and producers. The main products from deer farming are venison and velvet antler.

Table 6.8 shows the amount of venison production and exports, as well as the number of deer hides exported. These data include venison from commercial deer farms.

Velvet antlers are widely used in traditional Asian medicines. Production and exports from 2011–12 to 2015–16 are shown in Table 6.9. Most velvet antler production is exported.

[259] www.dpi.nsw.gov.au/biosecurity/vertebrate-pests/pest-animals-in-nsw/wild-deer/wild-deer; www.pestsmart.org.au/wp-content/uploads/2010/03/West2008_3.pdf

Goats

In some parts of Australia, wild (feral) goats (*Capra hircus*) are a pest species. Feral goats are common and widespread particularly in rangeland areas and to some extent in forested areas throughout Australia, except for the Northern Territory. Wild-caught goats contribute to Australia's domestic meat production and export of live goats, however the proportion taken from forest areas is unknown.

Table 6.10 shows the amount and gross value of production, meat export, and live goats exported. Data in Table 6.10 include goats and goat meat from commercial goat farms.

The Australian goat industry is heavily export-oriented, unlike other goat-producing countries. Since 2009 Australia has been the largest exporter of goat meat, and in 2015 accounted for 51% of world exports despite producing less than 1% of the world's goat meat. Australia's live goat export has accounted for around 15% of world trade since 2010 (ABARES 2017a).

The slaughter of goats increased from 1 million in 2000–01 to around 2.6 million in 2013–14, but has been relatively stable since 2013–14. In 2015–16, there were 2.2 million goats slaughtered. This expansion in slaughter has been driven by export demand, particularly from the United States. Goat consumption in Australia is limited to small niche markets. The gross value of goat production increased from $43.6 million in 2007–08 to $181 million in 2015–16.

Table 6.8: Venison production and exports, and exports of deer hides, 2011–12 to 2015–16

Product statistic	Metric	2011–12	2012–13	2013–14	2014–05	2015–16
Venison production	tonnes[a]	224	243	326	286	265
Venison exports	tonnes[a]	160	170	230	200	185
Deer hide exports	number	2422	–	–	–	–

–, not available

[a] Venison production and exports are reported as hot carcass weight.

Note: Export figures for 2011–12 differ from those in SOFR 2013 due to updated levies data.

Source: ABS (2011); Department of Agriculture and Water Resources (Levies section).

This table, together with other data for Indicator 6.1b, is available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

Table 6.9: Velvet antler production and exports, 2011–12 to 2015–16

Product statistic	Metric	2011–12	2012–13	2013–14	2014–15	2015–16
Production	kg	13,287	12,325	10,405	11,434	12,127
Exports	kg	12,092	8,157	4,582	9,760	11,356
Proportion exported	%	91	66	44	85	94

Note: Production figures for 2011–12 differ slightly from those in SOFR 2013 due to updated levies data.

Source: Department of Agriculture and Water Resources (Levies section).

This table, together with other data for Indicator 6.1b, is available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

Table 6.10: Australian goat production, export and value, 2011–12 to 2015–16

Product statistic	Metric	2011–12	2012–13	2013–14	2014–15	2015–16
Production	'000 tonnes	28.7	36.2	40.4	39.0	34.3
Gross value of production	$million	81.4	78.2	105.5	153.8	181.0
Meat export	'000 tonnes	34.4	38.3	36.5	29.6	29.9
Meat export	$million	113.6	145.8	198.9	258.2	226.0
Live goat exports	'000	71.9	61.3	81.2	91.0	80.7
Live goat exports	$million	9.7	7.2	9.9	9.6	10.3

Source: ABS (2017d); Meat and Livestock Australia unpublished data 2017; ABARES.

This table, together with other data for Indicator 6.1b, is available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

Table 6.11: Number of game pigs killed, and game pig meat production and exports, 2011–12 to 2015–16

Product statistic	Metric	2011–12	2012–13	2013–14	2014–15	2015–16
Animals killed	Number	119,100	23,500	21,000	41,900	63,800
Meat production	Tonnes	1,488	294	262	523	798
Meat export	Tonnes	1,468	274	242	503	778

Note: Figures for 2011-12 differ from those in SOFR 2013 due to updated or revised levies data.

Source: Department of Agriculture and Water Resources (Levies section); ABARES.

This table, together with other data for Indicator 6.1b, is available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

Game pigs

The game pig industry is based on the harvest of feral pigs (*Sus scrofa*), primarily in forests in northern and eastern Australia, where they are more prevalent. Game pigs are hunted for their meat, as a recreational activity and as a pest management practice.

The number of reported game pig kills, and game pig meat production and exports, declined substantially from 2011–12 to 2015–16 (Table 6.11). Almost all the production was exported.

Kangaroos and wallabies

Kangaroos and wallabies are harvested from the wild by shooters under a quota system administered by the state, territory and Australian governments, based on the principles of sustainability (see Indicator 2.1d). An industry has developed over the past 40 years from this harvest, producing meat for human consumption, pet food and skins.

Kangaroos (common wallaroo or euro, *Macropus robustus*; eastern grey kangaroo, *M. giganteus*; red kangaroo, *M. rufus*; and western grey kangaroo, *M. fuliginosus*) are harvested commercially for meat and skins in New South Wales, Queensland, South Australia and Western Australia. Bennett's wallaby (*M. rufogriseus*) and the Tasmanian pademelon (*Thylogale billardierii*) are harvested commercially in Tasmania. All these species dwell both in forests and non-forests, and are common and not endangered. Other kangaroo and wallaby species are protected from commercial harvesting.

Harvest of kangaroos occurred at a similar level over the 2011–2016 period, but has declined over the past 10 years. The total commercial harvest of kangaroos was 1.7 million in 2015–16, with a gross value of $42.8 million (Table 6.12); these figures are respectively 42% and 27% less than figures reported in 2006–07. The major factor in these reductions was the loss of the Russian Federation market in 2009–10. The total value of exports of kangaroo products (meat and skins) fell from $99 million in 2006–07 to $36 million in 2010–11, before recovering to $54 million in 2013–14. Export destinations for kangaroo meat in 2015–16 included Belgium (28% of total exports), Papua New Guinea (19%), Germany (18%), Netherlands (11%) and France (7%). Kangaroo skins are the largest component of the kangaroo export industry by value, with exports totalling $32 million in 2015–16, around two-thirds of total kangaroo product exports. The proportion of production and value from kangaroos derived from forests (animals living or sheltering in forests) is unknown.

In Tasmania, wallabies are commercially harvested for meat and skin. Agreed quotas and numbers of wallabies harvested (including pademelons) are based on management plans (see Indicator 2.1d). Export of wallaby products from Tasmania ceased after 2007–08. The Tasmanian Government allows harvesting of wallabies for the domestic market, provided the harvesting is within sustainable levels indicated in the management plan. Data on production of wallaby meat in Tasmania over the past few years have not been published. In 2010–11, production of wallaby meat was around 19 tonnes and the gross value of wallaby production was $170,000.

Beekeeping

There is a significant beekeeping industry in most states of Australia, producing products such as honey, dried pollen, beeswax, royal jelly, propolis and bee venom. The industry also performs (often paid) pollination services, and there is a trade in queen and packaged bees. An estimated 80% of Australia's honey is derived from eucalypts and related species (Somerville 2010).

Table 6.12: Kangaroo products: production, export and value, Australia, 2011–12 to 2015–16

Activity	Product statistic	Metric	2011–12	2012–13	2013–14	2014–15	2015–16
Harvest	Quota[a]	'000 animals	5,408	6,224	8,441	7,834	7,071
	Actual	'000 animals	1,800	1,767	1,841	1,664	1,727
	Gross value of production	$'000	36,815	34,487	37,081	33,656	42,837
Meat production	Human consumption	tonnes	14,229	13,382	14,449	12,943	13,273
	Pet food	tonnes	3,824	3,779	4,095	3,475	3,898
	Total	tonnes	18,053	17,651	18,545	16,418	17,171
Exports	Meat	tonnes	4,534	3,570	4,663	3,951	3,427
	Meat	$million	20.7	15.6	21.8	19.0	18.8
	Hides, skins, leather	'000 pieces	1,807	1,840	2,232	2,228	1,693
	Hides, skins, leather	$million	24.2	25.8	32.3	32.8	32.3

[a] Quota figures are for calendar year. For example, quota in 2011–12 refers to quota for 2012. Data include sustainable quotas and special quotas.
Note: Figures in 2011–12 differ from those in SOFR 2013 due to updated production and or price data, and/or ABARES methodologies.
Source: ABARES using data from the ABS (2017d); Australian Government Department of Sustainability, Environment, Water, Population and Communities[260]; Department of Agriculture and Water Resources (Levies section).

This table, together with other data for Indicator 6.1b, is available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

Table 6.13: Australian honey production, export and value, 2011–12 to 2015–16

Activity	Product statistic	Metric	2011–12	2012–13	2013–14	2014–15	2015–16
Production	Amount	Tonnes	21,989	23,585	22,167	18,166	18,211
	Gross value of production	$million	79.4	88.4	88.0	100.6	110.2
Exports	Honey	Tonnes	4,879	4,641	4,373	4,178	4,479
	Beeswax	Tonnes	207	358	358	268	266

Note: Production figure for 2011–12 differs from SOFR 2013 due to updated data from industry.
Source: ABS (2017d); ABARES.

This table, together with other data for Indicator 6.1b, is available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

[260] www.environment.gov.au/system/files/pages/ee20f301-6c6c-44e4-aa24-62a32d412de5/files/kangaroo-statistics-states-2018.pdf; www.environment.gov.au/biodiversity/wildlife-trade/natives

Over the period 2011–16, an annual average of 20.8 thousand tonnes of honey was produced, much of which was produced from forested lands. Honey production declined by 17% during this period, while the gross value of production increased by 39% and the amount of exports declined by 8% (Table 6.13). Honey production in Australia varies considerably between years due to variably dry seasonal conditions.

Eucalyptus oil

Eucalyptus oil is an essential oil that is extracted from the leaves of several species of the genus *Eucalyptus*. It has a wide range of commercial applications and may be found in perfumes, pharmaceutical products, and as a food additive and industrial chemical. Other Australian essential oils include sandalwood, tea-tree and boronia oils, from species of the genera *Santalum*, *Melaleuca* and *Boronia*, respectively.

Eucalyptus oil is harvested from plantations and from native forest under permit. Most Australian eucalyptus oil is produced from blue mallee (*Eucalyptus polybractea*), with smaller quantities obtained from narrow-leaved peppermint (*E. radiata* subsp. *radiata*) and oil mallee (*E. kochii*)[261]. Plantations of *E. polybractea* have been established for eucalyptus oil production in New South Wales, and some plantations of this species have been converted to oil production in Western Australia. The use of mechanical harvesting for *E. polybractea*, and improved distillation equipment, has greatly reduced the cost of production[262].

Eucalyptus oil is sold in domestic markets, and is both imported and exported. In 2011–12, eucalyptus oil production was estimated at 120 tonnes, with exports (including re-exports) estimated to be 149 tonnes (MIG and NFISC 2013). In some areas, the millennium drought running from 2000 to 2010 had a significant impact on eucalyptus oil production levels and operations. A national industry estimate for the 2011–2016 reporting period was not available, however some eucalyptus oil producers reported a 50% increase in production during this period. Production increased between 2011 and 2016 as plantations matured and as the farm gate price and seasons improved.

Other potential products from eucalyptus oil, such as jet fuel or other biomaterials, have been tested in Australia for proof-of-concept but are not currently commercial (e.g. Mendham et al. 2015). There is strong competition from overseas production, and new product development is occurring in Australia[263].

[261] eopaa.com.au/essential-oil-industry-australia/

[262] www.eucalyptusoil.com/australian-oil-production/future-production/future-production

[263] www.agrifutures.com.au/farm-diversity/eucalypts-oil/

[264] ATTIA (Australian Tea Tree Industry Association) (2010). Tea tree uses, ATTIA, Casino. www.teatree.org.au/teatree_uses.php

Tea-tree oil

Australian tea-tree oil from narrow-leaved paperbark (*Melaleuca alternifolia*; also called narrow-leaved tea-tree) is harvested principally from plantations in northern New South Wales and Queensland, and there is also a small harvest from natural stands on flood plains. Tea-tree oil has a wide range of uses that relate mainly to its antiseptic, anti-inflammatory and other healing properties. It is used in topical treatments to treat fungal, bacterial and viral infections, bruises and skin allergies, and also has industrial applications in solvents and disinfectants (RIRDC 2007b).

Table 6.14 presents data on production and exports of Australian tea-tree oil in 2011–12 and 2015–16. Approximately 85% of tea-tree oil production in Australia is exported for use in the cosmetics and pharmaceuticals industry. The remaining oil is used domestically as pure oil or as an ingredient in products such as soaps, shampoo and other personal products[264]. The estimated gross value of tea-tree oil production increased from 2012 ($12 million) to 2016 ($28 million) over the five-year period, reflecting improved market conditions, with increases in production (Table 6.14) and in average prices (from $32/kg to $46/kg).

Sandalwood products

Australia's current sandalwood production comes primarily from harvesting native sandalwood (*Santalum spicatum*) in Western Australia. Harvesting of native sandalwood in Western Australia is based on an allowable cut as specified in the *Sandalwood (Limitation of Removal of Sandalwood) Order (No. 2) 2015*. Indicators 2.1c and 2.1d discuss the sustainability of sandalwood production in Australia. The area from which native *S. spicatum* is available for harvest in Western Australia is spread across 14 million hectares (FPC 2017).

Around 160 tonnes of wild-grown, native northern sandalwood (*S. lanceolatum*) was harvested in Queensland in 2015–16, the smallest harvest since 2012–13. An average of 240 tonnes per year of this species was harvested in Queensland over the SOFR 2018 reporting period.

Debarked sandalwood, Kalgoorlie, Western Australia.

Table 6.14: Tea-tree oil production and exports, Australia, 2011–12 and 2015–16

Product statistic	Metric	2011–12	2015–16
Production	Tonnes	400	783
Exports	Tonnes	373	688

Source: ABS (2017d); ABARES.

This table, together with other data for Indicator 6.1b, is available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

Table 6.15: Sandalwood plantation area (hectares), by tree ownership, Australia, as at June 2017

Tree ownership	*Santalum spicatum*	*Santalum album*	Total
Public[a]	5,900	0	5,900
Private	12,000	14,100	26,100
Total	17,900	14,100	32,000

[a] Includes joint (public and private) tree ownership.
Source: ABARES.

This table, together with other data for Indicator 6.1b, is available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

Table 6.16: Sandalwood production, Australia, 2011–12 to 2015–16

Product statistic	Metric	2011–12	2012–13	2013–14	2014–15	2015–16
Wood production	tonnes	5,200	5,300	4,700	4,300	4,600
Harvested for domestic production	tonnes	3,200	3,300	3,100	2,900	3,200
Exported	tonnes	2,000	2,000	1,600	1,500	1,300
Oil production	kg	n.d.	1,100	1,300	1,600	2,600
Oil exported	kg	n.d.	900	1,100	500	2,100

n.d., no data
Note: Totals may not tally due to rounding.
Source: ABARES.

This table, together with other data for Indicator 6.1b, is available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

In 2015–16, there were 32,000 hectares of sandalwood plantations in Australia, located in the Northern Territory, Queensland and Western Australia (Table 6.15). This estate comprised approximately 17,900 hectares (56%) of *S. spicatum* and 14,100 hectares (44%) of Indian sandalwood (*S. album*), and these plantations are reported in the 'Other forest' category in Indicator 1.1a. Around 18% (5,900 hectares) of the sandalwood plantation estate consisted of public tree ownership and 82% (26,100 hectares) of private tree ownership in 2015–16. The first commercial harvest of *S. album* was completed in June 2014 (TFS 2014).

Table 6.16 presents the estimated annual sandalwood production in Australia for wood and oil for the period 2011–12 to 2015–16. Total wood production in Australia averaged 4,800 tonnes per year between 2011–12 and 2015–16. An average of 3,100 tonnes (65%) was harvested for domestic use and the balance was exported. An average of 1,700 kilograms of sandalwood oil was produced each year in Australia between 2012–13 and 2015–16, and the yearly production of oil has increased substantially over this period. The majority of oil produced in Australia (an average of 1,200 kilograms per year; 70% of total production) was exported.

Other essential oils

Other native species from forests are also used to produce small commercial quantities of essential oils, including lemon myrtle (*Backhousia citriodora*), boronia (*Boronia* spp.), fragronia (*Agonia fragrans*) and honey myrtle (*Melaleuca teretifolia*). The oils can be of high value, and are used in small quantities in cosmetics or food products. Cypress oil is being harvested commercially in the Northern Territory from plantations of the cypress pine *Callitris columellaris* var. *intratropica* planted in the 1960s and 1970s.

Boronia oil is a fragrant oil produced from the flowers of a perennial shrub endemic to Australia (usually *Boronia megastigma*). The oil is extracted using a solvent process and is further refined into either a waxy solid (a 'concrete') or a liquid (an 'absolute').

Boronia oil is used in perfumery and as food flavouring (Foster 2014). Traditionally, boronia oil has been produced from flowers picked in the wild, but most boronia oil is now produced from plantations using selected plant clones and mechanical harvesting.

Other non-wood forest product-based industries

Australia produces a range of other non-wood products that are at least partly forest-dependent. These include wildflowers, other native plants, herbs, spices, nuts, and fruits as native bush foods.

Two fisheries, mud crab (*Scylla* spp.) and white banana prawn (*Fenneropenaeus merguiensis*), have a direct link to forests. Adult mud crabs and nursery stock of these two fisheries dwell in mangrove forests. Commercial mud crab fisheries are managed by Northern Territory and Queensland fishery agencies, with Queensland reporting production and gross value of production (Table 6.17).

Table 6.17: Mud crab production, Queensland, 2005 to 2016

Year	Total catch (tonnes)	Gross value of production ($ million)
2005	969	15.5
2006	955	15.3
2007	931	14.9
2008	1,007	16.1
2009	1,044	16.7
2010	1,240	19.8
2011	1,439	23.0
2012	1,429	22.9
2013	1,340	21.4
2014	1,329	21.3
2015	1,189	19.0
2016	994	15.9

Source: DAF (2017b).

This table, together with other data for Indicator 6.1b, is available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

The native (bush) food industry spans a wide variety of Australian species, including anise myrtle, Australian finger lime, bush tomato, Davidson's plum, desert limes, Kakadu plum, lemon aspen, lemon myrtle, muntries, mountain or native pepper, quandong, wattle seed and riberry (Clarke 2012; see list of scientific names below). Many of these originate from forests. Information on the cultivation, production, health uses and plant improvement was reviewed in Sultanbawa and Sultanbawa (2016). The native food industry had an estimated value of approximately $17 million in 2011 (MIG and NFISC 2013), but limited information is available about production levels and value for individual species or the sector as a whole.

Currently 13 native foods, mostly forest species, are certified by Food Standards Australia New Zealand and available within the Australian and international markets (PwC's Indigenous Consulting 2017):

- Lemon myrtle: *Backhousia citriodora* (leaf and oil)
- Mountain or native pepper: *Tasmannia lanceolata* (leaf and berry)
- Bush tomato or desert raisin: *Solanum centrale*
- Anise myrtle: *Backhousia anisata* (leaf and oil)
- Finger limes: *Citrus australasica*
- Kakadu plum: *Terminalia ferdinandiana*
- Desert limes: *Citrus glauca*
- Quandong: *Santalum acuminatum*
- Muntries: *Kunzea pomifera*
- Wattleseed: *Acacia victoriae*
- Riberry: *Syzygium leuhmanii*
- Davidson's plum: *Davidsonia* spp.
- Lemon aspen: *Acronychia acidula*.

Some native foods are wild-harvested, such as Kakadu plum and mountain pepper (pepperberry), but many bush foods are grown on farms. A recent survey of the native food industry found that it is supply-constrained, with opportunities for growth (PwC's Indigenous Consulting 2017).

Lemon myrtle is one of the most cultivated and commercially mature species in the native food industry, with an estimated annual production in 2012 of between 575 and 1,100 tonnes (RIRDC 2014b) and an estimated farm gate value of $15 million dollars[265]. This compares with an estimated 5–15 tonnes of annual production for most other native food crops. Lemon myrtle is a medium-sized native tree with the leaves used for flavouring, essential oil and cosmetic ingredients. Estimated annual production of lemon myrtle oil in 2012 was between three and eight tonnes, with a farm gate value of $500,000. About 90% of lemon myrtle leaf and oil produced in Australia is exported to the European Union and the United States of America[266]. Originally harvested on a small scale from Australian rainforest, the majority of commercial lemon myrtle is now grown on farms in Queensland and the north coast of New South Wales.

Myrtle rust (*Puccinia psidii*), which was first found in Australia in 2010, severely damages new growth of species in the Myrtaceae family, and threatens lemon myrtle production. Growers of native bush foods may seek a permit to use specified fungicides for the treatment of myrtle rust on riberry, anise myrtle and lemon myrtle. Plantations of lemon myrtle established in Malaysia and China are not yet in full production but are expected to provide strong price competition for Australian product in the future[267].

An emerging product is Kakadu plum (*Terminalia ferdinandiana*), which has increasing interest in Australia and internationally because of the fruit's very high vitamin C content, and other properties. Case study 6.1 describes the emerging Kakadu plum industry.

[265] Agrifutures Australia, accessed 9 November 2017. Lemon Myrtle (24.05.2017) www.agrifutures.com.au/farm-diversity/lemon-myrtle/

[266] ibid

[267] ibid

Case study 6.1: Commercial harvest of Kakadu plum

Kakadu plum (*Terminalia ferdinandiana*) is a tree of small to medium size (3–8 metres) found in woodland forest and other vegetation types across northern Australia. This includes large areas of Aboriginal owned and managed lands in the Kimberley region of Western Australia and the top end of the Northern Territory. Kakadu plum is also known as bush plum, billygoat plum, gubinge (Kimberley), mimarral (Wadeye) and murunga (Arnhem land) (RIRDC 2014a; Gorman et al. 2016).

Kakadu plum has mainly been used as an ingredient in jams, sauces and juices. However, it is increasingly being dried and ground into a powder for use in dietary supplements and health foods. The fruit is sold in fresh, powdered or frozen puree form.

The fruit has extremely high concentrations of vitamin C (Brand et al. 1982; Williams et al. 2014) relative to other fruits. Kakadu plum fruit and leaf also have extremely high levels of phenolic compounds, such as ellagic and gallic acid, which give a high antioxidant capacity (Konczak et al. 2010, 2014). The phenolic-rich fruit extract has recently been found to have pronounced anti-inflammatory, anti-microbial and chemopreventative properties (Tan et al. 2011; Mohanty and Cock 2012), further supporting the many traditional uses of Kakadu plum as a medicine (Konczak et al. 2010).

The properties of Kakadu plum give it commercial application as a food (for its flavour and health benefits); as a preservative (for its antimicrobial properties[268]); in the cosmetic sector (skin creams and beauty products); as a food supplement; and in medical applications.

Commercial harvest of Kakadu plum commenced in the late 1990s. Most production in the Northern Territory and Western Australia comes from wild harvest, which occurs mainly on Aboriginal land and Crown land and requires government permits. Permits issued by the Northern Territory government ranged from 5,000 kg in 2012 to 10,000 kg in 2014 and 2015[269]. There is also a plantation of Kakadu plum in the Northern Territory and a number of small plantations in Western Australia, mostly on Aboriginal land (Gorman et al. 2016).

Jessica Brownlie, Gumnut Grey Creative Studios

Kakadu plum fruit.

The Wadeye Aboriginal community, which is 600 kilometres southwest of Darwin, has been harvesting wild Kakadu plum on a commercial basis for over a decade. In recent years, hundreds of community members have participated in the harvest and fruit collected has been handled by the Palngun Wurnangat Association, an Aboriginal-owned women's group. This has returned tens of thousands of dollars to the community. Fruit is also collected in other areas in the Northern Territory and by Aboriginal groups near Broome, Western Australia.

Following recent, increased awareness of the fruit's properties, demand is steadily increasing and the market is currently undersupplied. Current production is estimated to average 15–17 tonnes per annum (RIRDC 2014a). When processed into dried powder form, Kakadu plums are selling for up to $600 per kilogram[270].

Use of regional cooperatives which feed into supply hubs could facilitate consistency of volume and quality of fruit, and alternative production systems, such as horticulture, enrichment planting, or managing native stocks could help to increase yields (Gorman et al. 2016; Julian Gorman, Charles Darwin University, pers. comm.). Enrichment planting of a native stand is being trialled in the Kimberley (Lee and Courtenay 2016), and research on Kakadu plum domestication for commercial orchards has also commenced[271].

Rosemary Lott

Australian forest species are included in some health food products.

[268] www.abc.net.au/news/rural/2013-09-19/kakadu-plums-improving-prawns/4968046; www.abc.net.au/news/rural/2015-10-06/kakadu-plum-added-to-meals-to-improve-shelf-life-and-nutrition/6810928

[269] Wildlife harvest permit data from Northern Territory Department of Environment and Natural Resources. The actual amount collected is likely to be less than the permitted amount.

[270] www.abc.net.au/news/rural/2016-04-28/kakadu-plum-harvest-underway-in-wadeye-nt/7359856

[271] www.news.uwa.edu.au/201312046334/research/vitamin-c-rich-native-fruit-ripe-cash-crop-study; thewest.com.au/news/kimberley/global-plans-for-native-kimberley-super-fruit-ng-ya-129637

Indicator 6.1c

Value of forest-based services

Rationale

This indicator measures forest-based services such as ecosystem services, carbon credits, salinity mitigation and ecotourism. Forest-based services provide economic values and contribute to the sustainability of forests by providing significant social and environmental benefits.

Key points

- Australia's forests provide wood and non-wood forest products and a range of ecosystem services, such as carbon sequestration, soil conservation, catchment protection, recreation, and biodiversity conservation. Markets currently exist for only some of these services.
- Few data are available on the value of most forest-based services. The notable exceptions are the provision of wood, the value of which is reported in national accounts and by some forest managers; and the provision of water, which can be valued using data from irrigation agriculture and domestic water suppliers.
  - In 2015–16, the value of standing native forest timber in Australia was $1.8 billion, while the gross value of log production from native forests was $388 million.
  - In 2015–16, the value of standing plantation timber was $10.2 billion, while the gross value of log production from plantations was $1.9 billion.
  - The two asset values were calculated using different methodologies, so cannot be summed or compared with each other.

Forest ecosystem services are services provided by forest ecosystems without human input. They can be classified into several categories:

- supporting services (e.g. providing habitats for flora and fauna, formation of soil, cycling of nutrients, storage of carbon)
- provisioning services (e.g. provision of wood in growing trees, clean water in streams and rivers, genetic resources for utilisation)
- regulating services (e.g. regulation of water flows)
- cultural services (e.g. provision of recreation, ecotourism, amenity, aesthetic and heritage values).

Many of these services become tangible benefits with human input (e.g. when water is collected or wood harvested). Attempts to place monetary values on ecosystem services over many years have led to the development of the System of Integrated Environmental and Economic Accounts framework (SEEA), which was adopted by the United Nations Statistical Commission in 2012 and is now used by the Australian Bureau of Statistics (ABS) and other Australian government agencies (ABS 2017a).

The SEEA is based on internationally agreed concepts, definitions, classifications and accounting rules. It enables information to be organised into integrated and coherent accounts that can be used for a range of purposes, including national reporting and decision-making. The value of SEEA accounts to the user remains dependent on the accuracy and credibility of the data imported into the accounts, and on the method selected for valuing each environmental service. Other methods, such as 'Vegetation Assets, States and Transitions' (Thackway and Lesslie 2008)[272] and 'Accounting for Nature' (Wentworth Group of Concerned Scientists 2017) seek to monitor trends over time in the condition of natural assets by using scales and relative measurements, rather than monetary values. Methods involving 'Natural Capital' seek to monitor changes in ecosystem assets that underpin ecosystem services (ABS 2017a).

[272] The 'Vegetation Assets, States and Transitions' approach is described Case study 7.4 of SOFR 2013, pp.381–2.

These various methods are reviewed in the *Valuing Victoria's Parks* report prepared in 2015 by Parks Victoria and the Department of Environment, Land, Water and Planning, 2015[273]. This report also presents calculated values for ecosystem services provided by Victoria's parks and reserves, many of which are forested. These ecosystem services included tourism, water supply, mitigation of flood and storm-water damage, honey production and pollination services; parks and reserves also provide a number of other social values for which an economic value cannot readily be calculated, such as amenity, cultural connections, heritage conservation, carbon storage, and protection of species habitats and genetic diversity.

Valuation of water from forested catchments is discussed in Case study 6.2.

Timber assets

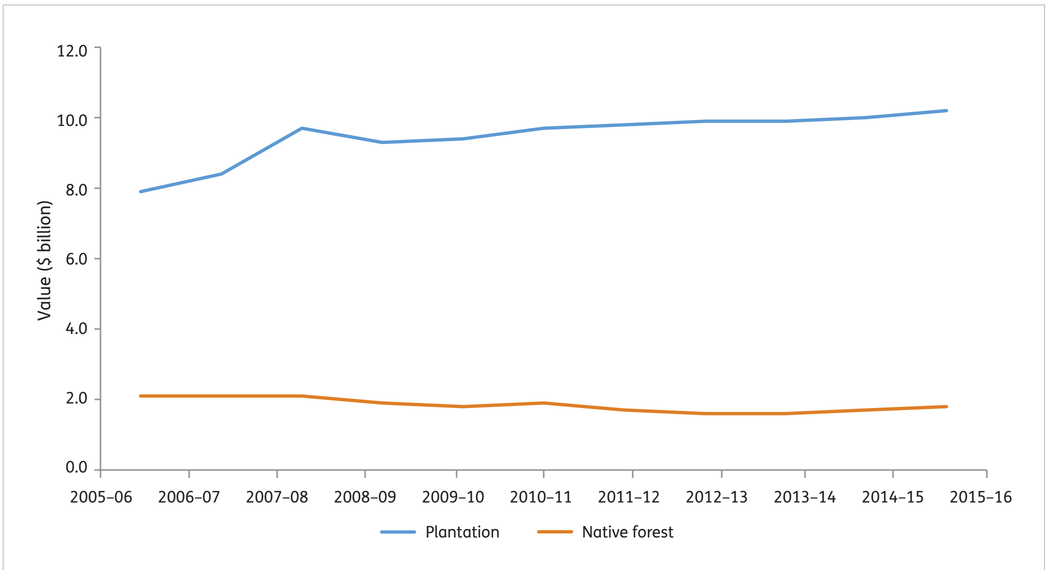
The ABS reports the value of Australia's 'standing timber assets', that is, wood that can potentially be harvested from forests, in Australia's environmental-economic accounts. These are shown in Figure 6.8 (see also Table 7.10). The standing timber assets underpin the ecosystem service of provision of wood for harvesting.

From 2005–06 to 2015–16, the value of standing native forest timber in Australia decreased from $2.1 billion to $1.8 billion (14%). This is consistent with the decline in the area of publicly owned native forests outside conservation reserves over that period (Indicator 2.1a). Over the same period, the value of standing plantation timber increased from $7.9 billion to $10.2 billion (29%). This is consistent with increases in the plantation area and average plantation age over this period (Indicator 2.1b). These two figures were calculated by different methodologies (the value of native forest timber is the net present value of the potential future stream of income to the owner of all native forests outside conservation reserves, whereas the value of standing plantation timber is the insurance value), so cannot be summed or compared with each other.

For the year 2015–16, the gross value of log production from native forests was $0.39 billion, a decrease of 36% from the value in 2005–06 (ABARES 2017c). The gross value of log production from plantations for 2015–16 was $1.9 billion, an increase of 77% over the value for 2005–06 (ABARES 2017c). Details of the value of log production are provided in Indicator 6.1a.

Some forest management businesses owned by state governments publish data on the value of timber in the native forests and plantations under their management (Table 6.18). Together, these businesses manage a little less than half of the public native forests managed for timber production, and around 20% of Australia's plantations. These figures cannot be compared readily with those in Figure 6.8 because they are for a mix of assets and because different valuation methods, product values and discount rates have been used.

Figure 6.8: Value of standing timber in Australia, 2005–06 to 2015–16



Note: The value of standing plantation timber is the insurance value. The value of standing native forest timber is the value for all publicly owned native forests outside conservation reserves plus the value for private native forests, all of which are assumed to be potentially available for timber production. The native forest values are derived from the net present value of the potential future stream of stumpage income.

Source: ABS (2017a).

The data used to create this figure, together with other data for Indicator 6.1c, are available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

[273] Until January 2015, the Department of Environment and Primary Industries: see parkweb.vic.gov.au/about-us/valuing-victorias-parks

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Table 6.18: Value of standing timber under state forest management, 2015–16

Business entity	Coverage	Timber value ($ million)[a]
Forest Products Commission (Western Australia)	Native forests, softwood plantations, sandalwood	310
Forestry Corporation of NSW	Native forests, hardwood plantations, softwood plantations	877
Forestry Tasmania	Native forests, hardwood plantations, softwood plantations	184
ForestrySA	Softwood plantations, Mount Lofty Ranges and Mid-North South Australia	46
VicForests	The portion of multiple-use public forests covered at the reporting time by the VicForests Allocation Order	49

[a] Valuations are in accordance with Accounting Standard AASB 141 and are based on deemed fair value less sale costs.
Sources: FPC (2016); FCNSW (2016a); Forestry Tasmania[274] (2016a); ForestrySA (2016); VicForests (2016a).

This table, together with other data for Indicator 6.1c, is available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

Payment for ecosystem services

Traditionally, many ecosystem services have been treated as public goods with little or no financial value, but more recently mechanisms have been developed to encourage payments for some of those services. These include government programs that pay landholders to manage forests and other types of native vegetation for environmental benefits.

The value of wood harvested for wood-based industries is considered in Indicator 6.1a, and the value of non-wood forest products is considered in Indicator 6.1b. Storage and sequestration of carbon is addressed in Indicators 5.1a and 7.1c. Water and soil values are addressed in Indicators 4.1a–e.

A range of government programs that seek to enhance forest-based services provided by private land, such as biodiversity conservation, do so by allotting value to conservation actions using market-based mechanisms. These include programs that offer information support, positive branding or the opportunity for formal protection of private land. Other programs offer a range of funding mechanisms, including direct payments and grants, reduced council rates, taxation benefits and in-kind contributions. In exchange for receiving this funding, landholders agree to undertake activities that promote biodiversity conservation, retention of native vegetation, or improvements in natural resource management. Such initiatives usually have monitoring mechanisms to provide assurance to program providers that participants are meeting their biodiversity conservation obligations. An example is the NSW Biodiversity Banking and Offsets Scheme[275].

The aesthetic quality of forests can be viewed as an amenity service that benefits the ecotourism sector. As well as providing enjoyment to participants, ecotourism generates economic benefits for the local and regional communities that provide tourist services, and supports complementary sectors such as accommodation, transport, restaurants and resorts (see Indicator 6.3b). Tourist visits to forested national and state parks in the national reserve system, and forests in other tenures such as state forests (multiple-use public forests), indicate the value of forests for ecotourism (see Indicator 6.3b).

The Carbon Farming Initiative, part of the Emissions Reduction Fund, is a voluntary carbon offsets scheme developed by the Australian Government that provides economic rewards to farmers and landholders who take steps to reduce greenhouse gas emissions. Farmers and landholders can choose whether or not to be involved. Under the initiative, they may be able to earn carbon credits from activities including reforestation (see Indicator 5.1).

[274] From July 2017, Sustainable Timbers Tasmania.
[275] www.environment.nsw.gov.au/biobanking/

Case study 6.2: Valuation of water from forested catchments

Forest vegetation is intimately connected to the hydrological cycle on forest land, and forest management actions affect hydrological flows. The common finding of many studies around the world is that timber harvesting leads to a temporary decrease in water loss from a site by transpiration, because the amount of vegetation canopy is reduced, and hence leads to a temporary increase in stream flow. Regrowth forests of one Australian species – *Eucalyptus regnans* (mountain ash) – are known to use more water than older forests of this species; this has also been taken to be the case for other species, but in many cases has not been documented. The broader link between forest transpiration and rainfall has also not yet been elucidated.

Quantification and valuation of water flowing from forests is always challenging (Bren 2009). The value of water when purchased through a tap or a bottle can be determined, but the value of water in the landscape cannot. The following factors need to be taken into account:

- If river flows are already very high, the value of additional water is negligible – at times of flooding, it might even be negative.
- In times of above-average rainfall, there is usually adequate or excess water provided by existing infrastructure, and additional water thus has a low value.
- Water released or absorbed as a consequence of forest management activities is geographically dispersed, and changes are often only detectable under certain conditions.
- The results of an Amazon Basin study (Rodriguez et al. 2010) suggest that water released as a consequence of forest modification can be absorbed by riparian (streamside) processes and may not reach a point of collection.
- Valuation of forested catchments involves a trade-off between water quality and water quantity – that is, these catchments produce clean and sustained stream flow, but produce a lower volume of water than catchments with other forms of land use.
- The outcome of forest water valuations depends heavily on the interest rate adopted, because of the long time periods involved in changing forest characteristics and the long time periods for a return (increased water) on investment in forest management. Most successful valuations consider a range of interest rates but base their decisions essentially on public-good criteria – the function of valuation is to provide insight on these criteria.

Thomson Dam, Gippsland, Victoria.

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The value of water transpired by growing regrowth forest has been argued to exceed the value of the wood extracted from mature forest (see Bren 2009). This argument has four problems. First, the relationship between water yield and forest age is known well for only one species (mountain ash, see above). For many forest types, reducing the forest density by partial harvesting or thinning enhances water yield (Bren 2015): this is a situation in which harvesting increases water values. Second, water is valuable but values are intangible in the absence of a water market. Third, predictions of the impacts on value of future relative shortage or excess are heavily dependent on the interest rate adopted. Fourth, complete removal of forest and replacement with vegetation such as grass or bracken could maximise water yields (indeed, this argument was used historically to justify forest clearing) but would have a negative impact on other values such as biodiversity, amenity or carbon storage

Water produced from some forested catchments may be valued by comparison with prices paid in irrigated agriculture or for domestic water supply. The spot price in irrigated agriculture can fluctuate between zero and $2,000 per megalitre, but a common historical price used to value water has been around $200 per megalitre for water that is already in storage and with enough gravitational energy to flow to the purchaser (see Bren 2009). City users of river or dam water often pay a much higher price than irrigators, reflecting the higher delivery and treatment costs, and this can further complicate the valuation of water and can lead to the existence of two parallel market prices for the same water (for example, water from the Thomson River Dam, Victoria, is used for irrigation in Gippsland and for domestic consumption in Melbourne).

More dramatic examples of the marginal valuation of water from forested landscapes involve cities that are faced with drought or an inadequate catchment area, and that have constructed large pipelines to remote areas, have commissioned desalination plants, or have accessed deep groundwater. In these cases, there is a large energy component in the cost of water delivered, and the marginal value of the water can be very high, such as $5–10,000 per megalitre. The high costs of provision of water through these mechanisms highlights the relative cheapness of water from forested catchments, where the major cost is simply the collection and distribution of the water.

Source: Leon Bren

Indicator 6.1d

Production and consumption and import/export of wood, wood products and non-wood products

Rationale

This indicator measures the consumption of forest-based products in Australia. Consumption trends over time provide a measure of the ability of Australian forest and timber industries, through both domestic production and importation, to meet Australian society's demand for forest-based products and of the industries contribution to the economy.

Key points

- Total consumption of sawnwood in Australia increased by 12% between 2010–11 and 2015–16, from 5.1 million cubic metres to 5.6 million cubic metres.
  - Consumption of hardwood sawnwood decreased from 0.75 million cubic metres to 0.69 million cubic metres over this period.
  - Consumption of softwood sawnwood increased from 4.3 million cubic metres to 5.0 million cubic metres over this period.
- Between 2010–11 and 2015–16, Australia's consumption of wood-based panels increased by 5% to 2.1 million cubic metres, while total consumption of paper and paperboard fell by 8% to 3.7 million cubic metres.
- Australia's trade in wood products experienced strong growth over the past decade, with the sum of imports and exports (total merchandise trade) exceeding $8 billion for the first time in 2015–16. Australia continues to be a net importer of wood and wood products.
  - Between 2010–11 and 2015–16, the total value of wood product imports increased from $4.4 billion to $5.5 billion, driven mainly by higher imports of miscellaneous forest products and wood-based panels.
  - The total value of wood product exports increased from $2.5 billion to $3.1 billion over this period, primarily due to higher exports of roundwood, woodchips, and paper and paperboard.
- Residential use of firewood declined by 12% between the period 2006–07 to 2010–11 and the period 2011–12 to 2015–16, whereas industrial use of fuelwood increased by 19% between these periods.
  - In the period 2011–12 to 2015–16, industrial fuelwood was used to generate an annual average of 40 petajoules of energy.
- Information on the production, consumption and trade of non-wood forest products is often difficult to obtain because of the generally small size of industries based on these products and their dispersed nature.
  - Beekeeping is one of the largest non-wood forest product industries, with an average of 20.8 thousand tonnes of honey produced annually over the period 2011–12 to 2015–16, much of which is produced from forested lands.

This indicator reports on the production, consumption and trade of wood and wood products, and non-wood products, by product category. Categories of wood and wood products are sawnwood, wood-based panels, and paper and paperboard. Because of the relatively small volumes of non-wood forest products and their highly dispersed nature, there is a relative lack of information about their trade; aspects of non-wood forest products are mostly reported in Indicators 2.1d and 6.1b.

Consumption (domestic consumption) is calculated as domestic production plus imports minus exports. The production figures used in this indicator are those reported in Indicators 6.1a and 6.1b and generally are from ABARES (2017c).

Sawnwood

Australia's total consumption of sawnwood, comprising softwood sawnwood and hardwood sawnwood, increased by 12% between 2010–11 and 2015–16, from 5.1 million cubic metres to 5.6 million cubic metres.

Softwood sawnwood is commonly used in housing construction for structural framing, and has other applications including furniture, decking and flooring. Consumption of softwood sawnwood increased by 15% between 2010–11 and 2015–16, from 4.3 million cubic metres to 5.0 million cubic metres (Figure 6.9). The increase in consumption occurred in parallel with increases in imports and domestic production (by 3% and 16%, respectively). Exports of softwood sawnwood decreased by 6% over this period.

Due to its widespread use in the construction and building industry, one of the key factors influencing consumption of softwood sawnwood is domestic residential dwelling commencements (ABARES 2017b). The total number of dwelling commencements, consisting of housing and other residential building commencements, increased by 43% between 2010–11 and 2015–16 (Figure 6.10). This increase was driven mostly by an increase of 87% in commencements of other residential buildings (including units, house conversions and multi-dwelling residences such as high-rise apartment blocks), while housing commencements increased by 15%.

Hardwood sawnwood is generally used where strength is important and for decorative purposes, such as for flooring, decking, cladding, joinery and furniture. Consumption of hardwood sawnwood decreased by 7% between 2010–11 and 2015–16, from 0.75 million cubic metres to 0.69 million cubic metres (Figure 6.11). The decrease in consumption corresponded with a decrease over the same period of domestic production and of imports (by 8% and 31%, respectively).

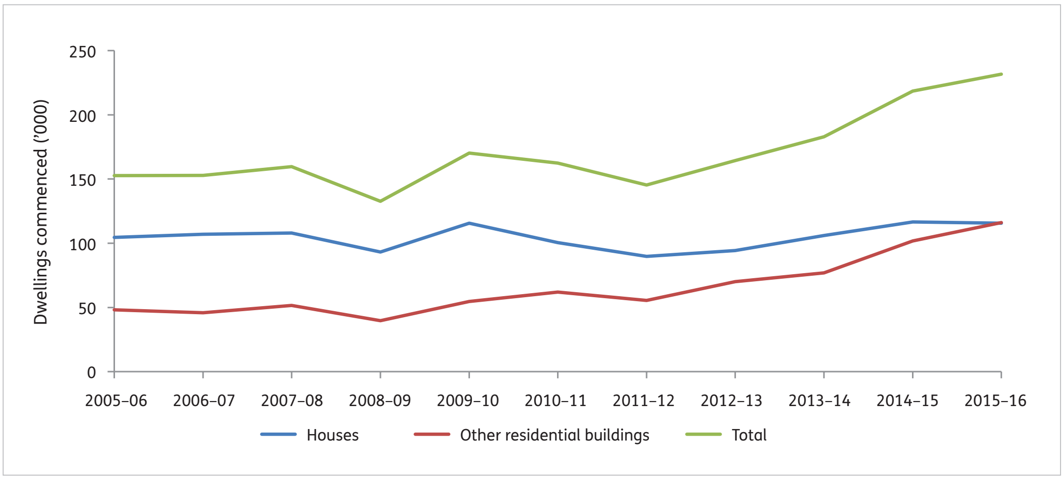
Exports of hardwood sawnwood also decreased, by 39%.

Figure 6.9: Softwood sawnwood consumption, production and trade, 2005–06 to 2015–16

Notes: Consumption is calculated as production plus imports minus exports. All categories include roughsawn and dressed sawnwood.
Source: ABARES (2017c).

The data used to create this figure, together with other data for Indicator 6.1d, are available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

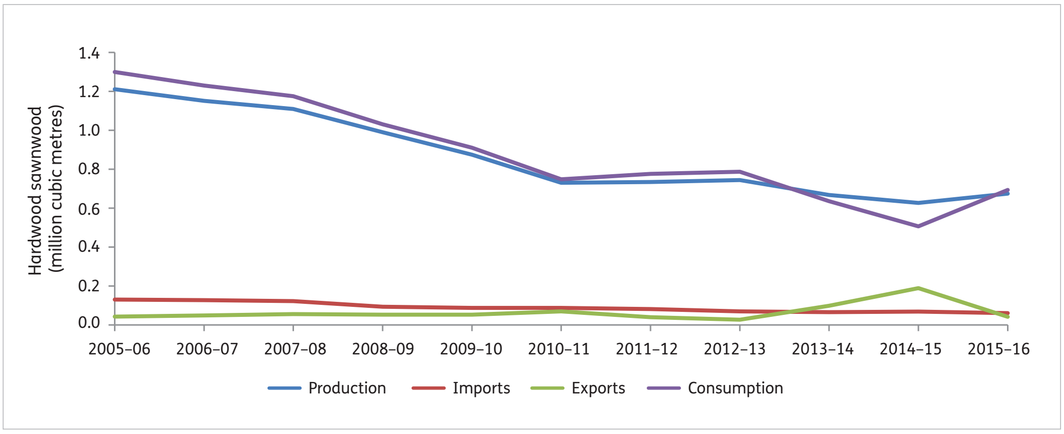
Figure 6.10: Housing and other residential building commencements, 2005–06 to 2015–16



Note: 'Other residential buildings' include units, house conversions and multi-dwelling residences such as high-rise apartment blocks.
Source: ABARES (2017c).

The data used to create this figure, together with other data for Indicator 6.1d, are available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

Figure 6.11: Hardwood sawnwood consumption, production and trade, 2005–06 to 2015–16



Notes: Consumption is calculated as production plus imports minus exports. All categories include roughsawn and dressed sawnwood.
Source: ABARES (2017c).

The data used to create this figure, together with other data for Indicator 6.1d, are available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

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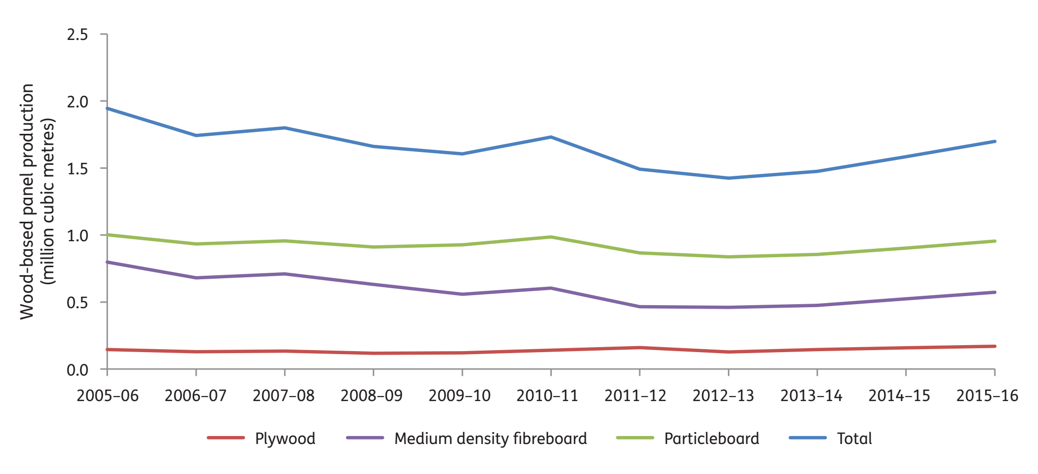
Wood-based panels

The wood-based panels category includes manufactured wood products such as medium-density fibreboard, plywood and particleboard that have various applications, including flooring, joinery (e.g. kitchen benches and cupboards), furniture and housing construction.

In 2015–16, Australia produced 1.7 million cubic metres of wood-based panels, a 2% decrease from 2010–11 (Figures 6.12 and 6.13). This production total includes 0.95 million cubic metres of particleboard (56% of total wood-based panel production), 0.57 million cubic metres of medium-density fibreboard (34%), and 0.17 million cubic metres of plywood (10%).

Consumption of wood-based panels grew by 5% between 2010–11 and 2015–16, from 2.0 million cubic metres to 2.1 million cubic metres (Figure 6.13). The increase in consumption occurred in parallel to a change in imports, which increased by 31% over the same period, from 407 thousand cubic metres to 535 thousand cubic metres. Domestic production and exports of wood-based panels both decreased (by 2% and 1%, respectively).

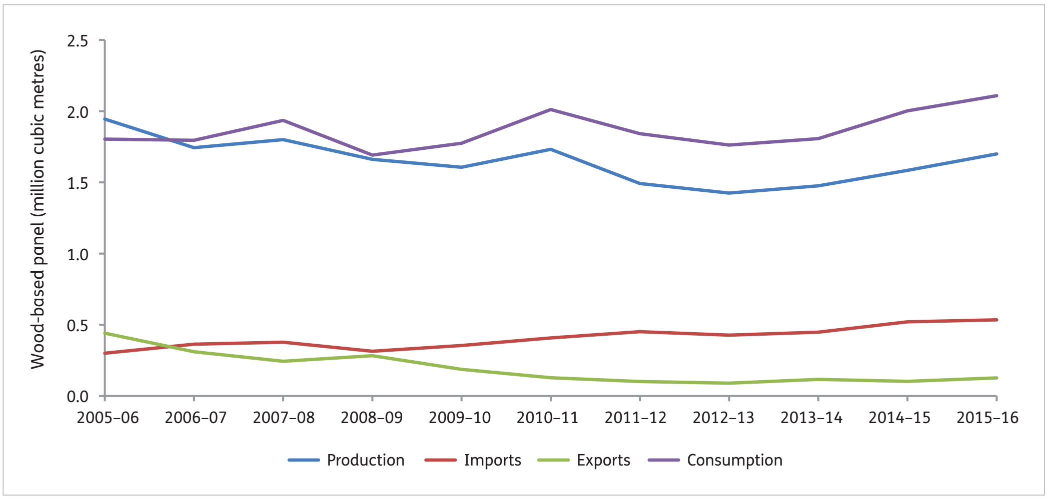
Figure 6.12: Production of wood-based panels, 2005–06 to 2015–16



Source: ABARES (2017c).

The data used to create this figure, together with other data for Indicator 6.1d, are available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

Figure 6.13: Wood-based panel consumption, production and trade, 2005–06 to 2015–16



Note: Consumption is calculated as production plus imports minus exports.
Source: ABARES (2017c).

The data used to create this figure, together with other data for Indicator 6.1d, are available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

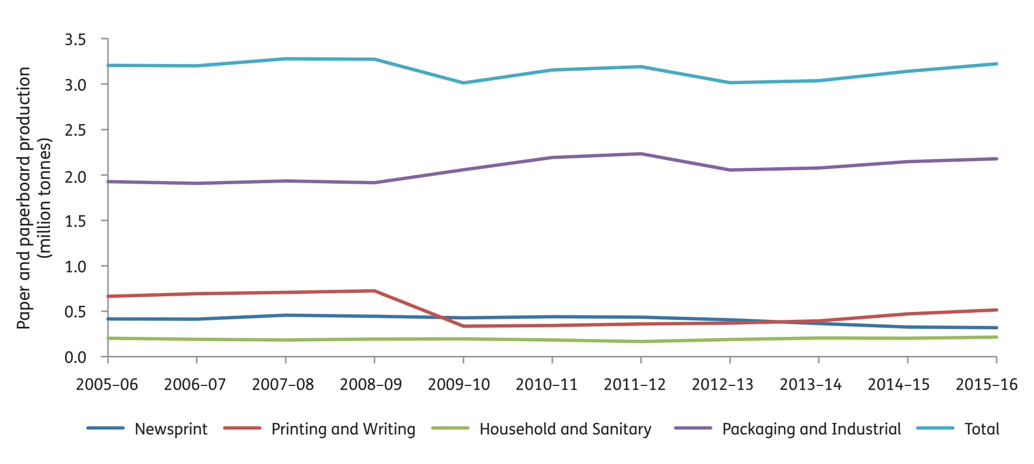
Paper and paperboard

The paper and paperboard category of wood products includes newsprint, printing and writing paper, household and sanitary paper, and packaging and industrial paper.

In 2015–16, Australia produced 2.2 million tonnes of packaging and industrial paper, accounting for 68% of total paper and paperboard production (Figure 6.14). Domestic production of printing and writing paper, and newsprint, totalled 0.51 million tonnes (16%) and 0.32 million tonnes (10%) respectively. Household and sanitary paper was the smallest component of paper and paperboard production, contributing 215 thousand tonnes (7%).

In 2015–16, combining these four categories of paper and paperboard, Australia produced 3.2 million tonnes of paper and paperboard products, a 2% increase from 2010–11 (Figures 6.14 and 6.15). Consumption of paper products declined by 8% over the same period, from 4.0 million tonnes to 3.7 million tonnes, while imports decreased by 15% and exports increased 10%.

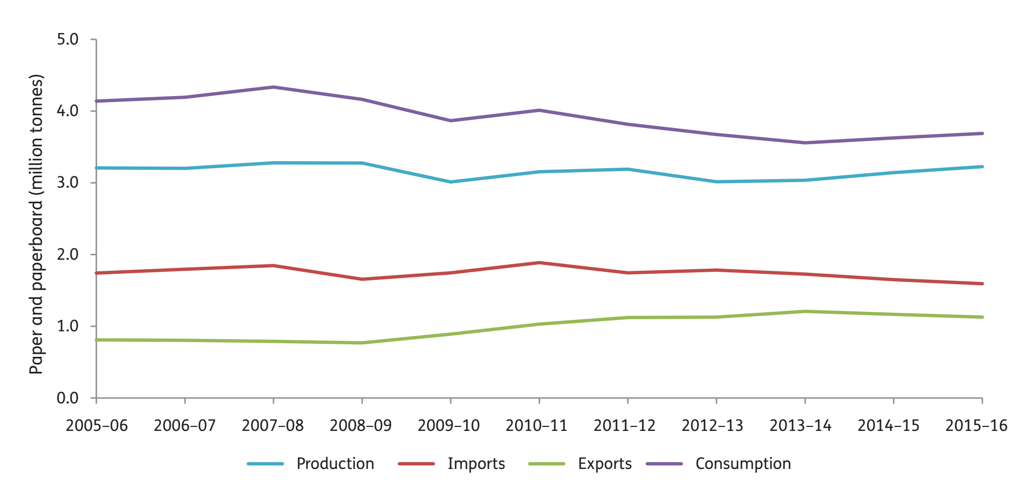
Figure 6.14: Production of paper and paperboard, 2005–06 to 2015–16



Source: ABARES (2017c).

The data used to create this figure, together with other data for Indicator 6.1d, are available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

Figure 6.15: Paper and paperboard consumption, production and trade, 2005–06 to 2015–16



Note: Consumption is calculated as production plus imports minus exports.
Source: ABARES (2017c).

The data used to create this figure, together with other data for Indicator 6.1d, are available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

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6.1d

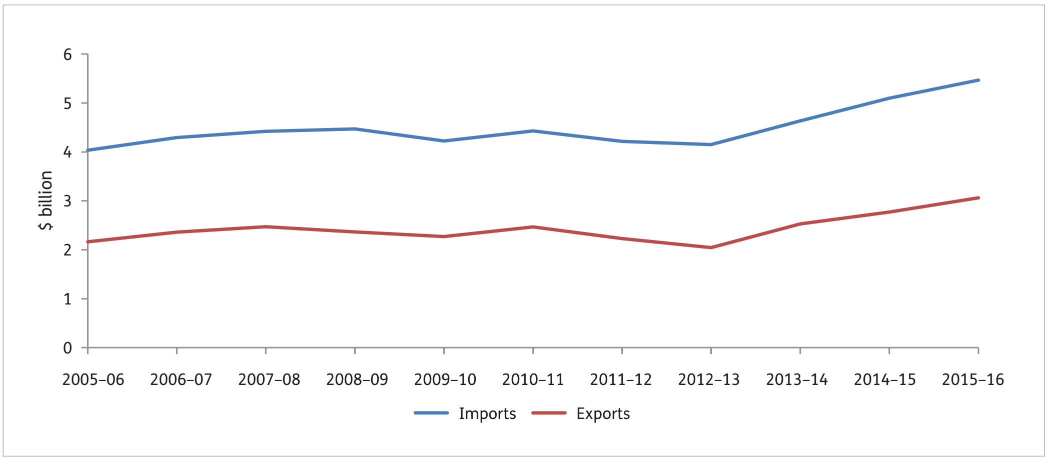
Trade performance

Over the past decade, Australia's trade in wood products has grown strongly. In 2015–16, the value of both imports and exports reached record levels, and total merchandise trade (the sum of imports and exports) was $8.5 billion (exceeding $8 billion for the first time).

Australia is a net importer of wood and wood products. Between 2010–11 and 2015–16, the total value of imported wood products increased from $4.4 billion to $5.5 billion (Figure 6.16). Most of this increase was driven by higher imports of miscellaneous forest products and wood-based panels (Table 6.19). In 2015–16, paper and paperboard imports accounted for the largest proportion by value of Australia's imported wood products, at 41% ($2.2 billion), down from 50% in 2010–11.

The value of wood and wood product exports also increased over the reporting period, from $2.5 billion to $3.1 billion (Figure 6.16).This increase was due primarily to growth in exports of roundwood, woodchips, and paper and paperboard (Table 6.20). Australia's largest-value exported wood product in 2015–16 was woodchips, accounting for 36% ($1.1 billion) of total export value, the same proportion as in 2010–11.

Figure 6.16: Trade in wood and wood products, 2005–06 to 2015–16



Source: ABARES (2017c).

The data used to create this figure, together with other data for Indicator 6.1d, are available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

Softwood sawlogs for export, Eden, NSW.

Table 6.19: Forest product imports, 2010–11 and 2015–16

Product type	Import value ($ million)		Proportion of total forest product imports by value (%)	
	2010–11	2015–16	2010–11	2015–16
Roundwood				
Total	**0.6**	**1.7**	**0.01**	**0.03**
Sawnwood				
Softwood roughsawn	134.6	111.9	3.0	2.0
Softwood dressed	247.7	360.5	5.6	6.6
Hardwood roughsawn	40.1	55.1	0.9	1.0
Hardwood dressed	50.3	27.7	1.1	0.5
Total	**472.8**	**555.2**	**10.7**	**10.2**
Miscellaneous forest products				
Total	**706.5**	**1,303.7**	**15.9**	**23.8**
Wood-based panels				
Veneer	20.9	23.6	0.5	0.4
Plywood	170.3	300.2	3.8	5.5
Particleboard	20.9	41.0	0.5	0.7
Hardboard	39.7	69.2	0.9	1.3
Medium-density fibreboard	34.5	51.3	0.8	0.9
Softboard and other fibreboards	3.0	4.0	0.1	0.1
Total	**289.3**	**489.3**	**6.5**	**8.9**
Paper and paperboard				
Newsprint	175.7	43.6	4.0	0.8
Printing and writing	1,347.4	1,036.4	30.4	19.0
Household and sanitary	185.2	305.3	4.2	5.6
Packaging and industrial	515.0	845.0	11.6	15.5
Total	**2,223.2**	**2,230.4**	**50.2**	**40.8**
Paper manufactures				
Total	**556.6**	**661.9**	**12.6**	**12.1**
Recovered paper				
Total	**0.4**	**0.3**	**0.01**	**0.005**
Pulp				
Total	**180.3**	**221.8**	**4.1**	**4.1**
Woodchips				
Total	**1.8**	**3.9**	**0.04**	**0.1**
Grand total	**4,431.5**	**5,468.2**	**100.0**	**100.0**

Note: Totals may not tally due to rounding.
Source: ABARES (2017c).

This table, together with other data for Indicator 6.1d, is available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

CRITERION 6

6.1d

Table 6.20: Forest product exports, 2010–11 and 2015–16

Product type	Export value ($ million) 2010–11	Export value ($ million) 2015–16	Proportion of total forest product exports by value (%) 2010–11	Proportion of total forest product exports by value (%) 2015–16
Roundwood				
Total	**197.6**	**438.0**	**8.0**	**14.3**
Sawnwood				
Softwood sawnwood	71.7	75.0	2.9	2.4
Hardwood sawnwood	43.2	28.1	1.7	0.9
Total	**114.9**	**103.0**	**4.7**	**3.4**
Miscellaneous forest products				
Eucalypt oil	6.1	31.5	0.2	1.0
Tea tree oil	2.9	31.2	0.1	1.0
Other	50.7	46.9	2.1	1.5
Total	**59.7**	**109.6**	**2.4**	**3.6**
Wood-based panels				
Veneers	52.1	24.1	2.1	0.8
Plywood	1.7	4.2	0.1	0.1
Particleboard	2.4	2.3	0.1	0.1
Hardboard	2.1	7.0	0.1	0.2
Medium-density fibreboard	39.4	27.9	1.6	0.9
Softboard and other fibreboards	0.6	1.1	0.03	0.04
Total	**98.3**	**66.5**	**4.0**	**2.2**
Paper and paperboard				
Newsprint	13.3	33.4	0.5	1.1
Printing and writing	88.4	128.5	3.6	4.2
Household and sanitary	94.0	53.2	3.8	1.7
Packaging and industrial	551.7	683.1	22.3	22.3
Total	**747.4**	**898.1**	**30.3**	**29.3**
Recovered paper				
Total	**240.0**	**248.6**	**9.7**	**8.1**
Woodchips				
Total	**884.4**	**1,095.8**	**35.8**	**35.8**
Other				
Total	**126.2**	**103.7**	**5.1**	**3.4**
Grand total	**2,468.7**	**3,063.3**	**100.0**	**100.0**

Note: Totals may not tally due to rounding.
Source: ABARES (2017c).

This table, together with other data for Indicator 6.1d, is available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

Firewood and fuelwood

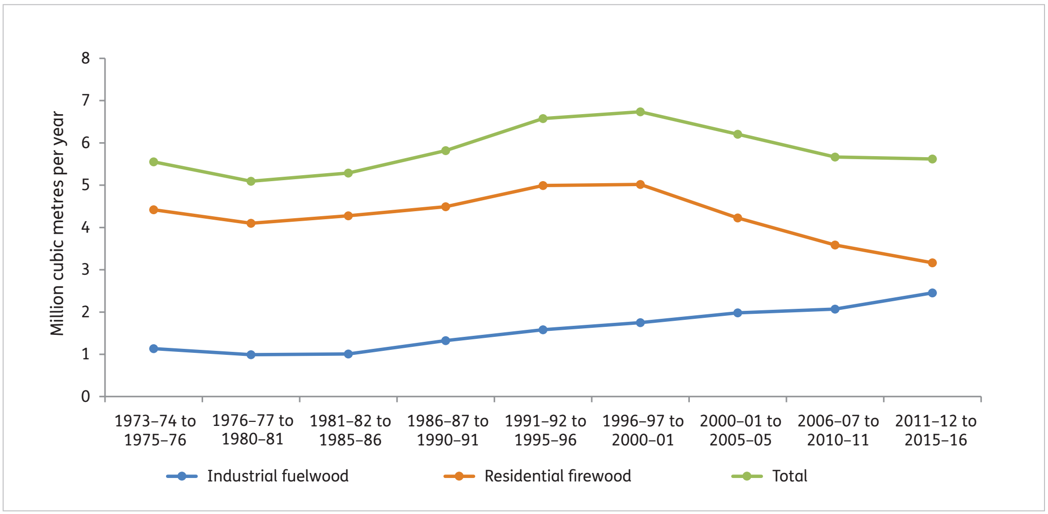
Firewood is wood used for residential heating, whereas fuelwood is wood or wood products used as industrial fuel or for bioenergy production. Together these are classified as 'wood and wood waste' in national energy statistics (DoEE 2017b). Industrial fuelwood includes wood waste generated during wood processing.

Between 2011–12 and 2015–16, annual average consumption of firewood plus fuelwood in Australia averaged 5.6 million cubic metres per year, a reduction from peak usage of 6.7 million cubic metres per year in 1996–97 to 2000–01 (Figure 6.17). Between the period 2006–07 to 2010–11 and the period 2011–12 to 2015–16, residential use of firewood declined by 12%, whereas industrial use of fuelwood increased by 19%.

Firewood is one of the most commonly utilised wood products, and is collected from plantations, agricultural lands and native forests. Its use is an important segment of the forestry sector, and important to regional communities. Between 1973–74 and 2015–16, residential firewood use averaged 4.3 million cubic metres annually (Figure 6.17). For the SOFR 2013 and SOFR 2018 reporting periods, New South Wales (including the Australian Capital Territory) and Victoria accounted for the majority of residential firewood use. Annual use of industrial fuelwood more than doubled between 1973–74 and 2015–16.

As a proportion of total residential energy use, firewood use decreased from 13.4% to 11.6% between the period 2006–07 to 2010–11 and the period 2011–12 to 2015–16 (Figure 6.18).

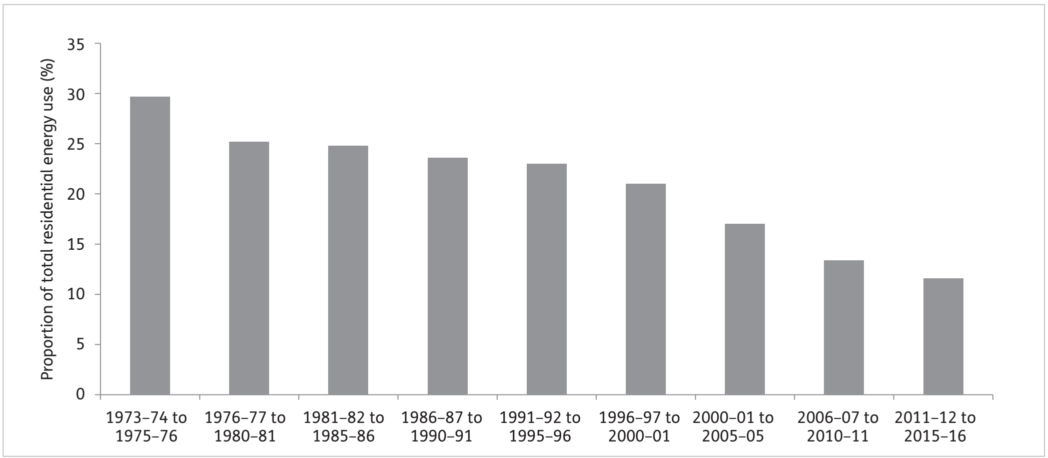
Figure 6.17: Residential firewood and industrial fuelwood use in Australia, 1973–74 to 2015–16



Source: DoEE (2017b) and ABARES databases.

The data used to create this figure, together with other data for Indicator 6.1d, are available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

Figure 6.18: Firewood use as proportion of total residential energy use, 1973–74 to 2015–16



Source: DoEE (2017b) and ABARES databases.

The data used to create this figure, together with other data for Indicator 6.1d, are available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

In 2015–16, wood and wood waste (equivalent to domestic firewood plus industrial fuelwood, including fuelwood used for bioenergy production) provided a total of 94 petajoules (PJ)[276] of renewable energy in Australia (Table 6.21). This was 26% of the total renewable energy consumption, and was greater than the combined contribution of wind power and solar (photovoltaic) power. Average annual growth in wind and solar (photovoltaic) power consumption was larger than average annual growth in wood and wood waste consumption (Table 6.21).

In the period 2011–12 to 2015–16, industrial fuelwood (wood and wood waste used across industries) was used to generate an annual average of 40 PJ of energy (DoEE 2017b). Of this, an annual average of 28 PJ of energy was generated from the manufacturing sector, and of this an annual average of 21 PJ of energy was generated from the wood and wood products and pulp, paper and printing industries (mainly using waste product from manufacturing processes).

Some of the wood and wood waste consumed for energy by industry is used to generate electricity. In 2015–16, wood and wood waste generated 248 gigawatt-hours of electricity, which was 0.7% of the total production of electricity from renewable sources (Table 6.22).

[276] A petajoule is 10^{15} Joules

Table 6.21: Australian renewable energy consumption by fuel type, 2015–16

Renewable energy source	Fuel type	Renewable energy consumption, 2015–16		Average annual growth in renewable energy consumption (%)	
		PJ	Proportion (%)	2014–15 to 2015–16	2005–06 to 2015–16
Biomass	Wood, wood waste[a]	93.3	25.8	3.8	-0.6
	Bagasse	102.2	28.3	-0.7	-0.9
	Other waste	2.5	0.7	19.1	n.a.
	Total biomass	198.1	54.8	1.6	-0.6
Biofuels	Ethanol	6.2	1.7	-7.4	n.a.
	Biodiesel	1.2	0.3	-73.4	n.a.
	Total biofuels	7.5	2.1	-34.4	12.6
Biogas		17.5	4.8	4.6	8.8
Hydro		55.1	15.3	13.9	0.6
Wind		43.9	12.1	6.4	18.7
Solar photovoltaic		24.6	6.8	23.6	59.1
Solar hot water		14.9	4.1	0.2	10.6
Total renewables		**361.6**	**100**	**4.1**	**2.6**

PJ, petajoule (10^{15} Joules); n.a., not available

[a] Domestic firewood plus industrial fuelwood

Source: Australian Energy Update 2017 (DoEE 2017b)

This table, together with other data for Indicator 6.1d, is available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

Table 6.22: Australian electricity generation from renewable sources by fuel type, 2015–16

Renewable energy source	Fuel type	Electricity generation from renewable sources		Average annual growth in electricity generation from renewable sources (%)	
		GWh	Proportion (%)	2014–15 to 2015–16	2005–06 to 2015–16
Bioenergy	Wood, wood waste	248	0.7	n.a.	n.a.
	Bagasse	1,810	4.7	n.a.	n.a.
	Municipal, industrial waste	43	0.1	n.a.	n.a.
	Sulphyte lyes, biofuels	417	1.1	n.a.	n.a.
	Landfill biogas	1,061	2.8	n.a.	n.a.
	Sludge biogas	211	0.6	n.a.	n.a.
	Total bioenergy	3,790	10	5.5	-0.5
Hydro		15,318	40	13.9	0.6
Wind		12,199	32	6.4	18.7
Solar photovoltaic		6,838	18	23.6	59.1
Geothermal		0	0	-64.1	-8.9
Total renewables		**38,146**	**100**	**12.1**	**6.8**

GWh, gigawatt-hours (10^9 Watt-hours); n.a., not available

Source: Australian Energy Update 2017, April 2018 update (DoEE 2017b).

This table, together with other data for Indicator 6.1d, is available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

Non-wood forest products

Non-wood forest products (NWFPs) comprise a wide diversity of products, including tree bark collected for paintings, eucalyptus and sandalwood oil, seeds, bush flowers, native foods, bee products, water, minerals, and animal meat and skins. Several industries based on NWFPs supply domestic and international commercial markets (see Indicator 6.1b).

Beekeeping is one of the largest NWFP industries. An average of 20.8 thousand tonnes of honey was produced annually over the period 2011–12 to 2015–16, and in 2015–16 the estimated gross value of production of honey and other bee products was $110 million (Table 6.13, Indicator 6.1b). Much of the production comes from forests. Between 2011 and 2016, on average 4.5 thousand tonnes were exported annually (Table 6.13, Indicator 6.1b) and 22.2 thousand tonnes of honey were consumed domestically (ABS 2017d). Imports increased in 2014–15 and 2015–16, mostly due to a significant rise in honey imported from China (ABS 2017d; van Dijk et al. 2016).

Although these are small industries, a significant proportion of crocodile hide, venison, goat and game pig meat, wood and oil from sandalwood, and tea tree and eucalypt oil production is exported (Indicator 6.1b). Most crocodile eggs, sandalwood, tea tree and eucalypt oil are derived from forest; for game meats the proportion derived from forest is unknown. Some native foods and artwork based on non-wood forest products are also exported.

In addition to providing wood and non-wood forest products, forests provide a range of environmental services, such as carbon sequestration, visual amenity (of value, for example, to the tourism industry), soil conservation, water production, and the conservation of biodiversity and cultural heritage. See Indicator 6.1c for a further discussion on these environmental services.

Structural-grade plywood made in Australia from plantation pine.

Indicator 6.1e

Degree of recycling of forest products

Rationale

This indicator measures the extent to which recycling or re-use of forest products occurs. As global demand for forest products increases, there is a growing need to meet societal demands for recycling of forest products.

Key points

- Between 2010–11 and 2015–16, the weight of recycled paper used for domestic paper and paperboard production fell from 1.8 million tonnes to 1.7 million tonnes, and the proportion of paper and paperboard production deriving from recycled paper fell from 56% to 53%. Over this period, the weight of paper waste exported for recycling increased from 1.3 million tonnes to 1.4 million tonnes.
- Australia recycled 60% of the 5.3 million tonnes of paper and cardboard waste generated in 2014–15. Of the weight recycled, Victoria, New South Wales and Queensland together recycled 82%.
- Lower weights of waste timber are recycled or re-used in Australia compared to the weight of paper and cardboard that is recycled, but various government and industry initiatives aim to increase timber recycling and re-use. Of the reporting jurisdictions, Victoria and South Australia recycled the most timber over the years broadly covered by the reporting period.

This indicator measures the extent to which wood-based products such as paper, paperboard and timber are recycled in Australia. Non-wood forest products may also be recycled or re-used (for example, through composting for use in agriculture and floriculture) but the indicator does not assess the extent of such use.

Paper is the major forest product that is recycled in Australia. This indicator presents two main recycling datasets, one from a 2017 ABARES survey of companies and covering paper and paperboard[277], and the other in 2016 from Blue Environment developed for the Department of Energy and the Environment[278] based on state and territory responses recorded using a national waste dataset reporting tool, and covering paper and cardboard[279]. Both datasets show that the proportions of these materials recycled in Australia have been relatively stable since 2010–11. Differences between the numbers from these two datasets are due to the different types of material included in each, and the methodologies employed.

Paper and paperboard recycling

Figure 6.19 shows the weight of recovered paper and paperboard[280] that is used for domestic paper and paperboard production, and the proportion of domestic paper and paperboard production that this comprises (ABARES 2017c).

Between 2010–11 and 2015–16, the weight of paper and paperboard produced in Australia increased by 2%, to 3.2 million tonnes. During the same period, the weight of recovered paper and paperboard used to produce paper and paperboard decreased by 4%, from 1.8 million tonnes to 1.7 million tonnes (Figure 6.19). The proportion of paper and paperboard production deriving from recovered paper and paperboard therefore fell between 2010–11 and 2015–16, from 56% to 53%. Since 2002–03, the proportion of paper and paperboard production in Australia that derives from recovered paper and paperboard has fluctuated around the long-term average of 54% (Figure 6.19).

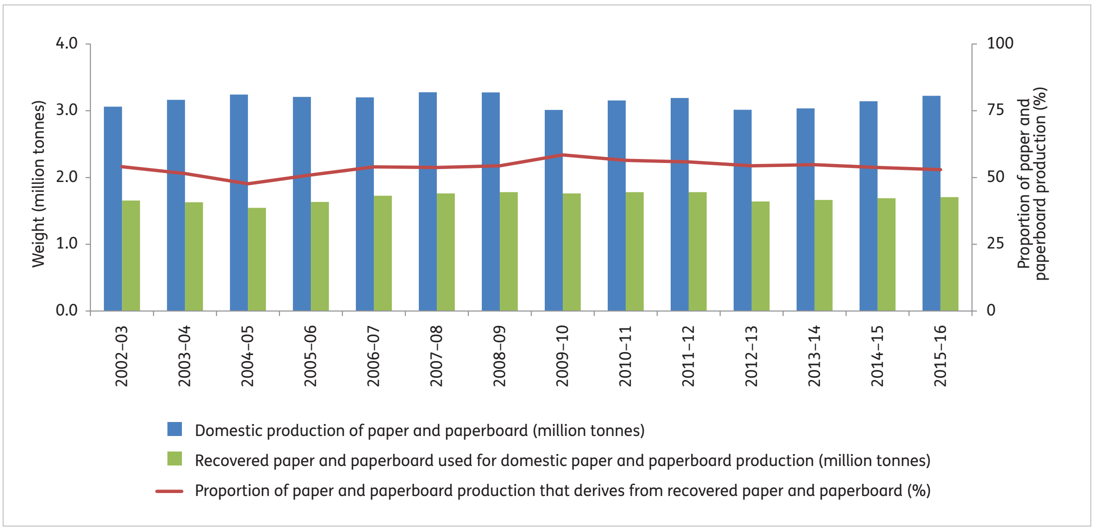
[277] 'Paper and paperboard' includes the categories newsprint; coated and uncoated printing and writing paper; household and sanitary paper; and wrapping and packaging paper and board.

[278] Until July 2016, the Department of the Environment.

[279] 'Paper and cardboard' is defined as comprising liquid paperboard (paperboard with layers of plastic; used for beverage containers), newsprint, magazines and office paper.

[280] Recovered paper and paperboard refers to paper and paperboard products that have known recycling potential and that have been removed or diverted from solid waste, or that have never been discarded as solid waste, and are intended for sale, use, reuse, or recycling. See www.paperrecyclingcoalition.com/faqs/paper-recycling-terminology/

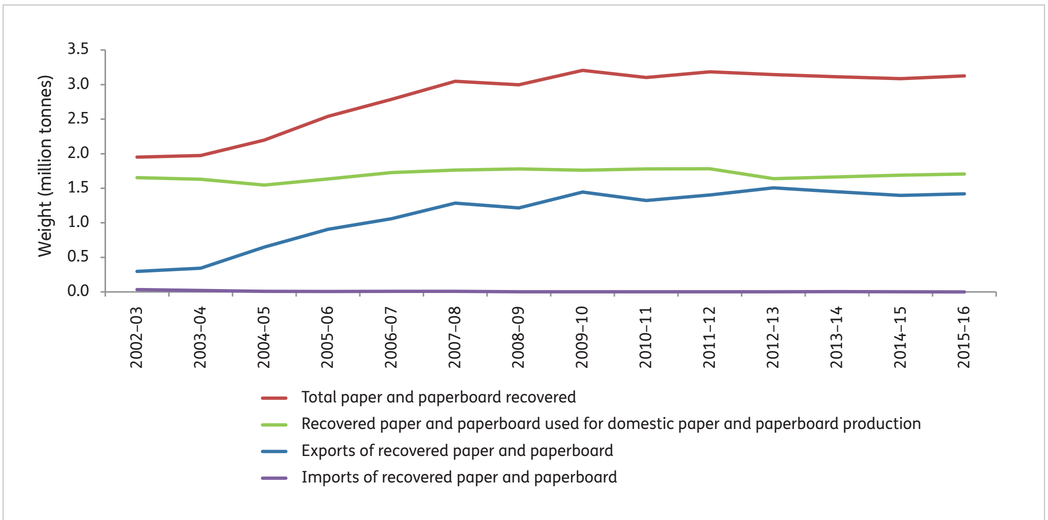
Figure 6.19: Recovered paper and paperboard used for paper and paperboard production, Australia, 2002–03 to 2015–16



Source: ABARES (2017c).

The data used to create this figure, together with other data for Indicator 6.1e, are available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

Figure 6.20: Recovered paper and paperboard exported or used domestically to produce paper and paperboard, Australia, 2002–03 to 2015–16



Note: Total paper and paperboard recovered comprises recycled paper used for domestic paper and paperboard production plus recycled paper exported.
Source: ABARES (2017c).

The data used to create this figure, together with other data for Indicator 6.1e, are available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

The weight of recovered paper and paperboard exports increased from 2002–03 until 2012–13, and since then has been relatively stable (Figure 6.20). Overall, between 2010–11 and 2015–16 the weight of recovered paper and paperboard exports increased by 7%, from 1.3 million tonnes to 1.4 million tonnes. The weight of recovered paper and paperboard imports is much smaller, and decreased between 2002–03 and 2015–16 from 35 thousand tonnes to 1 thousand tonnes. During the same period, the combined weights of recovered paper and paperboard exported and recovered paper and paperboard used to produce paper and paperboard (that is, the total weight of recovered paper and paperboard) increased by 1%, to 3.1 million tonnes (Figure 6.20).

Another dataset that reports on paper and paperboard recovery for the year ended 30 June 2016 is presented in Industry Edge (2017). In that year, Australia's reported total recovery of paper and paperboard fibre was 3.1 million tonnes, of which 1.7 million tonnes was used for domestic production and 1.4 million tonnes was exported.

Recycling of paper and cardboard waste

Blue Environment (2016) used state and territory government data and an industry survey to report on solid waste generation in Australia, and the fates of numerous waste categories, including paper and cardboard. Figure 6.21 shows the trends over time in the weight of paper and cardboard waste generated, recycled and disposed. In 2014–15, Australia generated 5.3 million tonnes of paper and cardboard waste, of which 3.2 million tonnes (60%) were recycled, and 1.6 million tonnes (30%) were disposed, predominantly to landfill (Figure 6.21). An additional 0.5 million tonnes (9%) were disposed to landfill and then generated methane (landfill gas) that was in turn used to generate energy. The proportion of paper and cardboard waste generated that was recycled in 2014–15 was slightly lower than the proportions reported during the period 2010–11 to 2013–14.

The weight of paper and cardboard waste that is recycled differs between states and territories. These differences are driven by population and therefore consumption levels, by socio-economic factors, by varying waste policies adopted by governments including local governments, and by access to recycling markets (Blue Environment 2016). In 2014–15, Victoria recycled the highest amount of paper and cardboard waste (1.44 million tonnes) in Australia, representing 45% of total national paper and cardboard waste recycling (Table 6.23). Recycling amounts were the next highest in New South Wales (0.71 million tonnes) and Queensland (0.49 million tonnes). Taken together, these three jurisdictions (which also have the highest populations of Australia's states and territories) recycled 82% by weight of Australia's recycled paper and cardboard waste.

The proportion of paper and cardboard waste recycled in 2014–15 was highest nationally in South Australia (78%), followed by Victoria (72%) and New South Wales (61%); and lowest in the Northern Territory (13%; but see footnotes to Table 6.23).

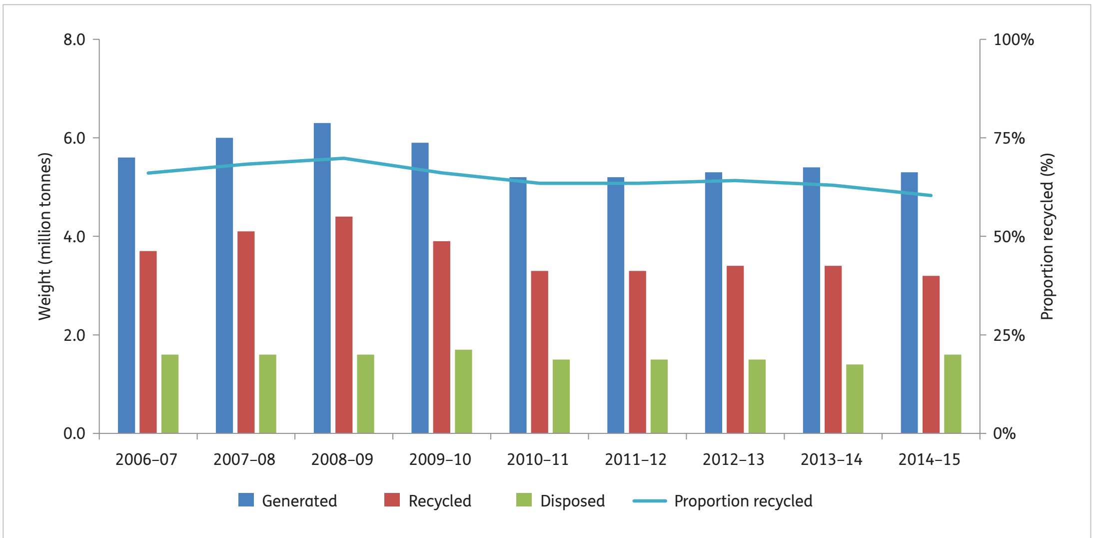
Indicator 5.1a addresses the contribution of Australia's forest products to the global carbon cycle, including the weight of carbon stored in wood products in use and landfill, and production of energy from biomass.

Timber recycling and re-use

Waste timber is generated mainly from construction, demolition, commercial and industrial sources, and includes untreated, treated and painted timber, engineered wood products, timber packaging, sawdust, and sawn offcuts. Using waste timber as firewood and fuelwood is not considered to be recycling.

Of the reporting jurisdictions, Victoria and South Australia recycled the largest amounts of waste timber over the years broadly covered by the reporting period (Table 6.24). Over the four years to 2015–16, South Australia recycled 273 thousand tonnes of waste timber (down 3%), and over the three years to 2014–15 Victoria recycled 398 thousand tonnes of waste timber (up 254%). Recycling amounts also increased over time in New South Wales and the Australian Capital Territory (by 63% and 511%, respectively, although from lower base-lines).

Figure 6.21: Paper and cardboard waste generated, recycled and disposed, Australia, 2006–07 to 2014–15



Notes: Totals may not tally due to rounding.

Paper and cardboard comprises liquid paperboard, newsprint and magazines, and office paper, but excludes waste from forestry production activities. Waste disposed that is converted to methane (landfill gas) and used to generate electricity is not shown above, and for this reason the sum of the weight recycled and the weight disposed does not equal the weight of waste generated. The proportion recycled is calculated as the weight of waste recycled divided by the weight of waste generated.

Source: Blue Environment Pty Ltd (2016).

The data used to create this figure, together with other data for Indicator 6.1e, are available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

Table 6.23: Paper and cardboard waste generated and recycled, by jurisdiction, 2014–15

	ACT	NSW	NT[d]	Qld.	SA	Tas.	Vic.	WA	Australia
Generation ('000 tonnes)[a]	76	1,162	39	1,007	300	127	2,000	558	5,269
Recycling ('000 tonnes)	30	706	5e	495	233	69	1,443	245	3,226
Disposal ('000 tonnes)	31	347	29	445	48	44	393	248	1,585
Used for energy recovery ('000 tonnes)[b]	15	109	4	67	20	14	163	65	457
Proportion recycled[c]	**39%**	**61%**	**13%[e]**	**49%**	**78%**	**54%**	**72%**	**44%**	**61%**
Proportion of national paper and cardboard recycled	**0.9%**	**22%**	**0.2%[e]**	**15%**	**7%**	**2%**	**45%**	**8%**	**100%**

[a] Generation equals 'Recycling' plus 'Disposal' plus 'Used for energy recovery'.

[b] Refers to processes that include capturing methane from landfill gas and converting it to electricity.

[c] 'Recycling' divided by 'Generation'.

[d] These data were obtained via an industry survey and may be under-reported.

[e] The relatively low proportion of paper and cardboard waste recycled in the Northern Territory partly reflects socio-economic factors and a low population density, but also may not fully capture the supply by the Northern Territory of waste paper and cardboard to pulp and paper mills domestically and overseas for reprocessing.

Notes: Totals may not tally due to rounding.

'Paper and cardboard' include liquid paperboard, newsprint, magazines and office paper, and excludes waste from forestry production activities.

Source: Adapted from Blue Environment Pty Ltd (2016).

This table, together with other data for Indicator 6.1e, is available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

Table 6.24: Weight of waste timber recycled, by jurisdiction, 2010–11 to 2015–16 (tonnes)

Waste timber recycling	2010–11	2011–12	2012–13	2013–14	2014–15	2015–16
Australian Capital Territory[a]	n.d.	632	n.d.	n.d.	3,862	n.d.
New South Wales	60,000	n.d.	n.d.	n.d.	98,000	n.d.
South Australia	n.d.	281,000	n.d.	n.d.	n.d.	273,000
Victoria	n.d.	112,381	n.d.	204,000	193,753	n.d.

[a] For the ACT, 'waste timber' measured as timber mulch sold by ACT Recycling Pty Ltd, with data covering the ACT region, including Queanbeyan and Yass (NSW).

Sources: Australian Capital Territory, ACT NOWaste and Parks and Conservation Service; New South Wales, unpublished reports conducted on behalf of the NSW Environmental Protection Authority; South Australia, Rawtec (2012, 2017); Victoria, Sustainability Victoria (2012, 2015, 2017a).

This table, together with other data for Indicator 6.1e, is available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

Only occasional data are collected on waste timber recycling and re-use in Australia, and estimates of waste timber recycling or re-use vary. For example, in 2009–10 'timber and wood products' was the category of waste with the highest proportion of recycling or re-use nationally, at 91% by weight (ABS 2013a). By comparison, Victoria estimated that 40% of waste timber was recovered for reprocessing in 2013–14 (Sustainability Victoria 2017b). The data show that less waste timber and wood product is recycled or re-used than paper and cardboard, and significant weights of waste timber and wood product are disposed in landfills. This is driven largely by the economics and regulation of recycling and reusing waste timber.

Factors that influence the extent of waste timber recycling and re-use in Australia include the regulatory framework for waste streams, including industry self-regulation. These regulatory factors set minimum standards, frame markets for recycling and re-use, and drive the development and application of new materials derived from waste. Other significant factors influencing timber recycling and re-use include collection, transport, storage and land-filling costs.

Particular wood-waste handling challenges include the requirement to separate contaminated and preservative-treated timber (FWPA 2008). Edge Environment (2012) and Blue Environment (2016) summarise waste regulation and legislation across jurisdictions, including landfill levies imposed by most states and territories, and policies and targets to increase recovery rates. Box 6.1 provides examples of initiatives to reduce timber and wood product waste.

Edge Environment (2012) reports that nationally there is lower market demand for recovered timber than other waste from construction and demolition sources, due largely to its low economic value, and the volume of material recovered being relatively small. Waste materials such as metals and masonry that are heavy, are generated in large volumes, and cost more to dispose receive priority attention for recovery and market development in the construction and demolition sector. A reported barrier to growing the recovered timber re-use market is the increasing mechanisation of demolition works, which makes salvage operations more difficult, and increases the potential for damage to high-value timbers.

Box 6.1: Initiatives to reduce wood waste

Various initiatives across Australia aim to increase the recovery and re-use of waste timber and wood products that would otherwise be sent to landfill. These initiatives reflect government policies, such as the 2009 National Waste Policy (EPHC 2010), and the potential for high economic returns to industry from the salvage market for reusable timber.

Timber Recycling fund: four Victorian businesses received $500,000 of government funding to increase timber recovery through projects including the manufacture of high-quality biomass pellets and heating briquettes. The projects have the potential to divert up to 27,500 tonnes of timber reported as going to landfill each year in Victoria (Sustainability Victoria 2017b).

Industry standards: Forest and Wood Products Australia has developed interim standards that provide recycled timber manufacturers, suppliers and users with the requirements for visually grading recycled hardwood timber intended for use in both structural and decorative applications (FWPA 2017).

Product stewardship: The National Timber Product Stewardship Group (NTPSG)[281] is an initiative of the timber and wood products industry to double the recovery of post-consumer timber and wood products to one million tonnes per year by 2017. The Commonwealth *Product Stewardship Act 2011* supports the efforts of the NTPSG and Australian businesses in other sectors by providing the framework to manage effectively the environmental, health and safety impacts of their products.

Recycling centres: Some regional councils around Australia operate recycling centres that recover and recycle timber waste specifically. The Hazelmere Resource Recovery Park run by the Eastern Metropolitan Regional Council in Western Australia, for example, recovers industrial timber waste and processes it into a reusable woodchip for various markets[282].

Timber recyclers and recycling services: Many businesses across Australia supply recovered waste timber and recycled timber products, many from valuable hardwood. Websites such as Austim[283] are also available to assist in finding wood waste recyclers and information on buying recycled timber and wood products.

Fuel pellets made from softwood processing residues being loaded onto a truck for transport to the port of Bundaberg, Queensland, from where they are exported to European and Asian markets.

Localised re-use markets exist for high-quality recycled timber, including for infrastructure timber (power poles and railway sleepers), hardwood flooring, and structural timber (Edge Environment 2012). Tasmania, for example, reports resource recovery of timber products, with tip and salvage shops offering old timber furniture and construction timber for re-use, including items recovered from demolitions or renovations (FPA 2017a). Other products manufactured from recovered timber include engineered wood products, mulch, compost, bedding and other products for animal use, as well as products used to generate energy, including pellets, liquid fuels and dried wood chips.

[281] www.timberstewardship.org.au

[282] www.emrc.org.au/waste-services/resource-recovery-project/hazelmere-resource-recovery-park.aspx

[283] www.austim.com.au/timber-recycling-scheme-directory

Indicator 6.2a

Investment and expenditure in forest management

Rationale

This indicator quantifies investment and expenditure in developing, maintaining, and obtaining goods and services from forests. It provides an indication of the long term and short term commitment to forest management, further processing and other forest uses.

Key points

- Australia's state and territory governments undertake many activities that, together, constitute forest management.
  - A range of state government data on forest management investment and expenditure are presented, but the ability to compare these measures is limited by differences in the classification of activities, in accounting arrangements, in reporting timelines, and in reporting for different tenures.
  - It is therefore also not possible to estimate national expenditure on forest management.
- Investment in the establishment of new commercial plantations, as well as re establishment of harvested commercial plantations, is important for future wood availability.
  - The annual rate of establishment of new commercial plantations in Australia declined from 4,200 hectares in 2011–12, to 900 hectares in 2014–15, then increased to 1,600 hectares in 2015–16.
  - During the period 2011–12 to 2014–15, new plantings comprised mostly hardwoods in Victoria, Queensland and the Northern Territory. During the period 2014–15 to 2015–16, new plantings comprised solely softwood plantations in New South Wales and Western Australia.
- The forest and wood products sector accumulated $4.12 billion of fixed capital in the period 2010–11 to 2015–16, including new plantations, equipment and buildings. Depreciation and amortisation expenses over the same period were $3.47 billion.
  - Capital formation net of depreciation and amortisation over this period was therefore $0.65 billion.

This indicator provides an overview of investment in forest management for forests providing goods and services. This includes expenditure by state and territory governments on public forest management, investment in establishment of new plantations and replanting of existing plantations (re-establishment), and investment in harvesting and in manufacturing involving forest products. Information on other forest investment is scarce; in particular, investment by the private sector (for both native forest management and plantation establishment) is either not available or is treated as commercial-in-confidence, and is therefore not released publicly.

Expenditure by state and territory governments

Australia's state and territory governments undertake many activities that, together, constitute forest management. These include management of weeds and pest animals; forest fire management; soil and water management; forest monitoring; forest health surveillance; forest resource inventories; biological surveys; provision of recreational opportunities; and silvicultural, post-harvest and wildlife management practices. However, state and territory agencies vary in the way they classify activities that constitute forest management, in the detail they provide on expenditure, and in the methods used for accounting for the valuation and depreciation of assets. These differences limit the comparability of investments in forest management between jurisdictions. Accordingly, the data presented below for various agencies vary widely, depending on the nature of the information available, and are generally not directly comparable between jurisdictions.

The general lack of consistent data on expenditure on forest management, and the absence of data for some tenures (such as many nature conservation reserves), make it difficult to determine the nature of changes in forest management expenditure over the reporting period.

No data were available for the Australian Capital Territory or the Northern Territory for this indicator.

New South Wales

The Forestry Corporation of NSW (FCNSW)[284] is a state-owned corporation that manages just under 2.2 million hectares of native forests, plantations and other vegetation types in New South Wales (FCNSW 2016d). It undertakes a range of activities aimed at developing, maintaining, and obtaining goods and services from state forests. These activities include:

- harvest supervision and assessment of environmental compliance
- management of weeds and animal pests
- fire management, including hazard reduction burning and bushfire fighting and prevention
- provision of recreational opportunities.

Table 6.25 shows the total reported expenditure by FCNSW, and the expenditure reported on some of these forest management activities, in the period 2011–12 to 2015–16.

Queensland

The Department of Agriculture and Fisheries[285] (DAF) is responsible for managing Queensland's land, water and vegetation resources, including forest resources (DAF 2016). Forest Products is a business unit of DAF and under the provisions of the *Forestry Act 1959* (Qld) is responsible for activities related to the supply of native forest timber and other forest products from state forests, timber reserves, other state lands, and forest consent areas. Timber rights to the state-owned plantations were sold in 2010, with the rights now held by HQPlantations Pty Ltd under a 99-year licence arrangement (Business Queensland 2016).

Table 6.26 shows total reported capital expenditure by DAF in native forests, and expenditure in managing native forests, in the period 2011–12 to 2015–16.

Table 6.25: Expenditure in New South Wales public native and plantation forests by Forestry Corporation of NSW, 2011–12 to 2015–16 ($ million)

	2011–12	2012–13	2013–14	2014–15	2015–16
Total operating expenses[a]	**213.8**	**196.7**	**205.0**	**192.0**	**206.9**
Forest management expenses (selected)					
Harvest management (hardwood forests)					
Supervision and environmental compliance	5.8	6.6	7.4	5.5	5.9
Harvest planning and pre-harvest surveys	5.7	5.5	5.3	4.5	5.0
Other forest management activities					
Firefighting and fire prevention (wildfire)	0.3	1.8	n.r.	n.r.	n.r.
Hazard reduction burning	6.2	8.2	n.r.	n.r.	n.r.
Post-establishment pest management	0.7	0.7	0.4	0.6	0.6
Weed management	0.8	0.7	0.6	0.7	0.7
Animal pest management	0.9	0.7	0.7	0.7	0.9

n.r., not reported

[a] Total operating expenses of FCNSW, not just expenditure on forest management.

Source: FCNSW (2013b, 2014b, 2015, 2016d).

This table, together with other data for Indicator 6.2a, is available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

Table 6.26: Expenditure in Queensland native forests by the Department of Agriculture and Fisheries, 2011–12 to 2015–16 ($ million)

Activity	2011–12	2012–13	2013–14	2014–15	2015–16
Capital expenditure in native forests	n.a.	0.1	0.1	0.0	0.2
Expenditure in managing native forests					
Multiple-use forests	n.a.	10.2	11.9	11.6	12.7
Other tenures[a]	n.a.	2.5	3.0	2.9	3.2

n.a., not available

[a] Other tenures comprise private, leasehold, other Crown land and unresolved.

Source: Department of Agriculture and Fisheries, Queensland.

This table, together with other data for Indicator 6.2a, is available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

[284] Until January 2013, Forests NSW.

[285] Until February 2015, the Department of Agriculture, Fisheries and Forestry.

South Australia

In South Australia, ForestrySA is responsible for managing commercial plantations on public land in the Mount Lofty Ranges and Mid-North[286] region, and also manages native forest reserves for conservation and recreation purposes. Table 6.27 shows that, over the reporting period, the total expenditure of ForestrySA (including employee benefits, payments to contractors, depreciation and amortisation) was highest in 2013–14, at $88.8 million, and fell to $61.4 million in 2015–16.

On 17 October 2012, the South Australian government sold three forward harvest rotations (up to 105 years) of ForestrySA's Green Triangle plantations to OneFortyOne Plantations Pty Ltd (OFO). Until 30 September 2015, ForestrySA managed the Green Triangle plantations under a plantation management agreement with OFO in return for a management services fee[287]. Income covering management of commercial plantations by ForestrySA over the reporting period, including income from forest management services received by ForestrySA under its agreement with OFO, peaked at $16.8 million in 2013–14 (Table 6.27).

Tasmania

In Tasmania, the Department of Primary Industries, Parks, Water and Environment (DPIPWE) has a number of programs for the management and protection of Tasmanian forests, including valuation and protection of old-growth forests, and monitoring and improvement of natural forest values such as land, biodiversity and water. The Parks and Wildlife Service (a part of DPIPWE) is responsible for managing large areas of forested reserved lands for conservation and recreation, including 412 thousand hectares of 'Future Potential Production Forests' (DPIPWE 2016).

Forestry Tasmania[288], a government business enterprise (and separate entity from DPIPWE), was responsible for managing public native forests and plantations, recreation and tourism facilities, roads and infrastructure over the reporting period. This included the management of 812 thousand hectares of public production forest that is now classified as 'Permanent Timber Production Zone' land (Forestry Tasmania 2016a). The expenditure by Forestry Tasmania on forest management activities is not separately reported.

Total expenses by Forestry Tasmania for operations, which include expenditure on forest management, research and operational and other activities, were about $150 million annually over the last three years of the reporting period, with lower values in the previous two years (Table 6.28). As part of this figure, the expenditure by Forestry Tasmania on fire suppression increased from $0.3 million to $11.2 million over the reporting period, due largely to the extensive bushfires in Tasmania in 2015–16.

Table 6.27: Expenditure on South Australia commercial plantation forests by ForestrySA, and management income received, 2011–12 to 2015–16 ($ million)

	2011–12	2012–13	2013–14	2014–15	2015–16
Total expenditure[a]	77.8	80.3	88.8	82.5	61.4
Income for management services[b]	0.2	10.0	16.8	13.1	3.3

[a] Total expenditure of ForestrySA, not just expenditure on forest management.
[b] Until 30 September 2015, ForestrySA managed silvicultural operations for OneFortyOne Plantations (OFO) in return for a fee.
Source: ForestrySA (2012, 2013, 2014, 2015, 2016).

This table, together with other data for Indicator 6.2a, is available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

Table 6.28: Total expenses for operations and fire management by Forestry Tasmania, 2011–12 to 2015–16 ($ million)

Activity	2011–12	2012–13	2013–14	2014–15	2015–16
Total agency operational expenses[a]	134.0	116.9	154.1	148.2	148.0
Fire management (costs of suppression)	0.3	5.1	3.0	0.5	11.2

[a] Values are total expenditure of Forestry Tasmania, not just expenditure on forest management.
Source: Forestry Tasmania (2012a, 2013a, 2014a, 2015a, 2016a).

This table, together with other data for Indicator 6.2a, is available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

286 After the SOFR reporting period, ForestrySA withdrew from managing plantations in the Mid North region of South Australia.
287 After that time, OFO internalised the management of its plantations (Government of South Australia 2015).
288 From 1 July 2017, Sustainable Timber Tasmania.

Victoria

The agency responsible for managing natural resources, including state forests, in Victoria has changed a number of times during the reporting period. As at June 2016, the Department of Environment, Land, Water and Planning (DELWP)[289] has broad responsibility for Victoria's natural environments (including forest fire management). VicForests is a separate, government-owned business responsible for the harvest, commercial sale and regeneration of harvested coupes from Victoria's state forests. Together with VicForests, DELWP (through Parks Victoria) is responsible for managing Victoria's parks and reserves, and state forests.

Table 6.29 indicates the expenditure on managing Victoria's parks, forests and public land between 2011–12 and 2015–16. Total expenditure, which includes expenditure on non-forested parks or areas of parks, fluctuated during the reporting period, and increased in 2015–16 to $328 million. Reported expenditure on land and fire management, which also includes expenditure on non-forest areas, similarly fluctuated over the reporting period and increased to $397 million in 2015–16. Expenditure for various management activities in multiple-use forests, and on forest health monitoring and management in nature conservation reserves, are also given on Table 6.29.

Western Australia

Over the SOFR 2018 reporting period, the Department of Environment and Conservation (DEC) and subsequently the Department of Parks and Wildlife (DPaW)[290] were charged with ensuring that Western Australia's plants and animals and the lands (including state forests, conservation parks and nature reserves) and water under the care of these agencies were managed appropriately for tourism, water and wood production. Table 6.30 indicates the annual expenditure from 2011–12 to 2015–16 by these agencies on forest management. Total expenditure by DEC increased to $56 million in 2012–13, and by DPaW increased to $62.7 million in 2014–15.

The Forest Products Commission (FPC) is the statutory authority responsible for the sustainable management and development of Western Australia's forest products industry using native forest, plantation and sandalwood products on land owned or leased by the state. Total expenditure on forest management by FPC, including the sustainable management of timber resources, was about $73 million annually over the reporting period (Table 6.30).

Table 6.29: Expenditure on public land management categories, Victoria, 2011–12 to 2015–16 ($ million)

Activity	2011–12	2012–13	2013–14	2014–15	2015–16
Land and fire management[a]	**315.0**	**383.5**	**382.3**	**347.8**	**396.5**
Management of forests and parks[b]	**231.8**	**199.0**	**199.2**	**298.9**	**328.2**
Management of multiple-use native forests	**38.0**	**40.3**	**36.6**	**40.2**	**38.1**
Commercial production	22.4	24.8	24.9	24.3	26.9
Recreation and tourism	8.2	8.1	5.3	5.8	2.2
Infrastructure construction and maintenance	6.7	5.9	4.8	6.8	6.5
Ecological protection and conservation	n.r.	0.2	0.05	1.2	1.1
Community involvement	n.r.	0.6	0.7	1.2	0.5
Forest health monitoring and management[c]	0.8	0.8	0.8	0.8	0.8
Management of nature conservation reserves					
Forest health monitoring and management[c]	0.8	0.8	0.8	0.8	0.8

n.r., not reported

[a] Figures for 2014–15 and 2015–16 are the expenditure in grouping 'Fire and emergency management'.

[b] Figure for 2015–16 is expenditure in grouping 'Management of forests, parks and public land'.

[c] 'Forest health monitoring and management' covers health surveillance, management and eradication responses for pests and diseases, and also Vegetation Forest and Monitoring Plots and bushfire monitoring across multiple-use public native forest and nature conservation reserve tenures.

Note: Values may not be comparable across years due to possible changes in these categories arising from agency changes during the reporting period.

Source: VicForests; DEPI (2014a); DELWP (2015, 2016).

This table, together with other data for Indicator 6.2a, is available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

[289] The Department of Environment and Primary Industries from April 2013 to January 2015.

[290] From 1 July 2017, the Parks and Wildlife Service, Department of Biodiversity Conservation and Attractions. Before 1 July 2013, DPaW was the Department of Environment and Conservation (DEC).

Table 6.30: Expenditure on forest management, Western Australia, 2011–12 to 2015–16 ($ million)

Activity	2011–12	2012–13	2013–14	2014–15	2015–16
Forest management (DEC)	53.6	55.9	n.a.	n.a.	n.a.
Forest management (DPaW)[a]	n.a.	n.a.	58.2	62.7	8.9
Forest management (FPC)	73.9	74.0	70.9	72.2	73.1

n.a., not applicable

[a] Values for 2013–14 and 2014–15 relate to expenditure by the agency's 'Forest Management Service'. The value for 2015–16 relates only to expenditure by the agency's 'Forest Management Plan Implementation Service' and cannot be compared with previous years.

Note: Changes in operational service areas between 2012–13 (DEC) and 2013–14 (DPaW) means that forest management expenditure between these agencies may not be comparable.

Source: DEC (2012a, 2013a); DPaW (2014, 2015a, 2016b); FPC (2012, 2013, 2014, 2015, 2016).

This table, together with other data for Indicator 6.2a, is available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

Investment in new commercial plantations and plantation re-establishment

Investment in the establishment of new commercial plantations is one form of investment in the production of wood. Australia-wide, the annual rate of establishment of new commercial plantations declined during most of the reporting period, from 4,200 hectares in 2011–12 to 900 hectares in 2014–15; during this period, new plantings comprised mostly hardwoods in Victoria, Queensland and the Northern Territory (Table 6.31). Establishment of new commercial plantations increased in 2015–16, with a total of 1,600 hectares of new plantations established, comprising softwood plantations in New South Wales and Western Australia (Table 6.31). The general downward trend in new commercial plantation establishment over the reporting period is consistent with the decline in new commercial plantations observed towards the end of the previous reporting period (2006–07 to 2010–11).

Table 6.32 shows the annual costs reported across four jurisdictions for commercial plantation establishment and re-establishment during the period 2011–12 and 2015–16. The areas of public and private commercial plantation re-establishment across all Australian jurisdictions during this same period are provided in Indicator 2.1e.

Table 6.31: Area of new commercial plantation establishment, 2011–12 to 2015–16 (hectares)

Plantation type and year	ACT	NSW	NT	Qld	SA	Tas.	Vic.	WA	Australia
Hardwood									
2011–12	0	<50	1,600	500	0	100	1,000	400	3,600
2012–13	0	0	1,700	100	0	<50	0	100	2,000
2013–14	0	<50	1,200	100	0	0	0	<50	1,300
2014–15	0	0	400	200	0	0	0	<50	500
2015–16	0	0	0	0	0	0	0	0	0
Total 2011–16	**0**	**<50**	**4,800**	**900**	**0**	**100**	**1,000**	**500**	**7,400**
Softwood									
2011–12	0	300	0	300	0	0	<50	<50	700
2012–13	0	300	0	0	<50	<50	<50	0	300
2013–14	0	200	0	0	0	0	100	<50	300
2014–15	0	100	0	<50	0	0	0	300	400
2015–16	0	1,400	0	0	0	0	0	200	1,600
Total 2011–16	**0**	**2,300**	**0**	**300**	**<50**	**<50**	**100**	**500**	**3,200**
All plantations									
2011–12	0	400	1,600	800	0	100	1,000	400	4,200
2012–13	0	300	1,700	100	<50	<50	<50	100	2,300
2013–14	0	200	1,200	100	0	0	100	<50	1,600
2014–15	0	100	400	200	0	0	0	300	900
2015–16	0	1,400	0	0	0	0	0	200	1,600
Total 2011–16	**0**	**2,300**	**4,800**	**1,200**	**<50**	**100**	**1,100**	**1,000**	**10,600**

Notes: Figures are areas of new plantations. Areas replanted as plantation following final harvest of a pre-existing plantation (re-establishment) are excluded. Data for Western Australia have been updated with figures from the FPC Annual Report 2016–17 (FPC 2017). Totals may not tally due to rounding. Figures are rounded to the nearest 100 hectares; areas reported as less than 50 hectares (<50) are between 1 and 49 hectares.

Source: National Plantation Inventory; Gavran (2013); Gavran (2015); Downham and Gavran (2017); FPC (2017).

This table, together with other data for Indicator 6.2a, is available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

Table 6.32: Cost of commercial plantation area establishment and re-establishment, 2011–12 to 2015–16

Jurisdiction and activity	2011–12	2012–13	2013–14	2014–15	2015–16	Total 2011–16
New South Wales[a]						
Cost of all plantation establishment ($ million)[b]						
Softwood	12.9	12.6	11.9	15.9	15.3	68.7
Hardwood	1.6	1.3	2.0	0.4	0.8	6.0
Total	**14.5**	**13.9**	**13.9**	**16.3**	**16.1**	**74.7**
Tasmania[c]						
Capital expenditure commitments for plantation establishment and re-establishment[d] ($ million)[e]	30.0	21.7	17.9	16.4	16.4	–[e]
Western Australia						
Purchase of investments (new plantations) ($ million)	4.8	5.2	4.7	5.6	5.9	26.3
South Australia[f]						
Expenditure in plantation forest management ($ million)						
Establishing new plantations and re-establishing existing plantations	n.r.	n.r.	3.3	2.6	2.1	8.0
Commercial production	n.r.	n.r.	6.2	5.2	4.6	15.9
Infrastructure construction and maintenance	n.r.	n.r.	2.0	1.2	0.6	3.7
Fire management	n.r.	n.r.	1.4	1.8	0.3	3.5

–, no data; n.r., not reported

a Plantations managed by FCNSW only, including third-party investor plantings, joint ventures and fee-for-service areas.

b Plantation establishment includes the cumulative cost associated with site preparation, planting, post-planting fertilising, and competition control.

c Plantations managed by Forestry Tasmania only.

d Described in Forestry Tasmania Annual Reports simply as 'establishment'.

e Capital expenditure commitments for each year are the sum of two sub-categories ('not longer than one year' and 'between one and five years'), hence cannot be summed into a 5-year total.

f Plantations managed by ForestrySA, including (until 30 September 2015) plantations managed for OneFortyOne Plantations Pty Ltd. Due to changes in accounting systems, data are not available for 2011–12 and 2012–13.

Source: FCNSW (2014b, 2015, 2016d); Forestry Tasmania (2012a, 2012b, 2013a, 2013c, 2014a, 2014c, 2015a, 2016a); FPC (2012, 2013, 2014, 2015, 2016). Data for South Australia provided by PIRSA Forestry and ForestrySA.

This table, together with other data for Indicator 6.2a, is available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

In the period 2011–12 to 2015–16, the Forestry Corporation of NSW established 2,400 hectares of mostly softwood plantations (Table 6.31). The total cost of plantation establishment and re-establishment for this period was $74.7 million.

Between 2011–12 and 2014–15, the area of new commercial hardwood plantations in the Northern Territory was 4,800 hectares (Table 6.31), which was the largest area of new plantations for all jurisdictions. No new plantations were established in 2015–16.

In the period 2011–12 to 2014–15, a total of 900 hectares of new hardwood plantations and 300 hectares of new softwood plantations were established in Queensland (Table 6.31). No new plantations were established in 2015–16.

In South Australia, ForestrySA is responsible for managing public plantation forests and have previously managed private plantations for OneFortyOne Plantations Pty Ltd. A very small area of new plantations was established directly by ForestrySA from 2011–12 to 2015–16. Table 6.32 indicates the expenditure by ForestrySA in managing commercial plantations during the period 2013–14 to 2015–16, including (until 30 September 2015) plantations managed for OneFortyOne Plantations Pty Ltd. The total cost of all plantation establishment and re-establishment in this period was $8.0 million, the total cost of all commercial production activities was $15.9 million, the total cost of infrastructure construction and maintenance was $3.7 million, and the total cost of fire management was $3.5 million.

In Tasmania, Forestry Tasmania manages plantations mostly located in state forest. A relatively small area of new plantations was established in Tasmania in the period 2011–12 to 2012–13, mainly hardwood plantations (Table 6.31). No new plantations were established in the period 2013–14 to 2015–16. Table 6.32 indicates that the capital expenditure commitments by Forestry Tasmania for plantation establishment (including re-establishment) decreased over the period 2011–12 to 2015–16, from $30 million in 2011–12 to $16.4 million in 2015–16.

In the period 2011–12 to 2013–14, a total of 1,100 hectares of new plantations (mainly hardwood plantations) were established in Victoria (Table 6.31). No new plantations were established in the period 2014–15 to 2015–16.

In Western Australia, the Forest Products Commission (FPC) is responsible for the harvesting and sale of state-owned wood assets in both plantations and native forests. In the period 2011–12 to 2015–16, a total of 1,000 hectares of new plantations were established in Western Australia, with approximately 500 hectares each of new hardwood and new softwood plantations established during this period (Table 6.31). Table 6.32 indicates that the total cost of the FPC investment in all new plantations in the period 2011–12 to 2015–16 was $26.3 million.

Investment in harvesting and manufacturing

The Australian Bureau of Statistics (ABS) has reported investment in the following three subsectors of the Australian forest and wood products sector: forestry and logging; wood product manufacturing; and pulp, paper and converted paper product manufacturing[291] (see also Indicator 6.5b and Box 6.2).

The ABS reports four parameters to measure investment and expenditure in various sectors of the economy. These data are based on random sampling of the industry and so are subject to both sampling and non-sampling errors. Changes in accounting methods adopted by industry, including approaches to asset valuation and depreciation, may also affect the accuracy of values reported. The four parameters are:

- **Gross fixed capital formation (GFCF)** – the total value of fixed-asset acquisitions (such as the establishment of new plantations, purchase of machinery, acquisition of goodwill and intellectual property rights) less any fixed-asset disposals
- **Depreciation and amortisation** – allocation of the cost of an asset over its service life (Fraser and Ormiston 2010), and considered as expenses. The depreciation and amortisation category does not include asset impairment or revaluation in regards to standing timber
- **Capital formation net of depreciation and amortisation** – GFCF less depreciation and amortisation. Reflects net formation of new productive capacity
- **Inventories** – intermediate goods (such as raw materials, fuels, containers), and goods held for sale or distribution. Reasons for accumulating inventory can range from anticipatory investment to over-investment. Reasons for reducing inventory can range from increased sales to impairments in the value of inventory holdings.

Table 6.33 presents data for investment and expenditure in the forestry and logging, wood product manufacturing, and pulp, paper and converted paper product manufacturing subsectors for the period 2010–11 to 2015–16. Investment and expenditure in these three forest industry subsectors fluctuated during this period. The three subsectors combined accumulated $4.12 billion of fixed capital between 2011–12 and 2015–16, including new plantations, equipment and buildings. Depreciation and amortisation expenses over the same period were $3.47 billion, capital formation net of depreciation and amortisation was $0.65 billion and the value of inventory holdings decreased by $47 million.

Across the period 2011–12 to 2015–16, capital formation net of depreciation and amortisation in the forestry and logging subsector was $420 million (Table 6.33). This reflects gross fixed capital formation of $1,156 million, and depreciation and amortisation of $736 million. The only year that net capital formation decreased in the subsector was 2015–16. Unlike many manufacturing sectors, fixed capital formation in this subsector can include acquisitions of natural resource fixed assets, such as plantations, which can appreciate over time as trees grow. The sector also reported an increase in the value of inventory holdings of $83 million between 2011–12 and 2015–16.

Capital formation net of depreciation and amortisation in the wood product manufacturing subsector was $429 million across the period 2011–12 to 2015–16, and was positive in all years during this period (Table 6.33). This reflects gross fixed capital formation of $1,411 million, and depreciation and amortisation of $982 million. The value of the sector's inventory holdings decreased during the first three years, and increased over the last two years, during this period, remaining largely unchanged overall.

During the period 2011–12 to 2015–16, capital formation net of depreciation and amortisation in the pulp, paper and converted paper product manufacturing subsector was negative $195 million, the lowest level of the three forest industry subsectors. Depreciation and amortisation ($1,747 million), which was higher than for the other two forest industry subsectors, exceeded gross fixed capital formation ($1,552 million). The sector reported decreases in the value of inventory holdings during three of the five reporting years, with a reduction in overall inventory of $131 million between 2011–12 and 2015–16.

[291] These three subsectors are based on the Australian and New Zealand Standard Industrial Classification (ANZSIC) 2006 (Trewin and Pink 2006). The 2006 ANZSIC was updated in 2013 (Pink and Welch 2013) with minor revisions but maintaining the scope, concepts and structure of ANZSIC 2006.

Table 6.33: Investment and expenditure in selected Australian forest and wood products subsectors, 2010–11 to 2015–16 ($ million)

Parameter	2010–11[a]	2011–12	2012–13	2013–14	2014–15	2015–16	Total 2011–16
Gross fixed capital formation							
Forestry and logging	192	259	290	192	226	189	1,156
Wood product manufacturing	279	325	309	207	289	281	1,411
Pulp, paper and converted paper product manufacturing	421	389	262	306	275	320	1,552
Total	**892**	**973**	**861**	**705**	**790**	**790**	**4,119**
Depreciation and amortisation							
Forestry and logging	130	149	184	0	114	289	736
Wood product manufacturing	385	317	222	0	229	214	982
Pulp, paper and converted paper product manufacturing	521	514	455	0	397	381	1,747
Total	**1,036**	**980**	**861**	**0**	**740**	**884**	**3,465**
Capital formation net of depreciation and amortisation							
Forestry and logging	62	110	106	192	112	-100	420
Wood product manufacturing	-106	8	87	207	60	67	429
Pulp, paper and converted paper product manufacturing	-100	-125	-193	306	-122	-61	-195
Total	**-144**	**-7**	**0**	**705**	**50**	**-94**	**654**
Change in inventory (over previous year/through period)							
Forestry and logging	-8	47	12	3	9	12	83
Wood product manufacturing	69	-114	-13	-12	91	49	1
Pulp, paper and converted paper product manufacturing	96	-37	-84	50	5	-65	-131
Total	**157**	**-104**	**-85**	**41**	**105**	**-4**	**-47**

[a] Revised from SOFR 2013 figures.

Source: ABS (2014, 2017b).

This table, together with other data for Indicator 6.2a, is available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

Indicator 6.2b

Investment in research, development, extension and use of new and improved technologies

Rationale

This indicator monitors the investment in, and adoption of, new or improved technologies in forest management and in forest-based industries. It also quantifies the level of research and development. Significant investment in research, development and new technologies results in continual improvements to forest management practices.

Key points

- Australian Bureau of Statistics data show that, from 2007–08 to 2013–14, total expenditure on research and development (R&D) reported by businesses in the forest and wood products sector declined from $144 million to $86 million.
  - From 2007–08 to 2015–16, expenditure on R&D reported by businesses in the forestry and logging subsector decreased from $22.0 million to $12.9 million.
  - From 2007–08 to 2015–16, expenditure on R&D reported by businesses in the pulp, paper and converted paper product manufacturing subsector varied, with a small overall decrease from $71.1 million in 2007–08 to $70.1 million in 2015–16.
  - From 2007–08 to 2013–14 expenditure on R&D reported by businesses in the wood product manufacturing subsector decreased from $51.3 million to $20.8 million.
  - Only partial data on R&D expenditure are available from the ABS for some years.
- A separate series of surveys of the forest and forest products sector, using a different definition of the sector from that used by the ABS, showed that R&D expenditure on forestry and forest products decreased from $87.8 million in 2007–08, to $48.1 million in 2012–13.
  - Adjusted for inflation, these surveys have shown that expenditure on forestry and forest products R&D has declined by 60.8% between 1981–82 and 2012–13.
- It is not possible to calculate the total expenditure on R&D by businesses, governments, universities and other agencies across the forest and wood products sector.
- A survey of timber industry processing facilities covering softwood and hardwood sawmilling, panel and plywood manufacturing for the period 2012 to 2017 estimated a total capital investment of $938 million during the period, including but not limited to investment in new technologies and new activities.
  - The majority of these new investments targeted increased productivity, higher recovery and improved grade yield in the sawmilling sectors, and increased productivity and development of new products in the panel and plywood sectors.

This indicator provides an overview of research and development (R&D) investment and investment in new and improved technologies in the forest and wood products sector.

Australian Bureau of Statistics survey data

The Australian Bureau of Statistics (ABS) collects data from businesses on their R&D expenditure across three subsectors of the forest and wood products sector: forestry and logging; wood product manufacturing; and pulp, paper and converted paper product manufacturing[292]. The ABS 'Survey of R&D, Businesses' (ABS 2015b, 2017e) is a biennial survey, with the change to the collection frequency from annual to biennial being made after the 2011–12 survey. The most recent data available from the ABS were released in 2017, and include data for the 2015–16 financial year, although data for R&D on wood product manufacturing were not included for that year.

In 2015–16, R&D was defined, for the purposes of ABS data collection, in accordance with the Organisation for Economic Co-operation and Development standard as 'creative and systematic work undertaken in order to increase the stock of knowledge – including knowledge of humankind, culture and society – and to devise new applications of available knowledge' (ABS 2017e). This definition excludes expenditure that expands production capacity using existing technologies, but includes expenditure on basic research ('research') and on ways of applying basic research in practice ('experimental development'). The ABS data also include only expenditure on R&D of $100,000 or more undertaken within the sector; R&D on forestry issues undertaken entirely by an entity outside the sector is excluded.

R&D in the forestry and logging subsector can focus on ways to improve forest management, wood production and harvesting of wood products, or on identifying new markets for standing wood (such as a market for reduced carbon emissions). R&D in the wood product manufacturing subsector aims to identify new forest-based products and methods for processed forest products (excluding pulp, paper and cardboard), such as new applications for timber in construction (Bayne and Page 2009), new timber treatments, and the identification of new export markets. R&D in the pulp, paper and converted paper product manufacturing subsector covers a range of areas, such as improving energy efficiency in the pulping and drying of wood, and the development of new wood-based products. For the SOFR 2018 reporting period, there was no ANZIC06[293] industry subdivision classification that covers research on biofuels and bioenergy.

The total estimated R&D expenditure by businesses in the three forest and wood products subsectors in 2013–14 was $85.9 million (Table 6.34; data are incomplete for 2009–10, 2010–11 and 2015–16, and unavailable for 2012–13 and 2014–15). This is a decline of $58.5 million (40.5%) from 2007–08. Adjusted for inflation over the period, this represents a decline of 47.8%. Forest and wood products sector business R&D expenditure declined as a proportion of total business R&D expenditure from a peak of 1.6% in 2005–06[294] to 0.79% in 2008–09, and further to 0.46% in 2013–14 (Table 6.34).

Table 6.34: Business R&D expenditure in the forest and wood products sector, and proportion of total business R&D expenditure, 2007–08 to 2015–16 ($ million)

Sub-sector	2007–08	2008–09	2009–10	2010–11	2011–12	2013–14	2015–16
Forestry and logging	22.0	26.0	37.6	33.2	25.8	21.8	12.9
Wood product manufacturing	51.3	57.1	57.5	62.4	38.2	20.8[a]	–
Pulp, paper and converted paper product manufacturing	71.1	53.8	–	–	48.3	43.3	70.1
Total research expenditure in the forest and wood products sector	**144.4**	**136.9**	**–**	**–**	**112.3**	**85.9**	**–**
Total business expenditure on R&D in Australia	15,047	17,291	16,760	18,007	18,321	18,849	16,659
Proportion of R&D expenditure that is forest and wood products sector R&D expenditure (%)	**0.96**	**0.79**	**–**	**–**	**0.61**	**0.46**	**–**

–, not available.

[a] Values reported by ABS to have a relative standard error of 25–50% and thus to be used with caution.

Notes:

ABS data collection frequency changed from annual to biennial after the 2011–12 survey.

Totals may not tally due to rounding.

Source: ABS (2015b, 2017e).

This table, together with other data for Indicator 6.2b, is available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

292 These subsectors derive from Australia and New Zealand Industry Classification (ANZIC06) industry subdivision classifications; see ABS (2017e).

293 ibid

294 Reported in SOFR 2013.

Business R&D expenditure in the forestry and logging subsector declined by 41.4% over the period 2007–08 to 2015–16, from $22.0 million to $12.9 million, while business R&D expenditure in the pulp, paper and converted paper product manufacturing subsector decreased by only 1.4% over the same period, from $71.1 million to $70.1 million. Business R&D expenditure in the wood product manufacturing subsector decreased by 59.5% over the period 2007–08 to 2013–14, from $51.3 million to $20.8 million (Table 6.34).

Independent survey data

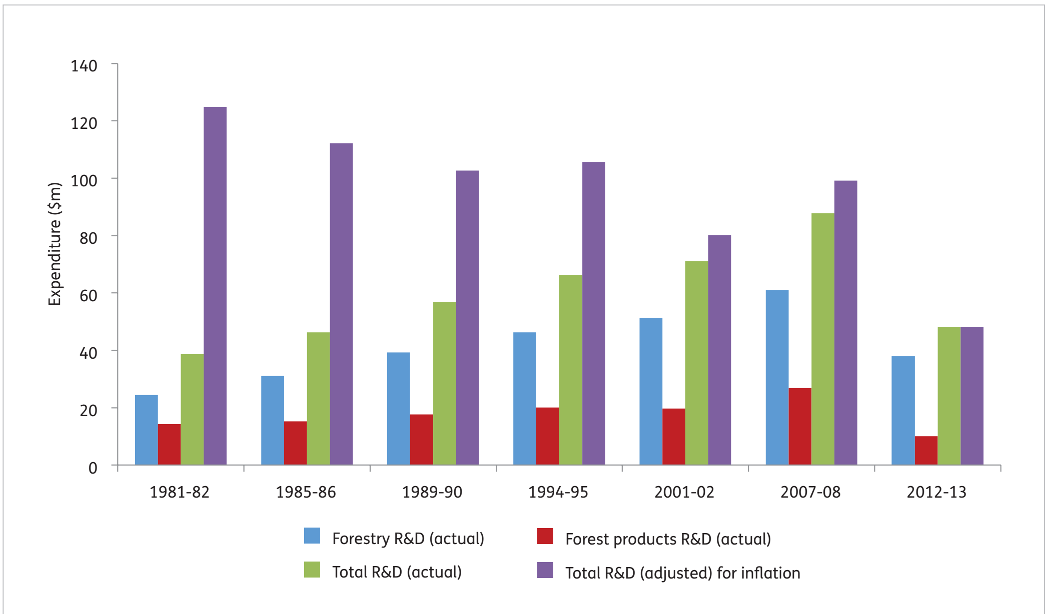
The ABS data are derived from R&D expenditure data reported by business entities. They differ from other estimates of R&D expenditure in the forest and forest products sector, due in part to differing survey methodologies and definitions.

A series of surveys conducted by Turner and Lambert (2005, 2011, 2012) has used a consistent methodology to collect data on expenditure on R&D on forestry and forest products for two segments of the sector at intervals from 1981–82 to 2007–08[295]. A less detailed extension of the same survey (Turner and Lambert 2016) estimated expenditure for the 2012–13 financial year.

'Forestry R&D' was defined by Turner and Lambert as research relating to the commercial management and protection of forests, including environmental and ecological considerations, but not research on areas managed specifically for conservation (e.g. forest areas in public nature conservation areas such as national parks), or costs of monitoring growth, health, nutrition or biodiversity. 'Forest products R&D' was defined by Turner and Lambert as including R&D on value-adding to timber, but not work on final product development (e.g. furniture production), production runs in mills, environmental monitoring or quality control assessment. For both 'Forestry R&D' and 'Forest products R&D', estimates included contributions from both public and private sources, and not just expenditure by business alone.

According to the results of the Turner and Lambert surveys, the estimated total expenditure on forestry and forest products R&D in 2007–08 was about $87.8 million, declining to $48.1 million in 2012–13 (Figure 6.01). The data also show that, although expenditure on forest R&D (unadjusted for inflation) increased in the period 1981–82 to 2007–08, when adjusted for inflation expenditure declined by 60.8% over the period 1981–82 to 2012–13.

Figure 6.22: Expenditure on forestry and forest products R&D, 1981–82 to 2012–13



Notes:

Expenditure values do not include expenditure for support, administration and surveys. Adjusted values were adjusted for inflation to 2012–13 prices using the consumer price index (ABS 2017c).

Sources: Turner and Lambert (2011, 2016).

The data used to create this figure, together with other data for Indicator 6.2b, are available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

295 Note that the Turner and Lambert surveys refer to 'forest products' and the ABS surveys refer to 'wood products'. Both terms relate to wood, rather than non-wood, forest products.

CRITERION 6

6.2b

National investment in Research, Development and Extension (RD&E)

The Australian Government invests directly in RD&E in the forestry and wood products sector, and also invests through CSIRO and through providing funding to Forest and Wood Products Australia that matches industry funding. The Australian Government also provides grant funding to universities and other research agencies, a proportion of which is expended on research relevant to the forest and wood products sector.

State and territory investment in RD&E

Investment in forest management and wood product R&D varies between Australia's states and territories, partly based on the scale of production forestry. The values presented here were supplied by state and territory government agencies.

In Queensland, significant state government investment in R&D continued (as highlighted in Case study 6.3), with almost $2.5 million invested in 2011–12, and over $3.6 million invested in 2015–16.

In New South Wales, investment by Forestry Corporation of NSW[296] (FCNSW) increased from over $1.3 million in 2011–12 to about $1.7 million in 2015–16. About $850,000 of the 2015–16 investment was funded from NSW Community Service Obligation (CSO) Grants, and the balance funded from FCNSW revenue.

In South Australia, the South East Forestry Partnership Program (SEFPP) was announced by the state government in November 2012 as a $27 million fund to stimulate investment in new technologies and equipment by new or existing businesses in the forestry industry in the state's South East. In 2015–16, $6.5 million of this funding was budgeted to provide milestone payments to funded projects from successive rounds of the SEFPP. In addition to the SEFPP, state government funding for Forestry SA activities in research and development was about $1.1 million in 2011–12, declining to about $0.75 million due to many of these activities now being undertaken by OneFortyOne Plantations.

In Tasmania, organisations undertaking research included universities, CSIRO, private forestry companies such as Norske Skog and Forico, the Forest Practices Authority, the Tasmania Fire Service, the Department of Primary Industries, Parks, Water and Environment (DPIPWE), Private Forests Tasmania (PFT), Forestry Tasmania[297], and other government and private agencies. The state government-funded PFT supports private forest owners and managers through research, business development and extension, and education. PFT expenditure for the period 2011–16 was over $1.2 million.

In Victoria, investment in R&D by VicForests in 2015–16 was approximately $161,000.

All states and territories that manage public production forests contribute to R&D through a forest grower's levy, which supports the delivery of programs by Forest and Wood Products Australia.

Areas of R&D investment

Investment in and adoption of new technologies has taken place across a broad range of areas of activity during the SOFR 2018 reporting period. In a report prepared for the national-level Forest and Wood Products Research, Development and Extension Forum (FWP RD&E Forum), Duff and Kile (2014) estimated the distribution of R&D effort across each of the headline national priorities developed by the FWP RD&E Forum (Table 6.35). Estimates of effort were based on the number of full-time equivalent research scientists in each field, as reported by the 12 largest research provider organisations contributing to forest and wood products RD&E effort in Australia.

Examples of applied research and development focused on industry innovation during the SOFR 2018 reporting period include:

- continued development of commercially valuable genotypes including improved genetics for existing and potential commercial species

Table 6.35: Distribution of R&D effort across headline national priorities developed by the FWP RD&E Forum

Area of activity	Proportion of effort
More volume and value from the existing and expanding estate	43%
Supply chain optimisation and manufacturing productivity	12%
Know, grow and diversify the market	11%
Resource risk management and biosecurity	22%
Environmental and social sustainability	11%

Source: Adapted from Duff and Kile (2014).
Note: Totals may not tally due to rounding.

This table, together with other data for Indicator 6.2b, is available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

296 Until January 2013, Forests NSW.
297 From July 2017, Sustainable Timber Tasmania.

Case study 6.3: Queensland Government research investment and capacity

The Queensland Government has maintained a strong forest and timber research capability, and invests around $4 million per annum to deliver industry priorities. A further $5 million per annum is invested by collaborators including Commonwealth bodies, universities and private industry.

Strategic investment in forest and timber industry research, development and extension is guided by the Queensland forest and timber industry research, development and extension framework, which was developed in conjunction with industry in 2014. In addition, the Queensland Government, through the Department of Agriculture and Fisheries[298] (DAF), has initiated the Centre for Future Timber Structures with the University of Queensland. This Centre has expanded the research effort into use of timber in mid-rise construction with major industry partners such as Arup, LendLease and Hyne, establishing the Australian Research Council Industrial Transformational Research Hub.

The Queensland Government delivers its research through a multidisciplinary forest and timber research group, Forestry and Biosciences RD&E, in DAF. This group concentrates its research investment on the priority areas of managing and improving forest productivity, forest health, and developing new forest products and processing systems.

The research is delivered through collaborative networks with universities and other institutes in Queensland, interstate and overseas, as well as with industry partners to achieve positive outcomes across the industry value chain.

- development of integrated genotype-by-environment-by-management regimes adapted to future growing conditions or new environments and that minimise losses from pests and diseases
- increasing the value recovery from the available forest resources from native and planted forests (e.g. veneer recovery and use, design of engineered wood products, and a range of exploratory studies on biomass utilisation, bioenergy and bio-refinery applications)
- improving the efficiency and reducing the costs of harvesting and transport operations
- development of models to predict and assess impacts of key risks, including changing incidence of pests, and climate change and attendant risks of increased fire incidence, changing rainfall patterns and drought
- contingency and response plans for exotic pest introductions.

Adoption of new technologies

A voluntary survey of selected wood-processing facilities to establish the total level of capital investment in the timber industry processing sectors was conducted by Zed and Zed (2017), covering the period 2012 to 2017. The four sectors identified were softwood sawmilling, hardwood sawmilling, panel manufacturing, and plywood manufacturing. Survey responses covered 52% of the softwood sawmilling industry, 40% of the hardwood sawmilling industry, 58% of the panels industry and 42% of the plywood industry. A total of $473 million was invested by the survey respondents over the five-year period. This was extrapolated by Zed and Zed (2017) to an estimated total investment of $938 million by all four sectors over that period.

The survey respondents provided information on the key technologies in which they invested and the benefits they sought to achieve from the investment. Capital items included major replacements or upgrades to current plant, as well as investment in new technologies and activities. The survey identified in detail the investment in new technology and the derived benefits.

In the sawmilling sectors, there was a focus on investment in scanning and optimisation technologies to support the drive for higher recovery, increased productivity and increased grade yield. These technology gains have been incorporated in most of the new equipment installed over the past five years (Zed and Zed 2017).

In the panel manufacturing sector, most new technology investments focused on improvements in manufacturing lines, to increase productivity and reduce costs. There was also investment in remanufacturing technologies to develop new product lines.

In the plywood sector, new technologies were adopted to derive a range of benefits, including access to new products and markets, meeting new design standards, reducing labour costs, and improvements to production efficiency.

Examples of recent innovations adopted in forest inventory and wood harvesting are presented in Case study 6.4 and Case study 6.5, respectively.


Samuel Shelley Photography

Sawn Hydrowood-harvested black heart sassafras.

298 Until February 2015, Department of Agriculture, Fisheries and Forestry.

Case study 6.4: Recent innovations for forest inventory and data capture

In the past, most features within forests, such as tree heights and the location of streams and roads, were mapped using a combination of aerial photographic interpretation and ground-based surveys. However, most of Australia's state and territory forest managers have now turned to airborne and ground-based scanning technology to replace traditional methods of forest mapping in native forests and plantations. These new approaches include 'light detection and ranging' (LiDAR) and digital aerial photogrammetric (AP) sensors mounted on a variety of platforms.

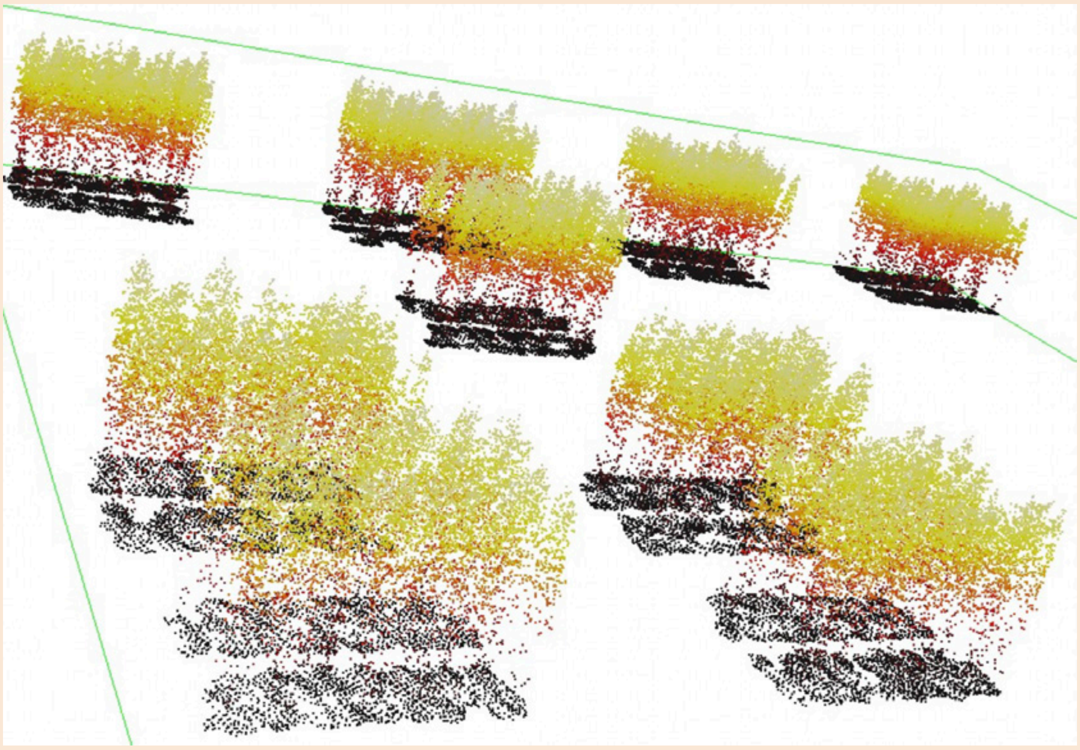
LiDAR equipment can be mounted on light aircraft and, increasingly, on small unmanned aerial vehicles (UAVs) flown over forests. The LiDAR equipment emits high-repetition, short-duration pulses of light directed at the forest, measures the time to the return reflection, and calculates target distance and bearing. Mounting LiDAR sensors on UAVs ('drones') has proven to be a reliable and relatively low-cost alternative to the use of light aircraft, with advantages including significantly reduced capital and operating costs, greater deployability, and potentially higher resolution due to lower operating altitudes (Goodbody et al. 2017).

As a direct sampling tool, LiDAR can capture a range of terrain and forest attributes more rapidly, objectively and cost-effectively than ground-based survey techniques. LiDAR can accurately determine features such as drainage lines, roads and slopes that can be combined into digital elevation maps, and can measure tree and forest heights.

Direct applications of LiDAR include determining forest canopy height and cover, forest stand density and basal area, forest growth stage, forest and vegetation classification, vertical and horizontal forest structure, forest fuel characteristics and regeneration success.

Over the last two decades, LiDAR has developed from a research tool to a fully operational assessment tool, and the technique now contributes to many areas of forest management, including forest mapping, topographic mapping, catchment management, reserve planning and mapping, carbon accounting, wood resource assessment, harvest planning, forest health and fuel-load assessment, and monitoring of mechanical harvesting operations and illegal logging activities.

More recently, studies have shown that 3D point clouds derived from digital aerial photogrammetric (AP) data (with one or more cameras on a moving aircraft) can provide a comparable level of accuracy to LiDAR-based approaches. New digital airborne camera systems, advanced image matching algorithms, and increased computing capabilities are available. Acquisition costs of AP data range from one-third to one-half of those of LiDAR (White et al. 2016). Recent trials in radiata pine (*Pinus radiata*) plantations in Tasmania have shown that reliable estimates of recoverable volume, determined compared to data on actual volumes recovered by harvesting machines as a reference, can be obtained using both LiDAR and AP data (Caccamo et al. 2018).



LAStools (lasview) screenshot of 3D point cloud representing trees in 18 research plots. Source: University of South Australia and Forestry SA.

Case study 6.5: Hydrowood – taking underwater harvesting from an idea to commercialisation

Worldwide, there are an estimated 300 million trees submerged in dams constructed from the 1950s to 1970s for hydro-electric schemes and water storage. This includes the dams used to generate hydro-electric power in Tasmania, with large amounts of forest resource submerged within these dammed lakes and rivers.

When plans were first approved to dam the Pieman River in western Tasmania in 1971, logging was resumed in the area, but only a small portion of the relatively inaccessible forest in the dam's footprint had been logged by the time the area was flooded in 1986. The now flooded area of temperate rainforest includes sought-after specialty timbers such as blackwood (*Acacia melanoxylon*), celery-top pine (*Phyllocladus aspleniifolius*), Tasmanian myrtle (*Nothofagus cunninghamii*), Huon pine (*Lagarostrobos franklinii*) and sassafras (*Atherosperma moschatum*). These timbers are now being extracted by Hydrowood for commercial use.

Hydrowood is one of the world's first underwater forestry operations, and required significant innovation in harvesting technologies, timber processing and marketing. The operation started in November 2015 and now runs seven days every week. The operation employs specialised sonar that enables the location of individual trees and the identification of species, and a specially developed, waterproof harvesting head and boom attached to machinery mounted on a barge. It recovers approximately one load of wood per day from underwater. The wood is sold to customers as a certified product, and chain-of-custody certification enables the harvest story to be passed along with each log. When processed, the salvaged timber has unique properties that drive high-end timber sales, with particular features unique to wood submerged for long periods of time.

Hydrowood purpose-built, waterproof harvesting head and boom attached to an excavator mounted on a barge.

CRITERION 6

6.2b

Indicator 6.3a

Area of forest available for public recreation/tourism

Rationale

This indicator measures the area of forest available for use by the community for recreation and tourism purposes. This provides an indication of the emphasis placed by society on the management of forests for recreation and tourism.

Key points

- Most forests in nature conservation reserves and multiple-use public native forests in Australia are available to the general public for recreation or tourism purposes. The total areas of native forest in these tenures are 21.7 million hectares and 9.8 million hectares, respectively. Some public land in other tenure categories may be similarly available.
- Substantial private forest areas are available for recreation and tourism, usually under commercial arrangements. Kakadu National Park in the Northern Territory is an example of reserved forest on private land tenure that is available for recreation and tourism.
- Some forests that are usually available for public recreation and tourism may be closed temporarily, mainly to ensure public safety. This may occur during adverse weather conditions or bushfire, or during times when certain forest management activities are occurring, such as wood harvesting or prescribed fire.
- Public forest areas may also be closed permanently to recreation and tourism if these activities are likely to compromise, or are not compatible with, the objectives of management for these forest areas, especially preservation and scientific reference areas.

Forests on public land

Most publicly owned forested lands designated for multiple use or nature conservation are available for general recreation and tourism activities. Other tenure categories of public land may also be available. Nationally, 31.5 million hectares of native forest are available for general tourism and recreation across the nature conservation reserves and multiple-use public forest estates (see Table 1.7, Indicator 1.1a), comprising 21.7 million hectares in nature conservation reserve and 9.8 million hectares in multiple-use public forest. Recreation and tourism activities include bushwalking, biking, camping, canoeing, eco-tourism ventures, hiking, hunting, picking berries and fungi, picnicking and horse-riding (see Indicator 6.3b).

Although various outdoor recreation and tourism activities may be undertaken in most public forests, access for some activities, such as hunting, and to some areas is restricted to protect specific scientific, natural, cultural or water supply values (see Case study 7.1). Publicly owned forest areas that are closed permanently to the public, and therefore not available for general recreation and tourism, include areas designated for scientific reference, study or research, nature conservation areas where preservation is a core objective,

Mt Erica road, near Erica, Victoria; forest roads constructed for management purposes are generally available for public recreation.

some water catchment areas, significant Indigenous cultural heritage sites, and defence training areas.

Forests that are usually available for public recreation and tourism may be closed temporarily during wood harvesting, extreme fire weather or other climatic events, total fire bans, fuel reduction burning, control of feral animals or weeds, or special controlled events (e.g. car rallies). Some of these access restrictions (e.g. due to pest and weed control) are more likely to apply to Australia's publicly owned plantation forests than to multiple-use native forests. Forest management plans typically specify the types of visitor and community activities that are permissible and outline the general conditions of use that apply. In forests not subject to forest management plans, the policies of the responsible forest management agency usually indicate the types of recreation and tourism that may take place, and the conditions of use.

The Australian Capital Territory has nearly 16 thousand hectares of multiple-use forest, with 98% of this area available for recreation and tourism. The 2% not available for recreation and tourism consists of the area of pine plantation leased and managed by the Department of Defence. All of the ACT's nature conservation reserves are available for recreation and tourism.

In New South Wales, the Forestry Corporation of NSW[299] manages over 2.1 million hectares of multiple-use forest. Of that area, over 300 thousand hectares of forest is managed for nature conservation purposes and is also available for recreation and tourism. Most areas in nature conservation reserves in New South Wales are also available for recreation and tourism.

In the Northern Territory, most areas in nature conservation reserves are available for recreation and tourism. There are no multiple-use forests in the NT.

In Queensland's public forests, over 3 million hectares of multiple-use forest (in State forests and timber reserves) are available for recreation and tourism. Most areas in nature conservation reserves, including national parks, conservation reserves, resource reserves and forest reserves, are available for recreation and tourism. Areas excluded from recreation and tourism in Queensland include scientific areas of national parks, freehold land, leasehold land, and unallocated state land or other tenures managed by Queensland Parks and Wildlife Service, and land for conservation purposes that are managed by other parties or trusts.

In South Australia, ForestrySA manages approximately 43,500 hectares of multiple-use forest and forest in nature conservation reserves. These forests are all available for recreation and tourism. Most areas in the nature conservation reserve estate are also available for recreation and tourism.

In Tasmania, over 700 thousand hectares of multiple-use forest and over 350 thousand hectares of other publicly managed forest land is available for recreation and tourism. The majority of forested land managed under Tasmania's *National Parks and Reserves Management Act 2002* is also available for recreation and tourism. In Tasmania, recreation and tourism are statutory management objectives for most reserve classes 'to encourage tourism, recreational use and enjoyment consistent with the conservation of the reserve's natural and cultural values'.

Victoria has over 3 million hectares of multiple-use forest, with 99% of this area available for recreation and tourism. Most areas in nature conservation reserves are also available for recreation and tourism.

In Western Australia, over 600 thousand hectares of multiple-use forest and over 750 thousand hectares of forest in nature conservation reserves are available for recreation and tourism within the area covered by the South West Western Australia Regional Forest Agreement.

Forests on private and leasehold land

Public access for recreation and tourism to forests on private land is generally restricted or not permitted, although little information is available about actual permitted uses. If access is required, it would be on application to the private landowner or manager for permission to undertake particular activities, unless specific commercial arrangements are advertised (e.g. a wildlife park). The same applies for forests on leasehold land, most of which is privately managed under long-term pastoral leases that grant the lessee rights of custody of the land — these leases impart a level of responsibility for the management of the land.

Of the 88.8 million hectares of forest on private and leasehold land (Indicator 1.1a), around 11.5 million hectares (13%) is in the National Reserve System (Indicator 1.1c). The Northern Territory contains more than 5.6 million hectares of reserved private or leasehold land, including reserved Indigenous land, and Queensland has more than 4.3 million hectares. Much of that land is available for recreation and tourism, including Kakadu National Park, which is an example of private land leased to the Australian Government for management of its nature conservation values under national park tenure.

In Tasmania, for two private land reserve types (private sanctuaries and private nature reserves) with a combined area of forest of about 14 thousand hectares, public access is at the discretion of the owner.

Bushwalkers, Casuarina Coastal Reserve, Northern Territory.

[299] Until January 2013, Forests NSW.

Indicator 6.3b

Range and use of recreation/tourism activities available

Rationale

This indicator assesses the range and number of recreation and tourism facilities provided in forests, their level of use and their contribution to the broader tourism sector. Appropriate and well managed facilities help to optimise visitor satisfaction as well as minimising environmental impacts associated with recreation and tourism.

Key points

- A wide range of recreation and tourism activities can be undertaken on forested land in Australia. There is considerable and increasing demand for recreation and tourism in public forested areas, including national parks, state forests and pine plantations.
- Tourism Australia data indicate that an annual average of 4.2 million people visited major forested tourism regions for bushwalking in the period 2011–12 to 2015–16, with 10% of these visitors identifying as international visitors. The proportion of international visitors to major forested tourism regions is especially high in northern Australia.
- This indicator also presents data on recreational facilities and visitor activities in public forests in the Australian Capital Territory, New South Wales, Queensland, South Australia, Tasmania and Victoria over the period 2011–12 and 2015–16
  - The increasing number of recreation and tourism facilities in public forests indicates considerable ongoing investment in providing for forest recreation and tourism.

This indicator reports the use of forests for a range of recreation and tourism activities, and the numbers of recreation and tourism facilities available for public use. Some facilities, such as walking or riding tracks, picnic sites and campgrounds, are provided solely for recreation or tourism activities. Other facilities, such as roads and vehicular tracks, are provided for a range of forest management purposes but are also available for use for recreation and tourism activities.

In each state and territory, public forest management aims to provide a range of opportunities for recreational pursuits (such as walking, running, cycling, driving, climbing, fishing, camping, canoeing, and water sports) consistent with demand, resources, environmental concerns and management intent, as well as facilities appropriate for each forest setting.

State forests and national parks

Australia's state forests, also known as multiple-use public forests, are generally open to the broadest range of public recreation and tourism activities available in Australia's forests. Greater restrictions on recreation and tourism activities are usually imposed in nature conservation reserves, because nature conservation is the higher management priority. Restrictions in nature conservation reserves typically include limits to the number of camping sites and access for trail-bike and horse riding; hunting and use of dogs is usually discouraged or not permitted in national parks. Many commercial plantations are also available for recreation and tourism activities.

State forests also provide a range of recreational opportunities that are generally available free-of-charge to the public, including use of picnic and camping areas, and access to state forest roads for vehicular activities. Some national parks, and some facilities in national parks, are accessed via an entrance gate with an entrance fee, and fees can be charged for overnight camping, with registration required to access popular camping sites and multi-day hiking trails. A proportion of these fees generally goes towards the ongoing maintenance of facilities and park management. Organised events and eco-tourism activities in state forests and national parks are administered by permit (or licence) systems, and there is typically an associated fee.

In 2015–16, Forestry Corporation of NSW[300] (FCNSW) as a State-owned corporation, spent \$3.7 million on recreation and tourism services from an annual Community Services Obligation grant of \$16 million from the NSW Government,

[300] Until January 2013, Forests NSW.

the grant recognising that a comparable privately owned commercial forestry business would not be expected to provide those services. FCNSW also spends additional funds on the management of recreation and tourism sites in multiple-use public forests.

Numbers of visitors

Visitor numbers in some public forests (mainly national parks and other reserves) are monitored regularly by a mixture of counts, estimates by management agency staff, and on-site surveys. Count data are based on entry fees, traffic counters and camping permits, and are relatively accurate ways to monitor use.

Use of unmonitored forests is difficult to measure because there can be many entry points, and visitors are widely dispersed. Use can also vary according to the day of the week and the season, and increases greatly during school holidays. Sites that are well signposted and promoted are visited more frequently than lesser known sites, where use depends more on local knowledge and personal experience. Because of the free access to state forests, and the many entrance points, data on use are generally not collected. However, data are collected for some locations, such as Cumberland State Forest in Sydney's north-west, which attracts more than 100,000 visitors per year.

National

Tourism Australia undertakes questionnaire-based surveys asking Australians and visitors to Australia about their trips and activities. The numbers of bushwalkers identified in these surveys are summarised in Table 6.36 for selected Tourism Australia National Landscapes regions for which forests are a likely component of their attraction as bushwalking destinations. The Tourism Australia data indicate that an annual average of 4.2 million visitors visit the major forested tourism regions for bushwalking, with 10% of these visitors identifying as international visitors.

The Greater Blue Mountains was the most popular destination for bushwalkers, perhaps because they are close to Sydney. Tasmania was the most popular for overnight visits, but the Australian Alps and south-west Western Australia received only slightly fewer overnight visitors. The proportion of international visitors is especially high in northern Australia.

States and territories

In the Australian Capital Territory, Namadgi National Park is the largest and mostly frequently visited nature conservation reserve, with camping and bushwalking the main forms of recreation in the park. There is difficulty in reporting recreational visitation in the park is due to the size, remoteness, area of use available to visitors, and the park's position on a through road, with many vehicles passing through but not stopping to visit the park.

The ACT's pine plantations are also extensively used and managed for recreational activities including walking, jogging, horse riding, cycling, camping, picnicking, fishing, musical events and car rallies. Visitor use in the plantation estate is now equal to the number of visitors to the ACT nature conservation reserves due to their close proximity to Canberra, the substantial high quality road and trail infrastructure, and the investment made in forest management.

Some of the recreation facilities available in public forests in the ACT are shown in Table 6.37. Usage of these facilities each year during the SOFR 2018 reporting period was estimated at about 4000 to 5000 people cycling, over 100,000 people walking or running, 14,000 to 18,000 people attending events, and over 200,000 people picnicking and playing.

Table 6.36: Bushwalking visitors to major forested tourism regions

	Annual average numbers of bushwalkers ('000)[a] 2011–12 to 2015–16			
National Landscape	**National visitors, overnight trips**	**National visitors, day trips**	**International visitors**	**Total**
Australian Alps, NSW and Victoria	424	199	14	637
Coastal East Gippsland, Victoria	130	n.d.	16	146
Greater Blue Mountains, NSW	350	791	60	1,201
South-west Western Australia	391	116	49	556
Northern NSW and south-east Queensland	196	283	122	601
Tasmania	467	302	93	862
Top End, Northern Territory	62	n.d.	36	98
Wet Tropics, north Queensland	80	n.d.	20	100
Total selected regions	**2,100**	**1,691**	**410**	**4,201**

n.d., no data reported due to inadequate sample size.
[a] Derived from survey data based on Tourism Australia's National Landscapes.
Source: Tourism Research Australia, Australian Trade and Investment Commission.

This table, together with other data for Indicator 6.3b, is available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

Table 6.37: Recreational facilities in public forests in the Australian Capital Territory, 2011–12 and 2015–16

		Number	
Activity	Measure	2011–12	2015–16
Riding or walking animals	kilometres of tracks	70	70
Cycling[a]	kilometres of tracks	267	267
Driving	kilometres of roads	–	1,433
Walking or running[b]	kilometres of tracks	224	239
Climbing	number of documented sites	2	2
Cultural heritage appreciation	number of managed sites	3	2
Events[c]	number of events	92	128
Camping	number of sites	7	7
Picnicking and playing	number of sites	23	23

–, data not available

[a] For multiple-use forest only; no data available for nature conservation reserves. Includes mountain bike-only tracks (101 km) and motocross tracks (56 km) in pine plantations. The mountain bike tracks are not accessible to motorbikes but mountain bikes can access the motocross tracks. This figure excludes roads and fire trails, but they are also accessible to mountain bikes.

[b] Tracks are specific for walking or running, but most mountain bike tracks and roads are also accessible for walking or running.

[c] Approved events only.

Note: values may include some non-forest sites.

This table, together with other data for Indicator 6.3b, is available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

Table 6.38: Use of nature conservation reserves for recreation and tourism activities on land managed by New South Wales National Parks and Wildlife Service, 2011–12 and 2015–16

	Number of visitors (millions)	
Activity	2011–12	2015–16
Riding or walking animals	n.d.	0.5
Cycling	1.4	1.9
Driving (includes motorbikes)	0.7	1.4
Walking or running	17.3	23.5
Climbing, caving and canyoning	1.0	1.0
Enjoyment and appreciation of nature	1.0	1.4
Camping (includes roofed accommodation)	1.7	2.9
Picnicking and playing	6.2	6.7
Snow activities	0.7	1.0
Water-based recreation	6.2	9.6

n.d., no data reported due to inadequate sample size.

Source: NSW National Parks and Wildlife Service, Office of Environment and Heritage; derived from commissioned market research, and park visitation data; data are for all nature conservation reserves managed by the NSW National Parks and Wildlife Service and therefore include use of non-forested areas.

This table, together with other data for Indicator 6.3b, is available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

In New South Wales, the National Parks and Wildlife Service surveys the use of nature conservation reserves for recreation and tourism activities, and collects park visitation data (Table 6.38). Bush-walking and running are the most popular activities, followed by picnicking and water-based activities. The number of visits to nature conservation reserves increased by about 40% over the SOFR 2018 reporting period.

FCNSW estimated that there were 28 million recreational visitors to NSW state forests during 2015–16. FCNSW managed and maintained more than 150 designated visitor sites (FCNSW 2016d), winning tourism awards for developments at five of these sites during the SOFR 2018 reporting period. One of these sites is illustrated in Case study 6.7.

In the Northern Territory, very little land is available for general recreation and tourism outside of nature conservation reserves. Permission is required to visit all private land (Indigenous freehold land and other freehold land, with the exception of Kakadu National Park) and pastoral leasehold land. Permission to visit Indigenous land is provided on request in most instances, but no member of the public is permitted to visit such areas unannounced. Annual visitor numbers to Kakadu National Park and Arnhem Land, which contain extensive forest areas, have increased over the SOFR 2018 reporting period, and average 222,000 between 2015 and 2017, and include international and Australian visitors (Tourism NT 2016, 2017).

Case study 6.6: Kowen Forest

Kowen Forest, at the eastern edge of the Australian Capital Territory, comprises 4,700 hectares of pine plantations interspersed with native forest. While being managed for commercial softwood sawlog production, it is also in high demand for recreational activities. Frequent activities include four-wheel drive rallying and driver training, mountain-bike (Figure 6.23) and motor-bike training and racing, mountain-bike orienteering, foot orienteering, rogaining, sled-dog racing, horse riding, camping, and training of military, emergency services and police personnel. These activities add a layer of complexity to management of the plantation for commercial timber production. Community relations issues can arise, for example, when maturing plantation blocks that have been used for bike riding for years become due for clearfelling and re-establishment.

Based on applications for access permits to Kowen Forest and other pine plantations in the ACT, the estimated average number of people participating in these activities in the SOFR 2018 reporting period was 8,600 per year. Considerable numbers of people also undertake activities in Kowen Forest for which permits are not required.

Figure 6.23: Mountain bike trail, Kowen Forest

CRITERION 6

6.3b

Case study 6.7: Forest Sky Pier, Orara East State Forest

Forestry Corporation of New South Wales won five awards for forest recreation and tourism facilities during the SOFR 2018 reporting period, including for developing the 21-metre timber and steel 'Forest Sky Pier' at Bruxner Park Flora Reserve in the Orara East State Forest, near Coffs Harbour.

Forest Sky Pier is located at Sealey Lookout, one of the best vantage points for viewing the Coffs Harbour's coastline (Figure 6.24). The lookout, the associated network of walking tracks through the forest, and picnic facilities attract more than 150,000 visitors a year.

Figure 6.24: Forest Sky Pier, Orara East State Forest

In Queensland, land managed by Queensland Parks and Wildlife Service (QPWS) includes multiple-use forest and nature conservation reserves. Some recreational activities available on land managed by QPWS are shown in Table 6.39. Activities shown, other than camping, have free access and are not monitored. There were over 1 million overnight campers on land managed by QPWS in 2011–12, rising to over 1.5 million in 2015–16. Hunting activities are not available on Queensland's public lands, they are restricted to private and leasehold lands only.

In South Australia, community use of forest reserves, including native forest reserves, managed by ForestrySA is a high management priority, especially in the Mount Lofty Ranges close to the Adelaide metropolitan area. During the 2015–16 financial year, 152 events were held in the Mount Lofty Ranges forest reserves. These attracted approximately 14,900 people participating in a variety of recreational and or educational activities including school, scout and university programs, motorsport competitions, mountain-biking, horse endurance rides, sled-dog racing, orienteering, defence training, filming and photography. Recorded visitors to all ForestrySA forest reserves for 2015–16 totalled 119,727, excluding regular activities where permits are not allocated (ForestrySA 2016).

The number of facilities provided for recreation in South Australian state forests, including pine plantations, and in parks and reserves managed by ForestrySA, are shown in Table 6.40. These numbers have not changed significantly over the SOFR 2018 reporting period.

In Tasmania, bush-walking, mountain-bike riding, climbing, abseiling, caving, nature observation, photography, swimming and other recreational activities take place in state forests, national parks and other reserves. Hunting is allowed by permit in some areas of state forests and on some reserves (game reserves, conservation areas and regional reserves). Visitor numbers to parks and reserves are monitored

Table 6.39: Recreational facilities in public forests in Queensland, 2015–16

Activity	Measure	Value
Cycling	kilometres of tracks	170
Driving	kilometres of roads	33,376
Walking or running	kilometres of tracks	2135
Climbing	number of documented sites	103
Events[a]	number of events	99
Camping	number of sites	460
Picnicking and playing	number of sites	208

Note: Values are for Queensland Parks and Wildlife Service managed lands only, and may include some non-forest sites, though most are in forest settings.

[a] Includes 16 commercial and 83 non-commercial events/festivals, for which permits were issued. The non-commercial events occurred primarily on conservation reserves and consisted of military, horse riding club, cycling, motor vehicle, and nature study activities.

This table, together with other data for Indicator 6.3b, is available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

Table 6.40: Visitor activity and facilities in land managed by ForestrySA, 2015–16

Activity	Measure	Value
Riding or walking animals	Parks available for riding	9
	Parks available for walking dogs	21
	Tracks on land managed by ForestrySA	75%
Cycling	Parks	9
	Cycling tracks on land managed by ForestrySA	All
Walking or running	Tracks in the network managed by ForestrySA	All
Climbing	Sites	4
Cultural heritage appreciation	Sites	4
Events or festivals	Events	163
Hunting	Game reserves	10
Camping	Camping areas	5
	Camp sites	94
Picnicking and playing	Parks and forests	All
Huts, houses	ForestrySA accommodation sites	9

Source: ForestrySA.

This table, together with other data for Indicator 6.3b, is available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

periodically and have increased by an average of 40% over the SOFR 2018 reporting period. Table 6.41 shows visitor numbers to selected forested national parks and reserves in Tasmania.

The Tahune AirWalk, located in state forest in southern Tasmania, continues to be one of the state's leading tourism attractions, receiving 75,000 visitors in 2015–16 (Forestry Tasmania 2016a).

Several major investments in the development of recreation and tourism facilities in forested areas were also completed in Tasmania in the SOFR 2018 reporting period. These include:

- Three Capes walking track, Tasman National Park, opened in late 2015
- Pumphouse Point Lodge, opened at Lake St Clair within the Tasmanian Wilderness World Heritage Area
- Blue Derby mountain-bike trail project, an 80 kilometre network of trails near Derby and within the adjacent Blue Tier Forest Reserve.

In Victoria, in the absence of visitor or use data specific to Victorian forests, the number of facilities provided for recreation activities in state forests can be used as a guide to the demand for various activities on that tenure (Table 6.42). Except for roads promoted as touring routes, the numbers of all facilities increased by an average of 9% in the SOFR 2018 reporting period. Notable increases were in tracks for dog walking and horse riding and in sites promoted for fishing.

In Western Australia, the area covered by the WA *Forest Management Plan 2014–2023* (CCWA 2013) provides important opportunities to meet the growing public demand for outdoor recreation and nature-based tourism in the south-west of WA. Some plantation areas are also important for recreation, with the use of public plantations for recreation being generally promoted. A wide variety of activities are available in the south-west forests of WA, including picnicking, bushwalking, cycling, camping, swimming, fishing and canoeing. There are also two gazetted off-road vehicle areas within pine plantations north of Perth. On occasions, areas covered by the management plan are also used for activities such as organised car rallies and adventure racing.

Table 6.41: Visitors to selected parks and reserves, Tasmania

	Number of visitors ('000)	
Location	**2010–11**	**2015–16**
Freycinet	200	272
Cradle Mountain	162	228
Mount Field	105	189
Tasman Arch (Tasman Peninsula)	n.a.	164
Lake St Clair	75	94
Narawntapu (Western entrance)	41	46
Hastings Caves and Thermal Pool	37	46
Maria Island	8	23

n.a., not available

Note: The locations listed are a selection of over 800 parks and reserves managed by the Parks and Wildlife Service, Tasmania. The Parks and Wildlife Service monitors a sample of parks and reserves to detect general visitor trends, including forested and non-forested areas.

Source: Parks and Wildlife Service, Tasmania, cited in FPA (2012, 2017a).

This table, together with other data for Indicator 6.3b, is available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

Table 6.42: Visitor activity and facilities in state forests, Victoria, 2011–12 and 2015–16

		Value	
Activity	**Measure**	**2011–12**	**2015–16**
Riding or walking animals	kilometres of tracks	40	96
Cycling	kilometres of tracks	320	364
Driving	kilometres of roads[a]	712	620
Walking or running	kilometres of tracks	761	745
Cultural heritage appreciation	number of managed sites	42	58
Events	number of events	152	195
Fishing	number of managed sites[b]	33	54
Camping	number of sites	240	256
Picnicking and playing	number of sites	250	267

[a] Refers to roads promoted as scenic drives, 4WD and trail bike touring routes; this is a small proportion of the total length of roads in state forests that can be used for recreation access. A corrected figure is included for 2011–12.

[b] Sites specifically promoted for fishing.

Source: Department of Environment, Land, Water and Planning, Victoria.

This table, together with other data for Indicator 6.3b, is available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

Recreation and tourism assets in the south-west forests of WA that provide an important basis for some tourism and recreation businesses include the Valley of the Giants and Tree Top Walk, the Bibbulmun Track and Munda Biddi Trail. Visitation to areas covered by the management plan reached 7.1 million visits in 2012–2013, which was 2.3 million visits (48%) more than in 2003–2004 (CCWA 2013).

Forest paths provided for walking, running and bicycle riding. Tuart forest near Bunbury, Western Australia.

Indicator 6.4a

Area of forest to which Indigenous people have use and rights that protect their special values and are recognised through formal and informal management regimes

Rationale

This indicator monitors the degree to which land is placed under appropriate tenure classifications or management regimes to protect Indigenous peoples' values in forests. An acceptable level of accountability for the protection of Indigenous peoples' cultural, religious, social and spiritual needs and values is an essential part of forest management.

Key points

- Australia's Indigenous land estate can be broadly divided into four land ownership and management categories: Indigenous owned and managed, Indigenous managed, Indigenous co-managed and Other special rights.
- In 2016, there were 438 million hectares of land in the Indigenous land estate. Of this, 69.5 million hectares was forested, corresponding to 52% of Australia's total forest area.
  - The Indigenous forest estate comprises 18.0 million hectares of Indigenous owned and managed forest, 4.9 million hectares of Indigenous managed forest, 5.7 million hectares of Indigenous co-managed forest, and 40.9 million hectares of forest under Other special rights (including native title determinations and Indigenous Land Use Agreements).
  - The 69.5 million hectares in the Indigenous forest estate as at 2016 represents an increase of 28.5 million hectares over the updated figure for 2011 reported by ABARES[301]. The increase has been driven primarily by an increase in the area of land over which Indigenous people have Other special rights.
  - Of the 69.5 million hectares of the Indigenous forest estate, 47.8 million hectares (69%) is in Queensland and the Northern Territory. Since 2011, the largest increases in the area of forest in the Indigenous estate have been in the Northern Territory, Queensland and Western Australia.
- Indigenous heritage sites are widespread across Australia. In 2016, there were an estimated 126 thousand registered Indigenous sites within forest.
  - The total area of forest in Indigenous heritage sites is difficult to estimate, due to the sensitivity and limited availability of spatial data.
  - Data from jurisdictional heritage registers indicate that, excluding the Australian Capital Territory and Victoria, there were 1.8 million hectares of forest in registered Indigenous heritage sites in 2016.

[301] The area figure for 2011 reported in SOFR 2013 was updated by ABARES in Dillon et al (2015)

This indicator presents data as at 2016 on the area of land over which Indigenous peoples and communities have ownership, management or rights of use. Only Indigenous community land is included, not land owned or managed by individuals. Detailed descriptions of each land category and its importance to Indigenous peoples, as well as its history and usage, are given in Indicator 6.4c, together with examples of engagement with forest management and use. The term Indigenous is used throughout the SOFR series to encompass all Aboriginal and Torres Strait Islander peoples; where the information provided relates to a particular people, that traditional owner group is named.

Indigenous land access, management or ownership

For reporting purposes, the information collected on Indigenous land has been grouped into four categories (Dillon et al. 2015):

Indigenous owned and managed: freehold lands that are both owned and managed by Indigenous communities

Indigenous managed: lands that are managed but not owned by Indigenous communities (e.g. Crown reserves and leases); and lands that are owned by Indigenous people, but have formal shared management agreements with Australian and state and territory government agencies (e.g. leased-back nature conservation reserves)

Indigenous co-managed: lands that are owned and managed by other parties, but have formal, legally binding agreements in place to include input from Indigenous people in the process of developing and implementing a management plan (e.g. nature conservation reserve memoranda of understanding)

Other special rights: lands subject to native title determinations, registered Indigenous Land Use Agreements and legislated special cultural use provisions. These are independent of tenure and, in most cases, do not grant ownership or management rights of land to Indigenous communities. They can provide for the right to access areas of cultural significance or the use of areas for cultural purposes (e.g. within protected water supply catchment areas), or can provide a legal requirement for consultation with the local Indigenous community before any major development activities take place.

A land parcel may be subject to more than one type of management. For this indicator, land is classified into the highest-ranked Indigenous land ownership and management category that is applicable (Dillon et al. 2015). For example, a land parcel that is subject to a native title determination, but that is also Indigenous owned and managed as a declared Indigenous Protected Area, is reported here as Indigenous owned and managed.

The amount of Indigenous land information accessible through government agencies at the national and state and territory levels is progressively increasing. There has also been a significant increase in the area of land under formal arrangements through which Indigenous people have rights to manage land and to protect their special values. Table 6.43 provides a list of the datasets collected for SOFR 2018; more detailed descriptions of each land category and its importance to Indigenous people, history and usage are given in Indicator 6.4c. As far as possible, data collated for this Indicator were current as at June 2016. The Database of Legal Indigenous Land Interests (held by the Indigenous Land Corporation), from which some data was drawn for SOFR 2013, was not used in SOFR 2018, as additional and up-to-date datasets were obtained from source agencies.

In all jurisdictions, government agencies responsible for the management of nature conservation reserves and other areas can consult informally with Indigenous community groups and representatives as part of normal operations. Consultation with community groups, including Indigenous people, can improve relations between these agencies and local communities, and lead to a range of positive outcomes for agencies, community groups and the environment. Informal arrangements (ad-hoc and non-ongoing consultation) are not included as Indigenous co-management arrangements in the data presented in this indicator.

In 2016, the national Indigenous estate contained 438 million hectares of land, of which 69.5 million hectares was forested (Table 6.44). This is 52% of Australia's total forest area. Of the 69.5 million hectares of forested land in the Indigenous estate, 47.8 million hectares (69%) is in Queensland and the Northern Territory. The proportion of forested land that is in an Indigenous land category varies from 15% in New South Wales, to 79% in the Northern Territory.

The 69.5 million hectares of Indigenous forested land comprises 18.0 million hectares of forested land that is Indigenous owned and managed, 4.9 million hectares of forested land that is Indigenous managed, 5.7 million hectares of forested land that has Indigenous co-management arrangements in place with government agencies, and 40.9 million hectares of forested land over which Other special rights apply (including native title determinations and Indigenous Land Use Agreements). Figure 6.25 shows the geographic distribution of the Indigenous forest estate across Australia.

Data for Indigenous land and forest areas as at 2011 were initially reported in SOFR 2013; subsequently, updated data were published in the *Australia's Indigenous forest estate (2013) v2.0* spatial dataset and in the Dillon et al. (2015) report that described development of the spatial dataset. Dillon et al. (2015) reported that, as at 2011, there were a total of 306 million hectares of land in Australia's Indigenous estate, of which 41.1 million hectares was forested (13% of Australia's total forest area). The total area of forest reported on Indigenous land has therefore increased by 28.5 million hectares over the period 2011 to 2016.

Table 6.43: Datasets compiled on lands over which Indigenous people have use and rights

Title	Year of currency	Source agency* and data availability
Indigenous owned and managed		
Indigenous Protected Areas[302]	2016	DoEE; available at www.environment.gov.au/fed/catalog/main/home.page through Find Environmental Data[303]. See also www.dpmc.gov.au/indigenous-affairs/environment/indigenous-protected-areas-ipas
Indigenous Land Corporation owned and transferred	2016	Indigenous Land Corporation (www.ilc.gov.au/Home/What-We-Do/Land-Purchased)
NSW Aboriginal Land Council and Local Aboriginal Land Council (LALC) lands	2016	NSW Land and Property Information[a] (www.nswlrs.com.au/). Obtained following consultation with NSW Aboriginal Land Council.
Northern Territory Aboriginal Lands Trust lands	2016	Northern Territory Department of Infrastructure, Planning and Logistics[b] (transport.nt.gov.au/)
Queensland Deed of Grant in Trust	2017	Queensland Department of Natural Resources, Mines and Energy (dds.information.qld.gov.au/dds/; www.dnrm.qld.gov.au/)
Queensland Aboriginal and Torres Strait Islander land trusts	2017	Queensland Department of Natural Resources, Mines and Energy (dds.information.qld.gov.au/dds/; www.dnrm.qld.gov.au/)
SA Aboriginal Land Trust and Indigenous community freehold	2016	SA Land Services Group (www.sa.gov.au/topics/planning-and-property/land-services). Obtained following consultation with SA Aboriginal Land Trust.
Tasmanian Aboriginal Land Trust lands	2016	Aboriginal Land Council of Tasmania (www.ourcommunity.com.au/directories/listing?id=44088)
Victorian Traditional Owner Settlement agreements	2016	Department of Environment, Land, Water and Planning (www.propertyandlandtitles.vic.gov.au/)
Victorian Indigenous community freehold (under various Aboriginal Land Acts)	2016	Department of Environment, Land, Water and Planning (obtained from National Native Title Tribunal)
Indigenous managed		
Leased-back nature reserves	2016	State and territory government conservation agencies; DoEE (Collaborative Australian Protected Area Database 2016, available through the Find Environmental Data website www.environment.gov.au/about-us/environmental-information-data/databases-applications)[304]
Leasehold lands associated with ILUAs	2016	Indigenous Land Use Agreement summaries on National Native Title Tribunal register; internet research (partial dataset only)
South Australia Indigenous community leases	2016	SA Land Services Group (www.sa.gov.au/topics/planning-and-property/land-services). Obtained following consultation with SA Aboriginal Land Trust.
Western Australian Aboriginal Lands Trust	2016	Western Australia Department of Aboriginal Affairs (www.daa.wa.gov.au)
Western Australian Indigenous pastoral leases	2016	Western Australia Land Information Authority, trading as Landgate (www0.landgate.wa.gov.au/)
Indigenous co-managed		
Nature conservation reserve memoranda of understanding or advisory committees	2014–2016	State and territory government conservation agencies; DoEE (Collaborative Australian Protected Area Database 2016, available through the Find Environmental Data website www.environment.gov.au/about-us/environmental-information-data/databases-applications)
Nature conservation reserves plans of management	Mainly 2013–2016	State and territory government conservation agency websites; DoEE (Collaborative Australian Protected Area Database 2016, available through the Find Environmental Data website www.environment.gov.au/about-us/environmental-information-data/databases-applications)
World Heritage Area memoranda of understanding or advisory committees	2016	State and territory government conservation agencies; DoEE (Australian World Heritage Areas dataset, available at Find Environmental Data website www.environment.gov.au/about-us/environmental-information-data/databases-applications)[305]
Other special rights		
Native title determinations[306]	2016	National Native Title Tribunal (NNTT) (www.nntt.gov.au/assistance/Geospatial/Pages/DataDownload.aspx)
Indigenous Land Use Agreements	2016	National Native Title Tribunal (NNTT) (www.nntt.gov.au/assistance/Geospatial/Pages/DataDownload.aspx)
NSW Aboriginal Areas	2016	NSW Office of Environment and Heritage (Department of Planning and Environment) (datasets.seed.nsw.gov.au/dataset/nsw-national-parks-and-wildlife-service-npws-estate3f9e7)
Western Australia national parks and reserves with customary use provisions (CALM Act 1984, as amended 2012)	2016	Western Australia Department of Parks and Wildlife
Drinking water catchments with legislated Indigenous rights for cultural use	2016	Western Australia Department of Water[c] (www.dwer.wa.gov.au); Melbourne Water (Yarra Tributaries Forest Reserve only; www.melbournewater.com.au)

DoEE, Australian Government Department of the Environment and Energy.

* Agency from which data obtained in 2017, and agency name at that time. Web URLs are current at time of SOFR 2018 publication.

a From 1 December 2017, the NSW Land Registry Services.

b Established 12 September 2016. Previously the Department of Infrastructure, Planning and Environment.

c From 1 July 2017, Department of Water and Environmental Regulation.

Source: ABARES.

There are three major drivers for this change in area of forest in the Indigenous estate over the period 2011 to 2016:

- addition of further land to the Indigenous land estate
- an increase in the reported area of forest in the Northern Territory (see Indicator 1.1a). Of the additional 8.5 million hectares of forest mapped in the Northern Territory, 8.3 million hectares occurs within the Indigenous estate, mostly in the categories 'Other special rights' and 'Indigenous owned and managed'
- improved availability and accessibility of information on Indigenous land from Australian and state and territory government agencies, and incorporation by ABARES of additional types of Indigenous land data (Table 6.43). This has also increased the accuracy of the compiled dataset on the Indigenous estate.

The largest increase in the area of land, and the area of forest, in the Indigenous estate over the period 2011 to 2016 has been in the 'Other special rights' category.

Additional information about the areas of individual Indigenous forest ownership and management categories, and the underpinning datasets, is provided in Indicator 6.4c.

Indigenous heritage protection

Indigenous cultural heritage comprises objects, sites and places of cultural value to Aboriginal and Torres Strait Islander peoples, including middens, artefacts, painting sites, gathering places, cultural dreaming places, burial sites, and sites of more recent historical significance. Aboriginal objects are items such as stone artefacts, grinding grooves, scarred or carved trees, stone tools and other created objects like baskets and necklaces. The process of learning, remembering, recording and potentially registering cultural heritage is important for maintaining and renewing Indigenous connection to land and culture, and also for non-Indigenous awareness and understanding of Indigenous cultural heritage. Case study 6.15 and Case study 6.16 (Indicator 6.5d) give examples of Aboriginal cultural heritage assessment and management within forests.

The Commonwealth, state and territory laws that protect Indigenous cultural heritage afford protection to all Indigenous cultural heritage sites, including those situated in forests. The legislation comprises the:

- *Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth)
- *Aboriginal and Torres Strait Islander Heritage Protection Act 1984* (Commonwealth)
- *Aboriginal Land Rights (Northern Territory) Act 1976* (Commonwealth)
- *Heritage Act 2004* (Australian Capital Territory)
- *National Parks and Wildlife Act 1974* (New South Wales)
- *Northern Territory Aboriginal Sacred Sites Act 1989* (Northern Territory)
- *Heritage Act 2011* (Northern Territory)
- *Aboriginal Cultural Heritage Act 2003* (Queensland)
- *Torres Strait Islander Cultural Heritage Act 2003* (Queensland)
- *Aboriginal Heritage Act 1988* (South Australia)
- *Aboriginal Relics Act 1975* (Tasmania)[307]
- *Aboriginal Heritage Act 2006* (Victoria) and *Aboriginal Heritage Amendment Act 2016* (Victoria)
- *Heritage Act 1995* (Victoria)[308]
- *Aboriginal Heritage Act 1972* (Western Australia).

All states and territories also have regulations, codes of practice and management prescriptions that govern the management of Indigenous heritage sites, including within forests. These instruments provide a level of protection for Indigenous heritage sites by minimising damage or disturbance to the sites, by imposing penalties for significant impacts, and by requiring prior consultation with the relevant Aboriginal heritage body or council regarding actions that might affect the site. Table 6.45 lists the Indigenous heritage registers and the key organisations responsible for Indigenous heritage protection in each state and territory.

Indigenous heritage sites are widespread across Australia. They can be difficult to find within forest due to the canopy cover and understorey, and limited ground visibility and access. Registration of sites is an ongoing process and new sites are added to registers after they have been found, assessed and verified. The term 'sites' is used to encompass heritage sites, objects and places (Table 6.46).

In 2016, there were 126 thousand registered Indigenous sites (including places and objects) within forest (Table 6.46). There are many more such sites that have not been registered for cultural reasons or due to insufficient resources. Indigenous heritage sites are generally protected irrespective of their registration status.

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302 Most but not all Indigenous Protected Areas are on Indigenous freehold land.

303 IPA dataset available at www.environment.gov.au/fed/catalog/search/resource/details.page?uuid=%7BC64658F0-95AD-4209-8D1E-F94BD0A4E827%7D

304 CAPAD dataset available at www.environment.gov.au/fed/catalog/search/resource/details.page?uuid=%7B4448CACD-9DA8-43D1-A48F-48149FD5FCFD%7D

305 WHA dataset available at www.environment.gov.au/fed/catalog/search/resource/details.page?uuid=%7B6C54FE6C-2773-47C6-8CBC-4722F29081EF%7D

306 A native title determination recognises, under Australian law, the traditional rights and interests to land and waters of Aboriginal and Torres Strait Islander people. Native title can be exclusive or non-exclusive. Exclusive native title determinations allow native title holders to control access to land. Both exclusive and non-exclusive native title are included in the 'Other special rights' category unless the land has been transferred to Indigenous ownership through jurisdictional legislation.

307 Amended and re-named as the *Aboriginal Heritage Act 1975* on 16 August 2017.

308 Updated to *Heritage Act 2017* in March 2017.

Table 6.44: Area of land and forest in the Indigenous estate, by Indigenous land ownership and management categories

Management category	Land cover type	Area ('000 hectares)								
		ACT	NSW	NT	Qld	SA	Tas.	Vic.	WA	Australia
Indigenous owned and managed	All	0	342	61,747	6,294	20,070	69	10	35,785	124,317
	Forest	0	134	11,490	4,847	253	11	4	1,250	17,989
Indigenous managed	All	0	207	4,270	3,160	2,893	0	103	16,817	27,450
	Forest	0	42	1,726	2,537	16	0	82	503	4,907
Indigenous co-managed	All	107	3,066	152	1,529	12,204	1,555	327	3,357	22,297
	Forest	100	2,274	55	1,006	638	863	255	539	5,731
Other special rights	All	0	1,247	37,383	75,904	43,916	0	8,138	97,027	263,615
	Forest	0	578	5,421	20,707	1,267	0	2,647	10,295	40,916
Total Indigenous estate	**All**	**107**	**4,862**	**103,551**	**86,887**	**79,083**	**1,624**	**8,579**	**152,985**	**437,678**
	Forest	**100**	**3,029**	**18,693**	**29,097**	**2,175**	**874**	**2,988**	**12,587**	**69,543**
Total forest in jurisdiction[a]		**142**	**20,368**	**23,735**	**51,830**	**5,060**	**3,699**	**8,222**	**20,981**	**134,037**
Proportion of total forest that is forest on the Indigenous estate		**71%**	**15%**	**79%**	**56%**	**43%**	**24%**	**36%**	**60%**	**52%**

[a] From Indicator 1.1a.

Note: Totals may not tally due to rounding.

Source: ABARES.

This table, together with other data for Indicator 6.4a, is available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

Table 6.45: Indigenous heritage registers in each jurisdiction, and requirements for consultation

Jurisdiction	Name of heritage register	Department that hosts the register	Authorised heritage bodies and Aboriginal groups with which consultation is mandated
Commonwealth	Commonwealth Heritage register	DoEE	Australian Heritage Council; Indigenous people with rights and interests to the place or object that is being nominated for the inclusion in the Commonwealth Heritage List
Commonwealth	National Heritage register	DoEE	Australian Heritage Council; Indigenous people with rights and interests to the place or object that is being nominated for the inclusion in the National Heritage List
Commonwealth	World Heritage List	DoEE	Indigenous people with rights and interests to the place or object that is being nominated for the inclusion in the World Heritage List
Australian Capital Territory	ACT Heritage Register	ACT Heritage, Department of Environment and Planning Directorate	ACT Heritage Council; relevant Representative Aboriginal Organisation (RAO)
New South Wales	Aboriginal Heritage Information Management System (AHIMS)	Office of Environment and Heritage	Aboriginal Cultural Heritage Advisory Committee; local Aboriginal groups and Local Aboriginal Land Councils (LALCs)
Northern Territory	Northern Territory Heritage register	Department of Tourism and Culture	Northern Territory Heritage Council; independent Aboriginal Areas Protection Authority
South Australia	Aboriginal Heritage register	Aboriginal Affairs and Reconciliation (AAR), Department of State Development[309]	South Australian Heritage Committee; Recognised Aboriginal Representative Bodies[310].
Queensland	Aboriginal and Torres Strait Islander Cultural Heritage register and database	Department of Aboriginal and Torres Strait Islander Partnerships (DATSIP)	Cultural Heritage Unit (DATSIP); Specified Aboriginal and Torres Strait Islander Cultural Heritage Bodies[311].
Tasmania	Tasmanian Aboriginal Heritage register	Aboriginal Heritage Tasmania, Department of Primary Industries, Parks, Water And Environment (DPIPWE)	Tasmanian Aboriginal Heritage Council; Aboriginal Heritage Officer (AHO)
Victoria	Victorian Aboriginal Heritage register	Aboriginal Victoria, Department of Premier and Cabinet	Victorian Aboriginal Heritage Council; Registered Aboriginal Parties (11 covering approximately 60% of Victoria[312])
Western Australia	Western Australian Aboriginal Heritage register	Department of Planning, Lands and Heritage	Aboriginal Cultural Material Committee, established as an advisory body by the Minister of Aboriginal Affairs

[309] From March 2018, the Department of the Premier and Cabinet.

[310] In South Australia, there are 25 incorporated Aboriginal organisations each representing a traditional owner group.

[311] There are approximately 65 registered cultural heritage bodies in Queensland.

[312] Registered Aboriginal Parties (RAPs) are organisations that hold decision-making responsibilities under the Victorian *Aboriginal Heritage Act 2006* for protecting Aboriginal cultural heritage in a specified geographical area.

Table 6.46: Number and area of registered Indigenous heritage sites within forest, by jurisdiction

	ACT	NSW	NT	SA	Qld	Tas.	Vic.	WA	Commonwealth register	National register	Total[a]
Number of sites within forest	845	56,073	5,263	1,635	41,200	7,247	11,921	1,872	8	17	126,081
Area of sites within forest (hectares)[b]	n.d.	37,548	5,981	192,800	331,300	2,479	n.d.	257,900	905,100	23,900	1,757,008

n.d., no data

[a] Total area is a minimum value as area figures for Australian Capital Territory and Victoria were not available.

[b] These figures do not include the area of forest in Australia's four World Heritage areas (Kakadu National Park, Uluru-Kata Tjuta National Park, the Willandra Lakes Region and the Tasmanian Wilderness World Heritage Area) that are listed for cultural values with the United Nations Educational, Scientific and Cultural Organization (UNESCO). Together, these four World Heritage areas contain a total of 2.09 million hectares of forest.

Notes:

Sites includes heritage objects, sites, places and landscapes registered in jurisdictional Indigenous heritage registers. Numbers and areas are derived from data in each jurisdictional register as at 30 June 2016, intersected with 2011 forest coverage (SOFR 2013), unless stated otherwise. Area values are estimates only, due to varying completeness and types of spatial data (point and polygon) within and between heritage registers. Where relevant, each jurisdiction applied a buffer (50 or 100 metres radius) around point data in order to derive area figures (see below); where site buffers overlap, areas were only counted once.

ACT: ABARES estimated the number of Indigenous heritage sites in the Australian Capital Territory using information in the online Australian Capital Territory Heritage Register (www.environment.act.gov.au/heritage/heritage_register), as at 12 July 2017. Since this was not a spatial dataset, relevant listings were identified based on Aboriginal heritage, and on occurrence in locations that are substantially forested according to the 2016 forest cover for the Australian Capital Territory (Indicator 1.1a). Data on the area of registered Indigenous heritage sites were not available.

NSW: A 50 metre radius buffer was applied to point data by the NSW Office of Environment and Heritage.

NT: ABARES derived site number and area estimates from an extract of the Northern Territory Heritage register provided by the Northern Territory Department of Tourism and Culture, as at 30 June 2016.

SA: Data provided by the SA Aboriginal Affairs and Reconciliation, Department of State Development; buffer size not available. The data for South Australia represents State Forest Reserves and the Naracoorte World Heritage Area.

Qld: A 100 metre radius buffer was applied to point data by the Queensland Department of Aboriginal and Torres Strait Islander Partnerships.

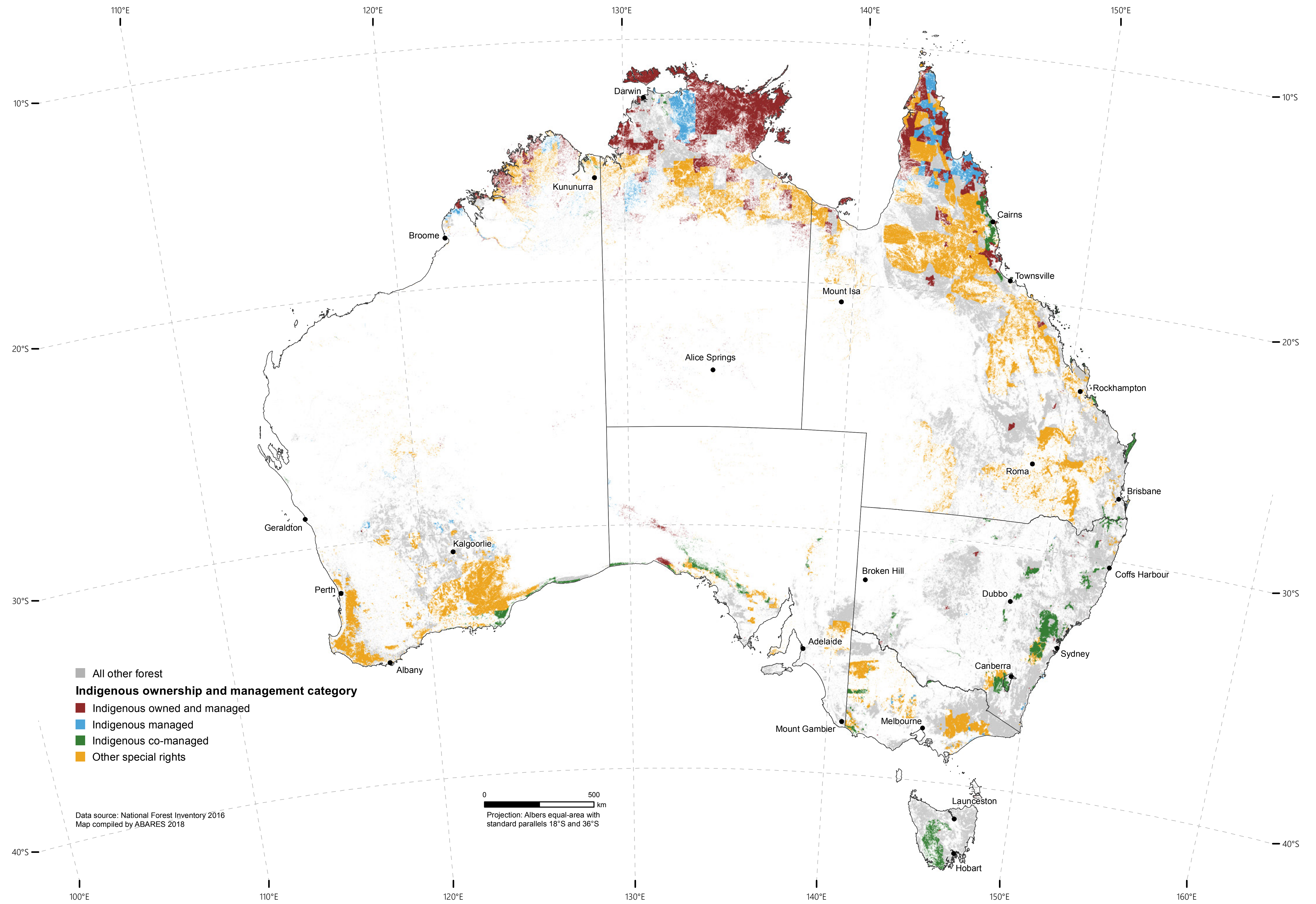
Tas.: A 50 metre radius buffer was applied to point data by Aboriginal Heritage Tasmania (DPIPWE). Tasmanian data includes the Tasmanian World Heritage Area.

Vic.: Data on the area of Indigenous heritage sites were not available

WA: Heritage data is polygon type; data provided by the Western Australia Department of Planning, Lands and Heritage (DPLH).

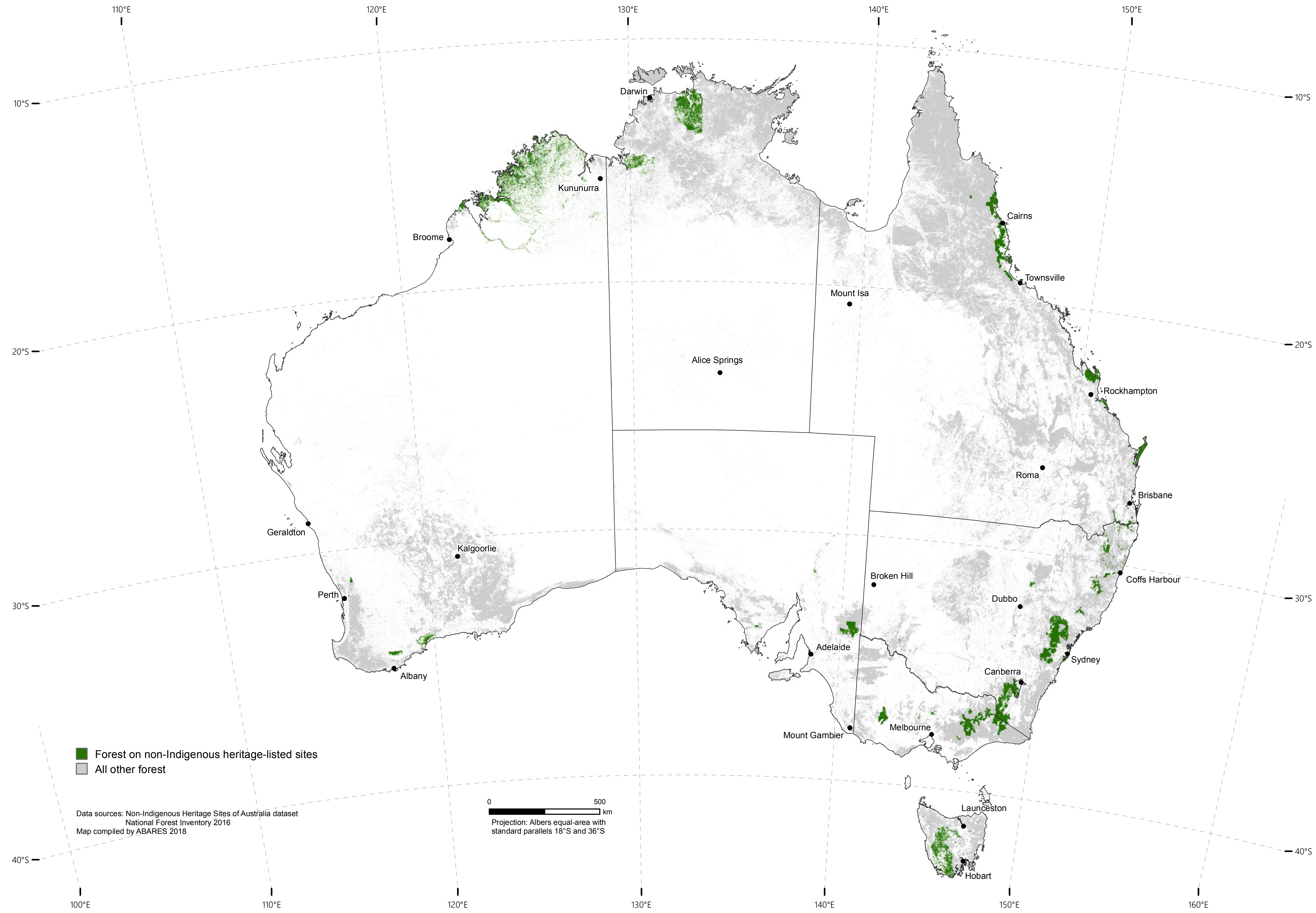
This table, together with other data for Indicator 6.4a, is available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

Figure 6.25: The Indigenous forest estate, by land ownership and management category



A higher resolution version of this map is available via www.doi.org/10.25814/5be3bc4321162

Figure 6.26: Forest on non-Indigenous heritage-listed sites



A higher resolution version of this map is available via www.doi.org/10.25814/5be3bc4321162

In Tasmania, a total of 103 additional Aboriginal heritage sites were identified in forested land in the period July 2011–June 2016 (FPA 2017a). Most of these were single stone artefacts or small scatters of artefacts. All sites were recorded on the Conserve Aboriginal database administered by Forestry Tasmania[313], and records were also sent to Aboriginal Heritage Tasmania for recording on the Aboriginal Heritage Register. Most of these sites were located after forest harvest or during cultivation for plantations, when the mineral soil was visible. The Forest Practices Code (FPA 2015b), established under the *Forest Practices Act 1985*, provides for the assessment, planning, management and protection of Aboriginal heritage within production forests. All new sites have been protected in informal reserves or machinery exclusion zones (FPA 2017a).

The total area of forest coinciding with Indigenous heritage sites is difficult to estimate, due to the sensitivity and limited availability of spatial data, and the constraints to observing heritage sites. Between 1975 and 2007, the Australian Government maintained the Register of the National Estate (RNE), a national list of places with historical, natural or Indigenous heritage significance. SOFR 2013 reported 1.5 million hectares of forest located within sites with Indigenous heritage value on the Register of the National Estate. As this register was closed in 2007, it was not used for SOFR 2018. Instead, data received from jurisdictional heritage registers indicate that, nationally, there were a minimum of 1.76 million hectares of forest within registered Indigenous heritage sites in 2016 (Table 6.45).

This figure is an estimate, because of different types of data across Indigenous heritage registers (Commonwealth, state and territory), the varying methods of estimating area including the different buffer areas around sites applied by jurisdictions, and the unavailability of area data on Indigenous heritage sites for the Australian Capital Territory and Victoria (Table 6.45).

[313] From July 2017, Sustainable Timber Tasmania.

Case study 6.8: Safeguarding Aboriginal heritage in Western Australian forests

In Western Australia, the *Aboriginal Heritage Act 1972* was enacted to facilitate the protection and preservation of Aboriginal remains and archaeological sites and objects on all land, including forests, irrespective of land tenure. These sites, places and objects include:

- culturally modified (scarred and carved) trees
- shell middens and fishing/farming implements
- cultural artefacts, rock paintings and carvings
- stone arrangements and grinding patches/grooves
- skeletal material and burial mounds or sites
- man-made structures.

Where Aboriginal remains and/or archaeological sites or objects are identified, the Department of Aboriginal Affairs develops and implements a heritage management strategy to protect the site so as to minimise or avoid damage to or disturbance of the site. This involves engagement and consultation with appropriate local Aboriginal authorities and communities.

In Western Australia, the Department of Aboriginal Affairs published the *Aboriginal Heritage Due Diligence Guidelines* in 2012, to assist land users and private companies in understanding their obligations under the *Aboriginal Heritage Act 1972*, how their activities could adversely impact Aboriginal heritage sites, and the planning process to mitigate the risk of disturbing/destroying these sites.

Amendments to the Western Australian *Conservation and Land Management Act 1984* in 2012 introduced a new management objective that requires the Department of Biodiversity, Conservation and Attractions (DBCA) to manage national parks and reserves to protect and conserve the value of the lands and waters to the culture and heritage of Aboriginal people, including obligations in regards to sites registered under the *Aboriginal Heritage Act 1972*. These amendments have also provided a statutory framework for joint management arrangements between Aboriginal people and the DBCA.

The Due Diligence Guidelines are available at www.daa.wa.gov.au/globalassets/pdf-files/ddg

Indicator 6.4b

Registered places of non-Indigenous cultural value in forests that are formally managed to protect those values

Rationale

This indicator measures and monitors management regimes for non-Indigenous cultural values, such as historical, research, education, aesthetic, and social heritage values. Maintaining these values is integral to the protection of non-Indigenous peoples values associated with forests.

Key points

- Heritage represents the tangible and intangible connections that people have with the past, through landscapes, landmarks, places, historic buildings, objects, significant events, customs and ceremonies.
  - Heritage registers are maintained at international, national, and state and territory levels, and in this indicator are used to compile a Non-Indigenous Heritage Sites of Australia dataset.
  - Sites listed in the various heritage registers are afforded protection from disturbance under the relevant jurisdictional Acts.
- As at 2016, 11.0 million hectares of forest was on non-Indigenous heritage-listed sites across all jurisdictions.
  - This is an increase of 3.7 million hectares of forest on non-Indigenous heritage-listed sites since 2011, mainly due to the registration of new heritage places.
- Various government departments and private organisations act to identify, conserve, promote and manage heritage values within forests, including through management plans.

Australia's forests include many sites that provide evidence of the interactions between people and forest landscapes, and the activities that have taken place on the continent since European settlement. Heritage includes the sites and objects that contribute to Australia's identity, including landscapes, landmarks, places and historic buildings and contents. Heritage can also represent intangible qualities such as people's feelings or associations with a site, and social, political, national or other cultural significance to a group. Heritage is what we inherit from the past and value enough today to leave for future generations[314]. Heritage can have cultural value at a local, regional, state, national or international scale.

In 1997, the Council of Australian Governments (COAG) agreed that heritage listing and protection should be the responsibility of the level of government best placed to deliver agreed conservation, management and interpretation outcomes. This decision recognised that state and territory governments had passed their own legislation to protect sites that were determined to be significant at the state and territory level. It was agreed that Commonwealth involvement in heritage should focus on places of national significance, including World Heritage properties.

In 2004, the Australian Government created the National Heritage List (NHL) and the Commonwealth Heritage List (CHL) to protect sites with national significance, through amendments to the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act)[315]. Australian sites registered on the United Nations Educational, Scientific and Cultural Organization (UNESCO) World Heritage List (WHL) are also protected under the EPBC Act (see Indicator 1.1c).

Table 6.47 summarises the international, national, and state and territory heritage registers that currently record Australian sites and places of heritage significance. Sites in the heritage registers are afforded protection from disturbance under the relevant jurisdictional Acts. Heritage registers are also compiled at the local government level in some areas of Australia, but are not reported here.

For SOFR 2018, the electronic spatial versions of each of the databases listed in Table 6.47 were obtained from the relevant

[314] Heritage Policies (2018) National Trust, www.nationaltrust.org.au/heritage-policies-wa/

[315] From March 2018, Department for Environment and Water.

Table 6.47: International, national, and state and territory heritage registers for Australia

Heritage register	Jurisdiction	Relevant Australian legislation	Agency responsible at June 2016	Description of register
World Heritage List (WHL)	International. Maintained by UNESCO World Heritage Centre Secretariat	EPBC Act	DoEE	Sites of outstanding universal value that are registered on the UNESCO World Heritage List
National Heritage List (NHL)	Australia	EPBC Act	DoEE	Sites of outstanding heritage value to the Australian nation
Commonwealth Heritage List (CHL)	Australia	EPBC Act	DoEE	Sites of significant heritage value that are owned or controlled by the Australian Government
Australian Capital Territory Heritage Register	Australian Capital Territory	*Heritage Act 2004*	Environment, Planning and Sustainable Development Directorate	Significant heritage places and objects with historical relevance to the people of the Australian Capital Territory
New South Wales State Heritage Register	New South Wales	*Heritage Act 1977*	Office of Environment and Heritage	Places of heritage significance to the people of New South Wales
Northern Territory Heritage Register	Northern Territory	*Heritage Act 2011*	Department of Tourism and Culture	Places and objects with heritage significance to the Northern Territory including Aboriginal or Macassan archaeological places.
Queensland Heritage Register	Queensland	*Queensland Heritage Act 1992*	Department of Environment and Resource Management	Sites and places of cultural heritage significance to Queensland
South Australian Heritage Register	South Australia	*Heritage Places Act 1993*	Department of Environment, Water and Natural Resources[316]	Places of heritage significance to South Australia
Tasmanian Heritage Register	Tasmania	*Historic Cultural Heritage Act 1995*	Department of Primary Industries, Parks, Water and Environment	Places of historical cultural heritage significance to the whole of Tasmania
Victorian Heritage Register	Victoria	*Heritage Act 1995*[a]	Department of Environment, Land, Water and Planning	Victoria's most significant heritage places and objects
Western Australian State Register of Heritage Places	Western Australia	*Heritage of Western Australia Act 1990*	Department of Planning, Lands and Heritage	Places of state cultural heritage significance

DoEE, Department of the Environment and Energy; EPBC Act, *Environment Protection and Biodiversity Conservation Act 1999;* UNESCO, United Nations Educational, Scientific and Cultural Organization.

[a] Subject to amendment in November 2016 and new Act gazetted in November 2017 (*Heritage Act 2017*).

Source: ABARES.

agencies, and used as inputs to update the Non-Indigenous Heritage Sites of Australia (NIHSA) dataset. As far as possible, data was current as at June 2016. Sites registered only for Indigenous values were excluded (Indicator 6.4b focuses specifically on non-Indigenous cultural values, whereas Indigenous heritage sites are reported in Indicator 6.4a). The NIHSA dataset was used to report on the area of forest on non-Indigenous heritage-listed sites.

For some non-Indigenous heritage-listed sites, the data only give a central point location rather than a description of an area. A 100 metre buffer was therefore applied to any point data, and the area of non-Indigenous heritage-listed sites reported for some jurisdictions is an estimate.

The datasets used for SOFR 2018 were the same as used for SOFR 2013. In SOFR 2008, the Commonwealth Register of the National Estate (RNE) was used to report the area of heritage sites on forested land that were registered for their historical and natural heritage values.[317]

Sites in the NIHSA dataset cover 28.5 million hectares across all jurisdictions. Of this land area, 11.0 million hectares are forested (Table 6.48; Figure 6.26).

[316] Heritage Places (2018) Australian Government, Department of the Environment and Energy, www.environment.gov.au/heritage/heritage-places

[317] The Australian Government's Register of the National Estate (RNE) dataset was established in 1975 under the Commonwealth *Australian Heritage Commission Act 1975* (repealed in 2004) as a register of sites of local, state and national significance. This Act provided all registered sites with a basic level of statutory protection, limited to actions of the Australian Government and its agencies. The RNE was closed in 2007, and ceased to be recognised as a statutory listing on 19 February 2012. The five-year transition period allowed jurisdictions to assess places in the RNE for inclusion into other heritage lists by 2012. Many of the places in the RNE are included in other statutory listings such as state heritage listings, the Commonwealth Heritage List (CHL) and the National Heritage List (NHL). See www.environment.gov.au/system/files/resources/45a69069-bdc1-4cdb-b8e8-2b24dfcec951/files/national-estate.pdf

Table 6.48: Area of forest on non-Indigenous heritage-listed sites, by tenure and jurisdiction ('000 hectares)

Tenure	ACT	NSW	NT	Qld	SA	Tas.	Vic.	WA	Australia
Leasehold forest	0	10	0	32	302	0	0	669	1,013
Multiple-use public forest	0	38	0	23	0	9	0	2	72
Nature conservation reserve	104	2,120	0	1,059	23	845	996	1,451	6,598
Private land	0	20	1,218	94	3	25	0	265	1,626
Other Crown land	0	6	374	347	0	33	24	824	1,609
Unresolved tenure	0	0	0	45	0	0	0	0	46
Total	**104**	**2,194**	**1,593**	**1,600**	**328**	**912**	**1,021**	**3,212**	**10,964**
Total forest in jurisdiction	**142**	**20,368**	**23,735**	**51,830**	**5,060**	**3,699**	**8,222**	**20,981**	**134,037**
Proportion of total forest that is forest on non-Indigenous heritage-listed sites	**73%**	**11%**	**7%**	**3%**	**6%**	**25%**	**12%**	**15%**	**8%**

Note: Forest cover from Indicator 1.1a. Totals may not tally due to rounding.
Source: Non-Indigenous Heritage Sites of Australia dataset, National Forest Inventory 2016, ABARES.

This table, together with other data for Indicator 6.4b, is available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

The 11.0 million hectares of forest on non-Indigenous heritage-listed sites as at 2016 is an increase of 3.7 million hectares from the area reported as at 2011 in SOFR 2013. This increase in area was primarily due to two large additions to the NIHSA:

- An extension to the Tasmanian Wilderness World Heritage Area was approved by the World Heritage Committee on 24 June 2013, adding more than 170,000 hectares of land. The extension was mainly along the northern and eastern boundaries of the Tasmanian Wilderness World Heritage Area, and incorporated extensive eucalypt forest and other forest, alpine and sub-alpine environments and significant karst and glacial landforms (Commonwealth of Australia 2013b).
- The Western Kimberley region was included on the National Heritage List on 31 August 2011, adding more than 19 million hectares of land to the register (see Case Study 6.9). Of this area added to the register, 2.9 million hectares (15%) is forested.

Registration of additional non-Indigenous heritage-listed sites over the reporting period, including in forest, occurred within most jurisdictions. The small reductions in area of forest on registered heritage-listed sites as at 2016 in the Australian Capital Territory and New South Wales compared with the previous reporting period were associated with changes in reported forest area in these jurisdictions (see Indicator 1.1a).

Of the total area of forest in Australia in June 2016, 8% is on non-Indigenous heritage-listed sites (Table 6.48). The proportion of forest that is on non-Indigenous heritage-listed sites is highest in the Australian Capital Territory (73%) and lowest in Queensland (3%). The largest area of forest on non-Indigenous heritage-listed sites occurs within nature conservation reserves and other Crown lands (Table 6.48), with World Heritage Areas contributing the largest area. Smaller areas are registered on private land, on which there are greater barriers to registration and conservation of sites. The majority of the non-Indigenous heritage-listed forest on private land in the Northern Territory is the Kakadu World Heritage Area, much of which is Indigenous land; Kakadu is listed as a World Heritage Area for both its cultural and natural outstanding universal values.

Forest heritage

Many non-Indigenous heritage sites are registered because of their social, economic or historical significance within states and territories, not with the specific objective of protecting and conserving forests. Forests have played an important role in Australia since early European settlement, and forest history is intertwined with European explorers' expeditions, early mining, pastoral expansion, the building of homes and new settlements, war, construction of railways, the establishment of the first forestry reserves, and changing Australian values (Cameron 2001; Powell 1998). The harvesting of wood and the manufacture of timber or wood products were closely linked to the development of the pastoral and agricultural economy. Evidence of early timber-getting and sawmilling activity is quite common in forests (e.g. in cypress forests, Cameron 2001).

Figure 6.28: Hewn timber and iron structures, part of the heritage-listed Weone gold mine, Victoria

Heritage Council Victoria, vhd.heritagecouncil.vic.gov.au/places/866

Case study 6.9: West Kimberley National Heritage Place

The West Kimberley National Heritage place, located in far north-western Australia, is significant for its historic, Indigenous, aesthetic and natural value (DoEE 2018c).

The region has a rich and dynamic history of Aboriginal culture, pastoral history and pearling. Indigenous people have occupied the west Kimberley region for at least 40,000 years with a strong history of adaptation and survival, particularly in the past 150 years since European settlement of the region. This region continues to be home to Indigenous groups practising traditional law.

The Kimberley coast was the location of some of the earliest European exploration of the Great Southern Land, including William Dampier's visit in 1688. Its pastoral history, involving both Indigenous and non-Indigenous people, includes the establishment of Fossil Downs Station in 1886 by the MacDonald brothers after a journey of more than 5,600 km droving cattle from Goulburn, NSW. Pearling is significant both for Aboriginal traditional use in rituals, ceremonies and trade, and for the early European and current industry.

The west Kimberley region also has outstanding ecological, geological and aesthetic features, including spectacular gorges and waterfalls, pristine rivers and vine thickets, and a coastline which is one of the most convoluted in Australia (Figure 6.27).

The west Kimberley region is home to a diverse range of flora and fauna, many of which are endemic to this region. These flora and fauna inhabit a range of different forested and non-forested environments, from coastal mangroves and eucalypt woodlands to pockets of rainforests (found scattered as isolated vine thickets), savanna woodlands and grasslands. The forests are of socio-economic and ecological importance, as they provide many resources for both Indigenous and non-Indigenous people.

Figure 6.27: The Kimberley coastline, north of Derby, Western Australia

Some heritage-listed sites show utilisation of timber for early settlements, gold mining and other commercial purposes. For example, the old Weone gold mine site near Myrtleford in Victoria, listed at the state-level for its cultural heritage significance, shows remnants of hewn timber and iron structures demonstrating the rough 'bush building' during these periods (Figures 6.28, 6.29). The Lowden Forest Park near Captains Flat in New South Wales (Case study 6.10) is an example of an early forestry camp.

Many of the larger registered non-Indigenous heritage-listed sites are listed to protect landscapes, which include forests. Examples of these larger heritage sites (and their heritage register category from Table 6.47) are Kakadu National Park in the Northern Territory, the Tasmanian Wilderness World Heritage Area, and the Gondwana Rainforests of Australia in

Figure 6.29: Water wheel, a key structure used to power huge stamping-battery machines, part of the heritage-listed Weone gold mine, Victoria

Heritage Council Victoria, vhd.heritagecouncil.vic.gov.au/places/866

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New South Wales and Queensland (all on the World Heritage List); the Australian Alps National Parks and Reserves, in the Australian Capital Territory, New South Wales and Victoria (all on the National Heritage List); High Conservation Value Old Growth Forests in New South Wales (on the New South Wales State Heritage Register); and the Grampians National Park in Victoria (on the Victorian Heritage Register).

Non-Indigenous heritage-listed sites are located across all tenure types (Table 6.48). The management approach for each site depends on the register under which it is listed, its ownership, and the type of heritage asset under management. Most registered heritage places within forests occur on public land (Table 6.48). For sites on private tenure, landowners work in conjunction with local states and territories to ensure adequate resources and support to manage and preserve the heritage values of the site.

Under the EPBC Act, any site on the World, National and Commonwealth heritage lists owned or leased by the Australian Government is required to have a management plan that outlines how the heritage values of the site will be protected. Where the Australian Government does not have ownership, the owners (e.g. state or territory governments, or private owners) are encouraged to develop and implement a management plan; this may include an agreement with the Australian Government for cooperative management. Joint management plans can be developed for sites that extend across multiple tenures. Owners of heritage sites on private land are required to submit development application plans to the relevant state agency or local government authority before undertaking any alteration of the site (including removal of trees), with the plan outlining how the heritage values of the site will be preserved and maintained.

Government-owned sites in forests are managed by relevant state or territory government agencies according to state forest codes of practice or other regulatory instruments, and many also have heritage management plans in place (e.g. conservation reserve management plans). Initiatives at local, state and territory, and national levels provide opportunities for funding for heritage conservation works.

The identification and conservation of heritage within forests can be difficult due to canopy cover, limited access, fire, funding constraints and social attitudes. However, since the late 1990s, awareness of the cultural heritage value of forests has increased (Cameron 2001). In addition to their responsibilities under legislation, various government departments and private organisations encourage research and community education, participation, and use of forest heritage sites. Active involvement by all sectors of the community in the processes of identification, conservation and use of heritage places is integral to good conservation outcomes, community appreciation and compliance.[318]

[318] www.nationaltrust.org.au/heritage-policies-wa/

Case study 6.10: Forest harvesting heritage in Tallaganda State Forest

Lowden Forest Park, in Tallaganda State Forest in the southern ranges of New South Wales, provides an example of how cultural heritage is managed in NSW State Forests.

Lowden Forest Park began its life as an informal camp in 1937, where timber harvesting contractors would camp in the forest during the week and return home on weekends. The camp was initially known as "Donoghue and Hopkins huts" after the sawmilling company that operated in that location. In 1952, a water wheel, built by William Hopkins and Spencer Hush in Queanbeyan, was brought to Lowden Forest Park to generate electricity for the camp and to recharge batteries from the trucks which transported harvested timber. After some time, as travel to and from the forest became easier, the camp ceased being used. The area was subsequently developed into a visitor area with walking tracks, camping and picnic areas surrounding the remaining heritage objects. Lowden Forest Park was officially opened in 1977 and is currently a popular visitor area.

The Park contains several historical items, including a water wheel (Figure 6.30), a bobtail that was used for pulling logs out of the forest (Figure 6.31), and a boiler that was used to produce steam to run machinery to cut timber (Figure 6.32). The water wheel has been repaired by the Forestry Corporation of New South Wales, including replacing the caulking with hemp (a traditional material) inserted into the wooden parts of the wheel to make them water-tight.

The wood race which delivered water to the wheel was also repaired, and the water wheel is now fully functioning. These historical items show current and future generations how people worked in forests in the past.

Figure 6.30: Historic water wheel under repair, Lowden Forest Park, New South Wales

Brendan Grimson, Forestry Corporation of New South Wales

Source: Forestry Corporation of New South Wales.

Figure 6.31: Bobtail used for pulling logs out of the forest, Lowden Forest Park, New South Wales

Brendan Grimson, Forestry Corporation of New South Wales

Figure 6.32: Boiler used to power machinery for cutting timber, Lowden Forest Park, New South Wales

Brendan Grimson, Forestry Corporation of New South Wales.

Indicator 6.4c

The extent to which Indigenous values are protected, maintained and enhanced through Indigenous participation in forest management

Rationale

This indicator measures the extent to which Indigenous people participate in forest management. Active participation in forest management reflects the relationship between people and the land, and the integration of Indigenous peoples' values with forest management practice, policy and decision making.

Key points

- Indigenous participation in forest management occurs through a variety of mechanisms, including direct land management, employment, co-management of reserve areas, consultation about cultural heritage, and programs for engagement with forests by urban Indigenous youths.
  - There is ongoing effort to include Indigenous cultural, contemporary and aspirational values in forest management, and ongoing efforts by land management agencies to consult and engage with Indigenous groups. However, it is difficult to measure the level of Indigenous participation at the national scale.
- The degree of management control and influence that Indigenous people have over forest relates to the Indigenous ownership and management category into which the forest is classified (Indigenous owned and managed, Indigenous managed, Indigenous co-managed, or covered by Other special rights).
  - The largest areas of forest in the Indigenous estate occur within Indigenous Land Use Agreement areas, and areas for which there has been a native title determination.
  - Other large areas of forest occur within the Northern Territory Aboriginal Land Trusts, Queensland Aboriginal and Torres Strait Islander land trusts, Indigenous Protected Areas, and owned and leased-back conservation reserves.
- A total of 22.0 million hectares in the Indigenous forest estate (32% of the Indigenous forest estate) are managed for conservation in Australia's National Reserve System.
  - There has been increased Indigenous participation in the development and implementation of management plans for forest reserves, conservation reserves and regional conservation areas across Australia.
- There is ongoing effort by land management agencies to improve Australian community understanding of Indigenous culture and connection with forests through provision of interpretive material. Communication of this information generally occurs by, or in consultation with, local traditional owners.

Indigenous peoples value forests for a range of cultural, social and economic reasons. This indicator discusses the relationship between the participation of Indigenous people in forest management and the protection, maintenance and enhancement of the values associated with forests. The term Indigenous is used here to encompass all Aboriginal and Torres Strait Islander peoples; where the information provided relates to a particular people, that traditional owner group is named.

In the past, the forest sector has dealt with Indigenous issues mostly in terms of archaeological cultural heritage sites, placing less emphasis on the values associated with a cultural or spiritual attachment to the land. However, the understanding by the forest sector of Indigenous values has changed significantly in recent years. In part, this is due to contemporary civil movements for social justice and land rights, and the greater community awareness and recognition of Australia's First Peoples. These have led to greater institutional commitment to increasing employment, consultation and inclusion of Indigenous peoples in land management. Larger numbers of Indigenous people are now employed in government agencies responsible for nature conservation or commercial wood production, and Indigenous people have a greater presence on natural resource management committees and in other forest-stakeholder forums. Lastly, there is growing recognition that traditional knowledge can inform forest management, especially in relation to management of forest fire regimes.

Indigenous values

Indigenous values can be divided into three broad but not mutually exclusive categories: heritage, contemporary and aspirational.

Heritage

Heritage values are associated with Indigenous history and are important for connecting people with the landscape. Features with heritage value include:

- archaeological sites, which provide tangible evidence of prior Indigenous presence. All jurisdictions protect archaeological sites through Indigenous heritage protection laws.
- natural landscape features associated with dreaming and creation stories. Information about these features is often held by individuals and passed on orally, and may or may not also be contained in historical records.
- places associated with Indigenous history and culture. These can include places of teaching, resource collection and work, but might not contain physical evidence of such associations. Most of this information is only available orally.
- secret and sacred places, information on which is held by particular knowledge holders and is released only according to customary laws. Most of this information is only available orally.

Contemporary

Indigenous people also value forests for contemporary reasons, including:

- landscapes of reconciliation and empowerment.
- places where Indigenous beliefs and customs can be integrated with modern living. For example, customary knowledge can be applied in economic development to produce wood products for the arts and crafts industry.
- economic independence, with both planted and native forests being valued by Indigenous people for their ability to contribute to economic independence.

Aspirational

Forests may also have aspirational value for Indigenous people. Many native forests are under public ownership, under which native title rights and interests may prevail; they can therefore potentially contribute to intergenerational equity. Native forests are valued as areas in which Indigenous people can gain greater autonomy and economic returns through a range of mechanisms, including ownership and management of country.

Land management arrangements

Indicator 6.4a presents information on the areas of forest that are owned, managed or co-managed by Indigenous people or where other special rights allow Indigenous people to participate in or influence forest management. Access and rights to use traditional lands for cultural purposes are very important for Indigenous communities, to ensure cultural values are maintained and renewed, to improve recognition and self-worth, and to facilitate knowledge, participation and consultation in land management.

The Indigenous forest estate covers 69.5 million hectares of forest in Australia (Table 6.44, Indicator 6.4a), which is 52% of Australia's total forest area. However, the degree of management control and influence that Indigenous people have over these forest areas varies, depending on the Australian, state or territory legislation that applies in each situation and the policies that are implemented in each jurisdiction.

Commonwealth legislation that provides for Indigenous recognition, access or participation in land management includes the *Native Title Act 1993*, the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), and the *Aboriginal and Torres Strait Islander Act 2005*. A native title determination recognises a set of rights and interests over land or waters where Aboriginal and Torres Strait Islander groups have practised, and continue to practise, traditional laws and customs arising from their original ownership under traditional law and custom[319].

The EPBC Act recognises the role of Indigenous people in the conservation and ecologically sustainable use of Australia's biodiversity, and includes provision for Indigenous advice

[319] auroraproject.com.au/what-native-title

on managing Commonwealth reserves[320]. The Indigenous Advisory Committee, established in 2000 under the EPBC Act [section 505A], advises the Minister for the Environment and Energy on environment and heritage programs, policy and consultation strategies, to facilitate better access and engagement for Indigenous peoples.

The Indigenous Land Corporation (ILC) is a corporate Commonwealth entity established in 1995 to assist Aboriginal and Torres Strait Islander people acquire and manage land to achieve economic, environmental, social and cultural benefits. The ILC's primary governing legislation is Part 4A of the Commonwealth *Aboriginal and Torres Strait Islander Act 2005*. The Commonwealth government also has programs that support Indigenous involvement in land and forest management, including Indigenous Protected Areas.

Further, each state and territory has its own legislation and arrangements that give Indigenous peoples involvement with land. Several mechanisms are commonly used:

- land transferred to Traditional Owners through an Aboriginal Land Rights Act or other state or territory legislation
- land purchased by an Indigenous trust or community representative bodies, such as the New South Wales Aboriginal Land Council and individual land councils
- land owned by the government (Crown land) but held in trust for use by particular Indigenous groups, with a requirement for an Indigenous community association, board or corporation to act as advisor or trustee and manager; this arrangement is common in Western Australia and South Australia
- land leased by an Indigenous community for long-term management, such as pastoral lands and land that forms part of Indigenous Land Use Agreements (ILUAs)
- formal joint management agreements, mainly for national parks and reserves, where the land is Indigenous owned and leased back to the government for joint management
- other arrangements where the land is not owned by Indigenous groups, but the whole area, or the cultural heritage aspects within it, are managed in consultation with local Indigenous groups, such as through memoranda of understanding (MOUs), membership on an advisory committee, or Indigenous involvement in development and implementation of a management plan for certain national parks and reserves
- legislation that recognises and allows Indigenous use of the land for traditional, customary purposes, with associated land management plans providing for this use.

Each of the above mechanisms gives some level of Indigenous access and rights to land, and the potential to contribute to land management including the management of forests on that land.

For reporting purposes, the information collected on Indigenous land has been grouped into four ownership and management categories (Dillon et al. 2015): Indigenous owned and managed; Indigenous managed; Indigenous co-managed; and Other special rights. Definitions of these four categories of Indigenous land are provided in Indicator 6.4a, and the degree of management control that Indigenous people have over land in each of these categories is described by category below. Area figures for the four categories sum to give the total area of Indigenous forest (Table 6.44, Indicator 6.4a), because each parcel of Indigenous land identified through one of the underpinning datasets is classified into the highest-ranked of the Indigenous ownership and management categories that apply to it (refer Dillon et al. 2015).

Each of the four categories of land ownership and management includes subcategories that relate to different Indigenous land arrangements; these were identified through inspection of different datasets, and supporting research. The area of forest within each subcategory of Indigenous land is also provided below. Area figures for the subcategories do not sum to the total area of the Indigenous forest estate, because some parcels of land may be subject to more than one type of Indigenous land arrangement or subcategory. For example, part of Kakadu National Park is included in both the 'Indigenous owned and co-managed nature conservation reserves' subcategory and the 'World Heritage Area' subcategory. Similarly, some lands that are classified as Indigenous owned and managed or Indigenous co-managed are subject to a native title determination and an ILUA.

The change in area between 2011 and 2016 reported for each Indigenous land ownership and management category and subcategory is the difference between the figures for 2016 reported in SOFR 2018 and those for 2011 reported in Dillon et al. (2015), which updated those reported for 2011 in SOFR 2013.

Amendments to legislation and policy between 2011 and 2016 have generally increased the capacity for Indigenous community ownership, management or co-management of land (Table 6.49).

Indigenous owned and managed lands

As at 2016, a total of 18.0 million hectares of forested land was Indigenous owned and managed (Table 6.44, Indicator 6.4a). This is an increase of 4.7 million hectares since 2011. Most Indigenous owned and managed lands are Indigenous freehold tenure under state and territory legislation, including land transferred from the crown to freehold tenure after native title determinations or agreements. An Indigenous Protected Area (IPA) or Indigenous Land Use Agreement (ILUA) can be negotiated after a native title determination for some Indigenous owned and managed land (see below).

[320] www.environment.gov.au/epbc/information-for/indigenous-stakeholders

Table 6.49: Main legislative changes in Australia relevant to Indigenous land and forest, 2011 to 2016[a]

Jurisdiction	Legislation/policy	Comment
Commonwealth	*Native Title Act 1993* (as amended 2013)	The *Courts and Tribunals Legislation Amendment (Administration) Act 2013* (Commonwealth) amended the *Native Title Act 1993* to improve the efficiency of the native title system through institutional reform, including a clearer focus on increasing the rate of land claims resolution[321]
	Aboriginal Land Rights (Northern Territory) Act 1976 (as amended 2013)	Relates to Kakadu lands
NSW	*Aboriginal Land Rights Amendment Act 2014*	Tighter conditions on sale of *Aboriginal Land Rights Amendment Act* land; allows Aboriginal Land Agreements; confirms business enterprise potential
	Crown Land Management Act 2016	Allows Local Aboriginal Land Council to manage dedicated Crown land
NT	*Aboriginal Land Rights Act* (as amended 2015)	Minor changes to township leasing
	Territory Parks and Wildlife Act 2014	Provides for Aboriginal joint management of certain parks and reserves
Qld	*Aboriginal and Torres Strait Islander Land (Providing Freehold) Acts 2014*	Applies to Deed of Grant in Trust (DOGIT), *Aboriginal Land Act 1991* (ALA) and *Torres Strait Islander Land Act 1991* (TSILA) land (townships) – allows smaller lots to transition to freehold
	ATSI Land Holding Act 2013	Aligns leasing between Acts
	Nature Conservation and Other Legislation Amendment Act 2016	Re-instated role of Act for conservation of nature while allowing for involvement of Indigenous people in management of protected areas
	Gazettal of Cape York Peninsular Aboriginal Lands (CYPAL) parks	Seventeen Cape York national parks renamed and gazetted as National Park Aboriginal (with some lands added)
SA	*Aboriginal Lands Trust Act 2013*	Greater autonomy from state for Trust lands
	Wilderness Protection Act 1992 (as amended 2013)	Extended co-management provisions to wilderness protection areas
Tas.	Tasmanian Wilderness World Heritage Area Management Plan (2016)	Potential future joint management
Vic.	*Traditional Owner Settlement Act* (as amended 2016)	Further provision for grants of aboriginal title under land agreements; streamlined process for authorising traditional owners to access and use natural resources (e.g. right to hunt wildlife and game, fish, and gather flora and forest produce)
	Dja Dja Wurrung agreement 2013, under the *Traditional Owner Settlement Act 2010*	First comprehensive native title settlement under the Act; formally recognises the Dja Dja Wurrung people as the traditional owners for part of Central Victoria
	Aboriginal Lands Act (as amended 2013)	Extended lease terms for Framlingham and Lake Tyers; revised governance
	Ngootyoong Gunditj Ngootyoong Mara South West Management Plan	New multi-park management plan using a partnership approach between Parks Victoria, the Gunditjmara Traditional Owners, Budj Bim Council and the Department of Environment, Land and Water Protection
WA	*Noongar (Koorah, Nitja, Boordahwan) (Past, Present, Future) Recognition Act 2016*	Act passed (although South West Native Title Agreement not registered until October 2018)
	Metropolitan Water Supply, Sewerage and Drainage By-laws 1981 and *Country Areas Water Supply By-laws 1957* (as amended 2016)	Provision for cultural use of certain areas
	Conservation and Land Management Amendment Act 2015	Greater provision for co-management of conservation reserves
	Regional management plans for conservation areas	Several multi-park management plan using a partnership approach between Department of Parks and Wildlife[322] and the Traditional Owners

[a] This table presents the main legislative changes between 2011 and 2016, and some examples of new management plans.

Indigenous Protected Areas

Indigenous Protected Areas (IPAs) are areas of Indigenous owned or managed land (or sea) created when traditional owners enter into a voluntary agreement with the Australian Government to manage the land for conservation, with government support (SVA Consulting 2016a). Currently, the majority of IPAs are Indigenous freehold land, but IPAs are evolving from a management framework based solely on Indigenous land tenure, to one involving multiple tenures coupled with cooperative management arrangements with other stakeholders (PM&C 2015a)[323]. IPAs form part of Australia's National Reserve System[324] (see Indicator 1.1c).

The IPA programme, developed in the mid-1990s, supports Indigenous landowners to use land and sea management as a framework for employment and natural and cultural heritage conservation outcomes (PM&C 2015b). All IPAs have management plans that are developed by the landowners as part of the IPA application process. These plans incorporate culturally significant, traditional land-management practices as well as other land-management practices to protect the significant values of the area. On-ground implementation of the management plans is undertaken by Indigenous landowners.

321 www.ag.gov.au/LegalSystem/NativeTitle/Pages/Pastnativetitlereforms.aspx

322 From July 2017, the Department of Biodiversity, Conservation and Attractions.

323 www.pmc.gov.au/indigenous-affairs/environment/indigenous-protected-areas-ipas

324 www.environment.gov.au/land/indigenous-protected-areas

Case study 6.11: Warddeken Indigenous Protected Area

The Warddeken Indigenous Protected Area (IPA) stretches across nearly 1.4 million hectares of gorge, forest and stone country in West Arnhem Land, Northern Territory, and is located next to Kakadu National Park. It serves as a globally significant conservation corridor that links the stony inland escarpment of the Arnhem Land plateau to the coast. The Warddeken IPA was declared in 2009 to conserve the unique environment including endemic plants, threatened and rare species, and important cultural, rock art and archaeological sites. The Warddeken IPA is also part of Australia's National Reserve System[325].

The land belongs to Nawarddeken, who are the traditional owners from at least 30 clan groups of the Bininj Kunwok language group. Bininj ownership of the area is recognised under the Commonwealth *Aboriginal Land Rights (Northern Territory) Act 1976*. In August 2007, the traditional owners formed Warddeken Land Management to assist the protection and management of country, combining traditional ecological knowledge with modern science. Rangers work on fire management, weed and feral animal control and monitoring threatened species. An important role for rangers is passing on traditional ecological knowledge to younger generations, and the rangers are important community role models.

The Australian Government has provided funds for this work under the Caring for our Country[326] initiative, through the Indigenous Protected Areas and Working on Country elements, with ongoing financial support from Bush Heritage Australia. The Indigenous Land Corporation has also provided assistance (plant and equipment) to the IPA so that Warddeken Rangers can improve road access and maintenance, control erosion, protect culturally important rock art sites, and improve access by community to plateau areas for culturally oriented camps[327].

The fire management project has been very successful in reducing the impact of late dry-season wildfires on the highly diverse environments of the West Arnhem Land plateau, with the area burnt reduced from 34% annually to less than 7% annually. This has led to significant

Warddekan forest fire management for carbon offsets and healthy country.

Continued

[325] www.environment.gov.au/indigenous/ipa/declared/warddeken.html

[326] Caring for our Country combined with National Landcare Programme in 2013.

[327] www.ilc.gov.au/Home/What-We-Do/Project-Profiles/Warddeken-Indigenous-Protected-Area

Continues

improvements in protection of endemic, highly fire-sensitive Anbinik (*Allosyncarpia ternata*) forests, and ongoing protection of the Arnhem Plateau Sandstone Shrubland Complex, a listed threatened ecological community. Outcomes are monitored through 120 reference sites maintained across the IPA. These sites are measured every two years to detect ecological responses to management.

Warddeken Land Management has successfully developed an innovative carbon abatement partnership with industry, and engaged in collaborative scientific research to position itself for entry into any future biodiversity credit scheme. The fire management work has generated substantial revenue as a result of carbon offset sales facilitated through partnerships including the West Arnhem Land Fire Abatement (WALFA) project (see Case Study 5.3) and ALFA (NT) Ltd. The Karrkad-Kanjdji Trust[328] also supports the Warddeken IPA and other IPAs to protect and manage natural and cultural environments by engaging these organisations with the philanthropic sector.

An evaluation of five IPAs and associated ranger programmes found significant positive outcomes for traditional owners (SVA Consulting 2016a). These included engaging Indigenous people in meaningful employment, achieving large-scale conservation outcomes, facilitating reconnection with country, culture and language, and helping to catalyse the development of an Indigenous land and sea based economy.

Sources: Warddeken Land Management; Warddeken Indigenous Protected Areas (IPA) Social Return on Investment Analysis, Department of the Prime Minister and Cabinet (www.pmc.gov.au/resource-centre/indigenous-affairs/warddeken-ipa-ranger); www.environment.gov.au/indigenous/ipa/declared/warddeken.html; www.ilc.gov.au/Home/What-We-Do/Project-Profiles/Warddeken-Indigenous-Protected-Area

As of January 2016, IPAs represent 44% of the National Reserve System (DoEE 2016a). Although several large IPAs are located in non-forested regions in the arid lands of Australia[329], 22 IPAs are located in forested areas of northern and eastern Australia with a mean annual rainfall of 1000 mm or above (ABARES, unpublished).

A total of 4.8 million hectares of forest are located in IPAs.

Case study 6.11 describes how Indigenous values are protected, maintained and enhanced through the management of forests in the Wardekken IPA in West Arnhem Land, Northern Territory.

Indigenous Land Corporation-owned and transferred lands

The Indigenous Land Corporation (ILC) was established in 1995 as an independent statutory authority of the Australian Government. The purpose of the ILC, as defined in the Commonwealth *Aboriginal and Torres Strait Islander Act 2005,* is to help Aboriginal persons and Torres Strait Islanders acquire and manage land to achieve economic, environmental, social and cultural benefits (ILC 2012). Further information on the Land Acquisition and Land Management Programs of the ILC can be found in its National Indigenous Land Strategy.[330]

The ILC has transferred much of its land to management by local traditional owners, who are required to prepare a management plan for the land prior to transfer. The ILC also supports Indigenous peoples through training and assistance to develop management skills and enterprises on the land.

There are 1.5 million hectares of forest located across all ILC-owned and ILC-transferred lands across Australia.

Aboriginal Land Council lands, New South Wales

New South Wales Aboriginal Land Council (NSW ALC) lands are lands granted or claimed under the *Aboriginal Land Rights Act 1983* or purchased or leased using the NSW ALC trust fund. The legal title of the land is held by the NSW ALC, which is a statutory body under this Act (NSW ALC 2014).

The NSW ALC mandate includes land acquisition either by land claim or by purchase, and establishment of commercial enterprises and community benefit schemes. It works in conjunction with a network of Local Aboriginal Land Councils (LALCs). The lands granted under the Act are freehold or leased; the freehold lands can generally be sold, leased, mortgaged or disposed of, subject to the land dealing provisions of the Act (NSW ALC 2014). The majority of the land is under the management of the 119 LALCs.

There are 74 thousand hectares of forest located across all NSW ALC lands.

Aboriginal Lands Trust lands, Northern Territory

Northern Territory Aboriginal Lands Trust (NT ALT) lands have been granted or claimed under the Northern Territory *Land Rights Act 1976*. The legal title of the land is held by an Aboriginal Lands Trust, which is made up of Indigenous people who hold the title for the benefit of all of the traditional landowners. The lands are inalienable freehold, which means that they cannot be acquired, sold, mortgaged or disposed of in any way (Central Land Council 2007).

The traditional landowners are the key decision-makers for NT ALT land. As the owner, the Aboriginal Lands Trust can approve the use of the lands for Indigenous housing, Indigenous business activities and other community purposes. However, before any activities take place, the appropriate Aboriginal land council (Central, Northern, Anindilyakwa

[328] karrkad-kanjdji.org.au

[329] www.pmc.gov.au/indigenous-affairs/environment/indigenous-land-and-sea-management-projects

[330] www.ilc.gov.au/Home/About-Us/Publications/National-Indigenous-Land-Strategy

or Tiwi) provides advice and consults with the traditional landowners to ensure that they understand and agree with the proposal. Once agreement has been reached, the land council provides directions to the NT ALT to carry out the proposal (Central Land Council 2007).

There are 12.5 million hectares of forest located across all Northern Territory Aboriginal Lands Trust lands.

Aboriginal Lands Trust, Anangu Pitjantjatjara Yankunytjatjara and Maralinga Tjarutja lands, South Australia

The South Australian Aboriginal Lands Trust (SA ALT) was originally established by the *Aboriginal Lands Trust Act 1966* to hold, in trust, titles of existing Aboriginal Reserves on behalf of all Aboriginal people in South Australia. Lands held by the SA ALT have been granted or claimed under the Act (Indigenous owned and managed), or are leased (Indigenous managed). The legal title of the land is held by the SA ALT, and the Trust board consists of Aboriginal members appointed by the South Australian Governor. The South Australian government worked with the ALT to review and update the Act and to reform the Trust, to ensure its relevance as an Aboriginal landholding authority into the future, which culminated in the creation of the South Australian *Aboriginal Lands Trust Act 2013*, which came into operation in July 2014[331].

Under the *Anangu Pitjantjatjara Yankunytjatjara Land Rights Act 1981*, land was granted to the Anangu Pitjantjatjara Yankunytjatjara (APY) people as inalienable freehold to be managed by the APY body corporate. Any pastoral leases within the area at that time remained in force as if APY had leased the land to the Crown and the Crown had sub-leased it to the lessee, until such time as the lease expired when the land ceased to be leasehold. Under the *Maralinga Tjarutja Land Rights Act 1984*, lands were handed back to the Maralinga Tjarutja (MT) people in 1985 to be managed by their body corporate.

There are 126 thousand hectares of forest located across all SA ALT lands and 127 thousand hectares of forest on APY and MT lands. Of the total 253 thousand hectares, 251 thousand hectares are Indigenous owned and managed freehold land, and 2 thousand hectares are Indigenous managed leasehold land.

Deed of Grant in Trust, Queensland

Deed of Grant in Trust (DOGIT) lands are former reserves and missions that have been granted by the Queensland Government to Indigenous groups for the benefit of Indigenous inhabitants or for Indigenous purposes. The grants were made under the Queensland *Community Services (Torres Strait) Act 1984* and *Community Services (Aborigines) Act 1984* (DERM 2008).

Each trust area is owned by the Indigenous community and is managed as a local government area. Incorporated Aboriginal councils, which elect representatives every three years, manage community affairs. The councils are able to make by-laws and appoint community police, and are responsible for maintaining housing, infrastructure, the Community Development Employment Program, licences, and hunting and camping permits. All DOGIT lands are inalienable freehold, which means that they cannot be sold; however, they can be leased (DERM 2008).

There are 493 thousand hectares of forest located on all DOGIT lands. The decrease since 2011 is due to the transfer of some lands to Queensland Aboriginal and Torres Strait Islander land trusts.

Queensland Aboriginal and Torres Strait Islander land trusts

The Queensland *Aboriginal Land Act 1991* and *Torres Strait Islander Land Act 1991* provide for the grant of Indigenous freehold land following a land claim, or the transfer of land. These two Acts are the main mechanisms for Indigenous land to be claimed and transferred in Queensland. Claimable lands are primarily available State land, and include national parks where determined available for claim by the relevant Minister. The transfer rules allow for lesser forms of Indigenous land ownership to be converted to Indigenous freehold, including DOGIT land, Aboriginal reserve land and available Crown land declared to be transferable (Wensing, unpublished)[332].

In the past, land trusts were established to hold this land for the benefit of Aboriginal and Torres Strait Islander peoples. New land trusts are no longer being established, and land is now granted to corporations registered under the Commonwealth *Corporations (Aboriginal and Torres Strait Islander) Act 2006* or existing land trusts. Existing land trusts continue to function, and are administered under the Queensland *Aboriginal Land Act 1991* or the Queensland *Torres Strait Islander Land Act 1991*. Existing land trusts have the option of establishing a corporation and transferring all land and assets to the corporation[333].

There are 4.8 million hectares of forest located across Queensland Aboriginal and Torres Strait Island Land Trust lands. This comprises 2.9 million hectares of forest that are Indigenous owned and managed, and 1.8 million hectares of forest that are Indigenous managed and within national parks.

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331 www.legislation.sa.gov.au/LZ/C/A/ABORIGINAL%20LANDS%20TRUST%20ACT%202013.aspx

332 Wensing E (2017). *A comparative analysis of the land dealing provisions in the native title and statutory land rights schemes in Australia: Background paper*, Unpublished paper, Australian National University, Canberra.

333 www.qld.gov.au/atsi/environment-land-use-native-title/land-trusts

Other Indigenous owned lands

There are 98 thousand hectares of forest that are Indigenous owned within other subcategories. This comprises 87 thousand hectares of forest with agreements under the Victorian *Traditional Owner Settlement Act 2010*, two thousand hectares of forest owned through two Aboriginal land Acts relating to Victoria, and 9 thousand hectares of forest owned and managed by the Tasmanian Aboriginal Land Trust.

The Victorian *Aboriginal Land Act 1970* was the first Act in Victoria, and in Australia, to recognise the entitlement of Aboriginal people to land. Under this Act, the deeds for the reserve land at Lake Tyers and Framlingham were transferred to their communities under trusts[334]. The *Aboriginal Land (Lake Condah and Framlingham Forest) Act 1987* was passed by the Commonwealth government at the request of the Victorian Government, under paragraph 51 (xxvi) of the *Australian Constitution*, and gives the traditional owners inalienable title to certain lands in the Lake Condah and Framlingham Forest area. It also gives the corporation of Aboriginal elders which manages the land the right to grant, with or without conditions, rights of access to the land, acquire compensation for land, or refuse mining rights affecting the land[335].

Indigenous managed lands

As at 2016, a total of 4.9 million hectares of forested land was Indigenous managed (Table 6.44, Indicator 6.4a). This is an increase of 1.7 million hectares since 2011.

Aboriginal Lands Trust, Western Australia

The Aboriginal Lands Trust (ALT) is a statutory body that was established under the Western Australian *Aboriginal Affairs Planning Authority Act 1972*. The trust is made up of a board of Indigenous people appointed by the Western Australian Minister for Indigenous Affairs. The ALT, with assistance from the Department of Aboriginal Affairs, is tasked with managing the ALT lands in a manner that will achieve social, cultural and economic advancement for Indigenous people. Any activities undertaken on ALT lands must be in accordance with the wishes of the local Indigenous community and in line with the land-use and development policy of the ALT (DIA 2005).

The ALT is a significant landholder, with responsibility for approximately 24 million hectares or 10% of Western Australia's land (DAA 2016). Lands held by the ALT can be freehold, leasehold or Crown reserve lands, can have been acquired through a variety of processes, and are held in trust for the use and benefit of Indigenous people. Any lands that are managed by the ALT can be granted to an Indigenous corporation to manage them.

There are 834 thousand hectares of forest located across all ALT lands in Western Australia.

Indigenous pastoral leases

In Western Australia, Indigenous pastoral leases are lands with a pastoral lease granted to Indigenous corporations under the *Land Administration Act 1997* (Western Australia). All pastoral leases that are held by Indigenous corporations are subject to the same rules and regulations that apply to non-Indigenous pastoral leases. The main activity that must be undertaken on these lands is the grazing of animals. Non-grazing activities cannot be undertaken without a permit from the Pastoral Lands Board; this includes clearing native vegetation and establishing plantations. The Crown maintains ownership of these lands (DIA 2005).

There are 377 thousand hectares of forest located across all Indigenous pastoral leases in Western Australia. Some of the 2 thousand hectares of forest on Indigenous leases managed by the South Australian Aboriginal Lands Trust may also be pastoral leases. Pastoral leases are also held by Aboriginal corporations in Northern Territory and Queensland, however data on these were not available.

Queensland Aboriginal and Torres Strait Islander land trusts: co-managed conservation reserves

These lands are conservation reserves on lands owned by Queensland Aboriginal and Torres Strait Islander land trusts (see above), and co-managed with the Queensland government. These are in addition to the subcategory of co-managed nature reserves described below.

There 1.7 million hectares of forest on co-managed conservation reserves under Queensland Aboriginal and Torres Strait Islander land trusts.

Other Indigenous owned and co-managed nature conservation reserves

The Australian, New South Wales, Northern Territory, Queensland, South Australian and Victorian governments have granted freehold ownership of a range of nature conservation reserves to Indigenous community groups, land trusts and land councils through Acts of parliament within the respective jurisdictions. The Indigenous owners have then either signed an agreement with the conservation agency for co-management, or have leased these reserves back to the relevant government environmental conservation agency, which in turn delegates the care, control and management of the reserve to a board of management.

The Indigenous owners of the reserves hold a majority of seats on the boards of management. Other stakeholders on the boards can include representatives of government agencies, conservation groups, local councils and other local landholders. The boards of management develop a management plan, which they implement and monitor using funds from the government agency as part of the lease agreement.

334 guides.slv.vic.gov.au/law/acts

335 parlinfo.aph.gov.au/parlInfo/search/display/display.w3p;query=Id%3A%22legislation%2Fbillsdgs%2FNHN10%22

Indigenous owned and co-managed nature conservation reserves are classified as Indigenous managed lands because, although legally owned by Indigenous groups, these groups do not have sole management control over the land: control is often shared with non-Indigenous government and community representatives.

There are 2.8 million hectares of forest located across Indigenous owned and co-managed nature reserves in Australia, in addition to Queensland land trusts (see above). Of this area, Queensland and the Northern Territory have 1.0 and 1.7 million hectares of forest in conservation reserves under this arrangement, respectively. In Victoria, lease-back arrangements include lands within the Dja Dja Wurrung agreement 2013 under the *Traditional Owner Settlement Act 2010* (Victoria).

Indigenous co-managed lands

As at 2016, a total of 5.7 million hectares of forested land were Indigenous co-managed, being government-owned land with Indigenous co-management arrangements in place (Table 6.44, Indicator 6.4a). This is an increase of 1.0 million hectares since 2011.

The area of Indigenous co-managed forest increased in most jurisdictions since 2011, and in particular in South Australia, as a result of changes to governance arrangements. The increase of Indigenous co-managed forest in New South Wales is due to the recent addition of reserves and Indigenous agreements to the Indigenous estate, as well as the inclusion of an additional dataset on NSW Aboriginal Areas since SOFR 2013. A decrease in the area of Indigenous co-managed forest in Queensland since 2011 is due to the transfer of some Cape York Peninsular Aboriginal Lands and some IPAs to the Indigenous managed and the Indigenous owned and managed categories, respectively.

Nature conservation reserve memoranda of understanding

Nature conservation agencies in all jurisdictions except Tasmania have negotiated memoranda of understanding (MOUs) with local Indigenous communities for the joint management of a number of nature conservation reserves. Under these MOUs, the Indigenous community may be involved in the development and implementation of reserve management plans to protect sites of Indigenous cultural significance. Some ILUAs (see below) include co-management agreements. The Crown in each jurisdiction maintains ownership and management control of these lands.

Co-management arrangements can be associated with formal, legal recognition of Indigenous rights to undertake customary activities on certain lands. For example, Part 4A of the New South Wales *National Parks and Wildlife Act 1974* provides that Traditional Owners or Aboriginal persons with the consent of the relevant board may enter onto and use the lands for gathering traditional foods, hunting or fishing provided this is for domestic purposes, or for ceremonial and cultural purposes to the extent that the entry or use is in accordance with the tradition of the Aboriginal traditional owners. This excludes use of protected (threatened) species and species subject to any legislation applying to the land or to a park or site plan of management. Similarly, in Western Australia, Aboriginal native title holders may undertake certain customary activities on section 8AA land and some 8A land under the *Conservation and Land Management Act 1984* (Western Australia), that is, lands over which there is an agreement for joint management by the Department of Parks and Wildlife[336] and native title holders.

The combined area of forest within government-owned co-managed nature conservation reserves with MOUs and advisory structures (see below) is 3.0 million hectares.

Advisory structures: government-owned co-managed conservation reserves

Formal consultation arrangements with Indigenous communities can occur where conservation reserves are government-owned, through co-management boards, advisory committees, or consultation mechanisms specified in reserve management plans. Land on which informal or ad-hoc consultation with stakeholders, including Indigenous groups, is undertaken as part of forest operations has not been included in the Indigenous estate.

Reserve management plans are required under legislation, and many New South Wales and Queensland national parks and nature reserves specify ongoing Indigenous consultation in these management plans. In 2004, South Australia amended legislation to share responsibility for the management of national parks and conservation parks with Aboriginal groups through either a co-management board or co-management advisory committee. Further legislation amendments were made in 2013 to extend co-management to areas protected as wilderness. Several regional agreements have been made in recent years under this arrangement. In Western Australia and Victoria, a number of agreements have been made with Traditional Owners that include co-management arrangements for certain forest, public and nature reserves. Several regional, multi-reserve management plans have also been developed with Indigenous consultation and co-management arrangements (see Table 6.49).

In New South Wales, Aboriginal Areas are Crown land reserved under the *National Parks and Wildlife Act 1974* (New South Wales) to protect and conserve areas significant to Aboriginal culture and to allow use by Aboriginal people for cultural purposes. Management of the Aboriginal Area may include providing opportunities for Aboriginal people to access Country, and to maintain, renew or develop cultural practices and associations. Most Aboriginal Areas are categorised as co-managed because they have a MOU or ILUA, or because there is a Plan of Management or Statement of Management Intent which specifies joint management or ongoing consultation with traditional owners. The total area of forest within Aboriginal Areas is 23 thousand hectares, the majority of

336 From July 2017, the Department of Biodiversity, Conservation and Attractions.

which is categorised as Indigenous co-managed. A small area of Aboriginal Areas is categorised as 'Other special rights'.

There are currently no formal joint management arrangements in place for Tasmanian national parks, however there are Aboriginal representatives on the National Parks & Wildlife Advisory Council which advises the Director of National Parks and Wildlife and the relevant Minister on management issues relating to Tasmania's national parks and reserves. Because the arrangements are not specified for individual reserves, Tasmanian parks have not been included in the Indigenous co-managed category. While currently an advisory arrangement, the 2016 Management Plan for the Tasmanian Wilderness World Heritage Area outlines a joint management proposal.

World Heritage Areas

World Heritage Areas are Matters of National Significance under the EPBC Act. Australia's World Heritage-listed areas have Indigenous representatives on advisory committees that provide advice to the World Heritage Area management committee on the management of sites of Indigenous cultural significance. World Heritage Areas can be owned by the Crown or by private parties, and can exist on any land tenure type; however, only areas that are owned by the Crown, or have co-management agreements with private landowners in place, have the capacity for Indigenous co-management.

Some World Heritage Areas overlap with other land management arrangements. For example, about half of the area of Kakadu National Park, which is also a World Heritage Area, is owned by Indigenous peoples. The Kakadu Board of Management, which has an Aboriginal majority representing traditional owners of land in the park, determines management policy and is responsible, along with the Parks Australia director, for preparing a management plan for the park. The management plan is the main policy document for the park, addressing long-term strategic goals and guiding day-to-day operations.

The Wet Tropics Regional Agreement (2005) was the first agreement of its kind in Australia, and provides for the cooperative management of the Wet Tropics of Queensland World Heritage Area by the 18 Rainforest Aboriginal peoples associated with the area, and the Australian and Queensland Governments[337]. Three IPAs overlap the Wet Tropics World Heritage Area: Mandingalbay Yidinji IPA, Girringun IPA, and Eastern Kuku Yalanji IPA[338].

There are 4.7 million hectares of forest in the Indigenous estate across all World Heritage areas. This comprises 0.3 million hectares that are Indigenous owned and managed (IPAs within the Wet Tropics), 1.2 million hectares that are Indigenous managed, and 3.2 million hectares that are Indigenous co-managed. The forest in the Indigenous managed category comprises Kakadu lands that are both

[337] www.environment.gov.au/heritage/about/world/management-australias-world-heritage-listed/managing-world-heritage-australia/indigenous-world-heritage

[338] www.wettropics.gov.au/caring-for-country-1

Indigenous owned and World Heritage (1.2 million hectares) and a small area (approximately 100 hectares) in Uluṟu-Kata-Tjuṯa National Park. Both of these parks are Indigenous owned and are leased-back to the Commonwealth government for co-management.

Other special rights

As at 2016, Indigenous peoples have been granted 'Other special rights' over a total of 40.9 million hectares of forest (Table 6.44, Indicator 6.4a). This is an increase of 21.1 million hectares since 2011. Part of this increase is due to the increase in the reported area of forest in the Northern Territory (Indicator 1.1a), and part is due to the inclusion of additional datasets on areas of forest with 'Other special rights', but there has also been an increase in the actual forest area in this category due to recent native title determinations and ILUAs.

Native title determinations

Native title is the recognition, under Australian law, that some Indigenous people have rights to and interests in land that derive from traditional laws and customs. Native title rights can include the right to live in, access and collect resources from an area, along with the right to visit and protect sites of cultural significance.

In some cases, native title includes the right to possess and occupy an area to the exclusion of all others. This includes the right to control access to, and use of, the area. However, this right only exists over certain areas or tenures, such as unallocated or vacant Crown land and some areas already held by, or for, Indigenous Australians (NNTT 2009).

Native title does not always grant legal title of an area to an Indigenous community group, but it does give the right to participate in decisions on how the land is used by other people. Native title rights may co-exist with other rights not involving native title; in the event of conflict, the native title rights give way to the non-native title rights (NNTT 2009).

As at 2016, there are 28.0 million hectares of forest with native title determinations. Of this area, 22.7 million hectares are not included in any other Indigenous land ownership and management category.

Indigenous Land Use Agreements

The Commonwealth *Native Title Act 1993* allows for Indigenous Land Use Agreements (ILUAs) to be made between Indigenous people who hold or may hold native title, and other interested parties (e.g. private companies or government agencies), about how land in an area covered by the agreement will be used and managed. ILUAs can be made as part of a native title determination, or separately.

ILUAs do not equate to ownership of land. The agreements deal with the use of land, and can cover a range of issues that may or may not relate to forests. For example, an ILUA may cover one or more forms of access to land for exploration or mining, change in land use, access to pastoral leases, terms and conditions of claim settlements, or joint management arrangements in relation to conservation areas. The agreements can include assurances about protection of cultural heritage and the environment, employment and training opportunities, and communication between parties.

Often, national parks and reserves within the land covered by an ILUA are subject to co-management arrangements (see above). For example, the Githabul ILUA in northern New South Wales establishes a joint management arrangement for the eleven parks in the ILUA area, including the Tooloom Falls (Bandahngan) Aboriginal Area created in 2009. The ILUA has resulted in the ongoing employment of Githabul people in the care and maintenance of these parks.

As at 2016, there are 33.2 million hectares of forest under ILUAs. Of this area, 25.9 million hectares are not included in any other Indigenous land ownership and management category.

Other areas with customary practice rights (Aboriginal Areas and some drinking water supply catchments)

In addition to Indigenous land ownership, management and co-management, native title or ILUAs, there are certain other situations where Indigenous rights to undertake customary (traditional) activities are formally recognised within an Act or regulations. This can include the right to visit and protect sites of cultural significance, and to undertake ceremonial and cultural practices at Aboriginal registered sites. The type of customary activities permitted may be specified, to ensure the intent of the overarching legislation, such as water protection or biodiversity conservation, is maintained. Datasets relating to such land were not incorporated in the Indigenous land dataset compiled for 2011 by Dillon et al. (2015), but are included in the 'Other special rights' category for SOFR 2018.

In the Yarra Tributaries Forest Reserve, Victoria, and in some protected water supply catchments in south-west Western Australia, formal provision has been made for Indigenous groups to undertake certain customary activities. As part of negotiations for the Noongar South West Native Title Settlement, the Western Australian *Metropolitan Water Supply, Sewerage and Drainage By-laws 1981* and *Country Areas Water Supply By-laws 1957* were amended in June 2016 to specify those Noongar customary activities that are permitted, and to clarify the locations and activities that are not permitted due to risks to drinking water quality.

Amendments to the Western Australian *Conservation and Land Management Act 1984* have also recognised the rights of Aboriginal people to undertake traditional practices on conservation reserves that are traditional lands. Under the 2012 amendments, activities are considered to be done for an Aboriginal customary purpose if they involve traditional practices to do with making and eating food, making and using medicine, practising artistic, ceremonial or other cultural activities, and doing other things involved with any of the above, including using natural resources such as ochre, stones and soil for ceremonies. No activity is considered customary if it is done for financial gain or reward[339].

There are 5.9 million hectares of forest in this subcategory 'Other special rights'. Of this, 5.2 million hectares are Western Australian conservation reserves with legislated provisions for Aboriginal cultural use.

Indigenous participation in forest management

Indigenous participation in forest management occurs through a variety of mechanisms, including:

- forest ownership and management
- joint management of national parks and conservation reserves
- Indigenous Land Use Agreements
- native title rights
- consultation by public forest management agencies
- direct employment in the forest sector
- community employment schemes
- cooperative research programs
- partnerships with government and industry
- consultation about cultural heritage within forests
- programs for urban Indigenous youths' engagement with forests.

It is difficult to measure the level of Indigenous participation through the above mechanisms at the national scale. However, there is a diverse range of activities that demonstrate Indigenous participation in forest use and management. Indigenous people provide critical knowledge that contributes to the protection and maintenance of forest values independent of any legal right to land. Engagement derives from the concern of Indigenous peoples and communities to protect forest heritage and culturally sensitive sites, and from involvement in decision-making about matters relevant to the forest.

Forest ownership involves direct management responsibility by Indigenous people and communities. This provides opportunities for integrating traditional and contemporary forest management practices, forming land management partnerships, employing Indigenous people, and renewing and continuing cultural practices. Pastoral leases and some ILUAs also give direct Indigenous management responsibility for forests on those lands. In limited instances, Indigenous owned and managed land is used for commercial forestry (see Case Study 6.13), which provides local resources and employment and direct Indigenous involvement in forest management.

There are 22.0 million hectares of forest across all Indigenous lands that are included in the National Reserve System (determined through intersection of the Indigenous forest estate spatial dataset with the Collaborative Australian Protected

[339] www.dpaw.wa.gov.au/parks/aboriginal-involvement/92-customary-activities

Areas Database 2016), where conservation is the legislated management intent (see Indicator 1.1c). This represents 32% of the forest area in the Indigenous estate, and 16% of all Australian forest. A total of 90% of the area of Indigenous managed forest and 95% of the area of Indigenous co-managed forest are in the National Reserve System, as are 28% of the area of Indigenous owned and managed forest, and 17% of the area of Indigenous forest with 'Other special rights'.

A recent study (Renwick et al. 2017) highlighted the role of Indigenous peoples in contributing to conservation of Australia's biodiversity. Renwick et al. (2017) used an older dataset of Indigenous lands to report that three-quarters of Australia's 272 terrestrial or freshwater vertebrate species listed as threatened under national legislation have projected ranges that overlap Indigenous lands; this figure includes forest and non-forest areas, as well as species that are not forest-dwelling. Hotspots where the ranges of multiple threatened species overlap with Indigenous lands occur predominantly in coastal areas and in northern Australia (see also Figure 1.23, Indicator 1.2b).

Indigenous owned and co-managed lands include lease-back arrangements such as Kakadu National Park, and reserves designated under the Queensland *Nature Conservation Act 1992* as Cape York Peninsular Aboriginal Lands[340]. The management arrangements between the Bininj/Mungguy people and the Director of National Parks with regard to Kakadu National Park are an example of an innovative cooperative management arrangement (DoEE 2016b). Protected area and land management authorities regularly visit the park, as do groups of Indigenous people interested in joint management from within Australia and overseas, and the model of joint management used in Kakadu and Uluṟu-Kata-Tjuṯa National Parks has been a blueprint for joint management more broadly.

Agreements may be developed to co-manage a park for nature conservation purposes whether or not native title has been formally determined. In Victoria, the *Traditional Owner Settlement Act 2010* provides a number of mechanisms for consultation and participation of traditional owners in managing natural resources, continuing cultural practices and achieving land management agreements, either through a native title settlement or other arrangements.

Cooperative management is one outcome from the Native Title settlement process with the Gunditjmara Traditional Owners[341]. The Ngootyoong Gunditj Ngootyoong Mara South West Management Plan is a new type of multi-park management plan, developed using a unique partnership approach between Parks Victoria, the Gunditjmara Traditional Owners, Budj Bim Council and the Department of Environment, Land, Water and Planning (DELWP). The plan was released in May 2014, and covers nine parks managed or co-managed by Parks Victoria, Cobboboonee Forest Park managed by DELWP, 132 reserves and a regional park managed by Parks Victoria, and six properties owned by the Gunditjmara community including three IPAs. The plan integrates the knowledge of the Gunditjmara traditional owners into park management.

On government-owned conservation reserves, many management plans or statements prepared during the period from 2011 to 2016 specify arrangements for Indigenous co-management. Ongoing consultation on cultural heritage and culturally significant sites is common to these agreements. Indigenous advice can influence other park management. For example the Management Statement for Amamoor National Park, Queensland includes an aim of encouraging traditional owners to identify and document values, sites, artefacts and places of cultural heritage significance so that management strategies and decisions relating to fire regimes, access and track maintenance minimise potential threats to these values[342]. Apart from cultural heritage sites, more comprehensive co-management agreements can include Indigenous input into park management, tourism and visitation, and employment as guides or as rangers who undertake weed and feral animal control, biodiversity monitoring, fire management (see Case study 6.11) and other work. For example, the Murrumbung Rangers use cultural burning practices to manage vegetation in Namadgi National Park, ACT.

Other mechanisms for participation by Indigenous peoples in forest management include engagement with natural resource management and forest management agencies, Indigenous forestry, biosecurity surveillance, tourism, and participation in forest-related programs. NSW National Parks and Wildlife Service supports the Aboriginal educational program 'Connecting to Culture Sydney'. It immerses urban Aboriginal youth into Aboriginal culture within NSW national parks close to Sydney. Participants take part in camping trips, ongoing fieldwork on Country, recording and preserving Aboriginal sites, and discovering Australian native plants and traditional practices[343].

Most state and territory departments responsible for commercial forest management have policies, programs and guidelines to facilitate Indigenous employment in forestry (see also Indicator 6.5d) and the engagement of Indigenous peoples with forests. Parks Victoria has an active program for the employment of Indigenous people in land under its management. Forestry Corporation of New South Wales (FCNSW)[344] have supported Indigenous trainees while they complete forestry qualifications (FCNSW 2016a). Case Study 6.12 provides further information on the involvement of FCNSW with Indigenous groups.

Finally, Indigenous tourism provides opportunities for employment and renewing connection to country for Indigenous guides and participants, as well as offering visitors an insight into the culture of the local Indigenous

340 www.npsr.qld.gov.au/managing/joint_management_of_cape_york_peninsula_national_parks.html

341 Source: Parks Victoria Annual Report 2014–15 (parkweb.vic.gov.au/about-us/publications-list/annual-reports); Victorian National Parks Association (2015) Exploring Victoria's national parks. Victorian National Parks Association (vnpa.org.au/publications/exploring-victorias-national-parks/)

342 www.npsr.qld.gov.au/managing/plans-strategies/statements/pdf/amamoor.pdf

343 www.nationalparks.nsw.gov.au/conservation-programs/connecting-to-culture-sydney

344 Until January 2013, Forests NSW.

people. Mossman Gorge, located in the Daintree National Park, Queensland, is owned by the local Indigenous group Kuku Yalanji who manage interpretative dreamtime walking tours, which give visitors the opportunity to experience the beauty of the rainforest and learn about traditional bush foods (Mossman Gorge Centre 2017). The Kuku Yalanji aim to minimise the impact of tourism on the park, including through a low emissions bus which takes tourists to designated areas (Langton 2018).

The Bundian Way is the first Indigenous walking trail to be listed on the New South Wales State Heritage Register, and honours the Koori people who used this trail extensively to commute from Targangal (Kosciuszko) to Bilgalera (Fisheries Beach) on the south coast of New South Wales (Blay and Eden Local Aboriginal Land Council 2011) (Figure 6.33). The first stage of the Bundian Way was opened to the public in March 2016; visitors can experience self-guided tours from Eden's Cocora Beach to Quarantine Bay.

The Gumgali Track (Case study 6.14) is also providing opportunities for Aboriginal-initiated tourism, and for involvement in NSW public-use forest management. Other examples of Indigenous tourism are given in Langton (2018).

Figure 6.33: Workers clear and widen a section of the Bundian Way, the first Aboriginal pathway to be listed on the New South Wales State Heritage Register

Case study 6.12: Forestry Corporation of New South Wales engagement with the Aboriginal community

The Forestry Corporation of New South Wales (FCNSW) aims to protect, nurture and manage Aboriginal cultural heritage and significant sites while creating sustainable partnerships with the Aboriginal community. A team of Aboriginal Partnership Liaison Officers (the FCNSW Aboriginal Partnerships Team) works with Aboriginal communities throughout NSW to find, protect and manage Aboriginal cultural sites on State Forest prior to road works, and prior to forest harvesting and regeneration. The team engages Aboriginal organisations (mostly Local Aboriginal Land Councils) to help with site surveys and to contribute to management of sites and areas of significance. As at June 2016, the area under FCNSW management included six gazetted Aboriginal Places, 3,453 protected Aboriginal sites, and 1,140 hectares managed for Aboriginal cultural heritage. The number of sites is increasing over time, and FCNSW aims to manage cultural heritage on all lands for which they have responsibility.

The FCNSW Aboriginal Partnerships Team develops partnerships or arrangements with Aboriginal organisations to provide access to areas of significance, traditional resources and materials, land for teaching and camping, culture camps, and bark for traditional canoe making. For example, the Anaiwan Aboriginal Traditional Owners use and manage a former forestry depot for cultural teaching and camping. Joint management partnerships in place or under development include with the Darkinjung Local Aboriginal Land Council (LALC) for the joint management of Warre Warren Aboriginal Place in McPherson State Forest inland of the Central NSW Coast, and with the Githabul Rangers for management of Toonumbar State Forest near Kyogle.

FCNSW also encourages projects undertaken by 'green teams' within Aboriginal organisations and Local Aboriginal Land Councils. FCNSW has supported and worked with other Indigenous groups, including the Durrunda Wajaarr Green Team, the Coffs Harbour and District LALC, the Eden Local Aboriginal Land Council, and Keepa Keepa Incorporated, an affiliation of the Awabakal Land Council. FCNSW also participates in community projects which assist Aboriginal people, such as through the provision of salvage timber as firewood for Biripi Aged Care.

FCNSW also provides land-based permits for Aboriginal groups to manage specific areas of land, or for community enterprise development, with the aim, in partnership with Aboriginal people and organisations, of building Aboriginal enterprises that manage significant areas of forest with a focus on sustainability, profitability and strong partnerships.

Case study 6.13: Indigenous forestry

Indigenous communities own large areas of contiguous forest in northern Australia, whereas the areas of Indigenous owned forest in southern Australia are relatively small and widely dispersed. Much of the land owned and managed by Indigenous communities is managed for conservation and cultural purposes, but some forested areas are available for harvesting and other uses, depending on wood harvest rights and the agreement of traditional owners.

In southern Australia, a small number of Indigenous businesses cut and supply firewood to their local area, and other communities are scoping the feasibility of a mix of enterprises on Indigenous forest lands. The Indigenous Land Corporation owns small areas of existing plantations (*Pinus radiata*, *Eucalyptus globulus* and sandalwood) on properties acquired for agricultural purposes.

Gumatj men employed at the local Gunyangara timber mill in Arnhem Land.

In the Northern Territory, Tiwi Islanders have long been involved in commercial plantation forestry of brown salwood (*Acacia mangium*) for pulp wood production.

In remote areas of Australia, obtaining timber from regional centres can be extremely expensive, and softwood from *Pinus* species, although reasonably readily available, is not resistant to termites that commonly occur in northern Australia. Harvesting local native forests can provide local employment in Indigenous communities, and be a source of more durable timbers for housing construction, replacing timber imported from elsewhere.

The Yolgnu-Gumatj people of East Arnhem Land harvest trees near Nhulunbuy from mining lease areas about to be cleared of forest for mining, and have a small factory producing furniture and roof trusses. The main species is Darwin stringybark (*E. tetradonta*), which is a class 1 hardwood, good for construction, decking and outdoor furniture. The Wadaye community of West Arnhem Land has two sawmills used for cutting timber to build furniture. In north Queensland, the Aurukun community are negotiating to develop forestry salvage operations associated with mining on the western side of Cape York. In Queensland, the Cape York Timber mill has a harvest contract with Yintjingga Aboriginal Corporation to harvest on their lands, and to pay royalties to the Lama Lama community. The main species harvested is Darwin stringybark, with in addition some Melville Island bloodwood (*Corymbia nesophila*) and Cooktown ironwood (*Erythrophleum chlorostachys*).

CRITERION 6

6.4c

Case study 6.14: Gumgali Track

The Gumgali walking track, located north of Coffs Harbour, New South Wales, is based on the travel route used for tens of thousands of years by the local Aboriginal people to connect Orara Valley and the coast. The traditional owners of the land are the Gumbaynggirr people. The walking track follows the ridge line to Korora lookout, passing through the eucalypt forest of the Bruxner Flora Reserve, part of the Orara East State Forest.

Gumgali track arose from a partnership between Forestry Corporation of New South Wales, Interpretative Design Company, the Coffs Harbour and District Local Aboriginal Land Council, and the Coffs Harbour Elders Group (Gumbaynggirr) who gave their permission for the re-telling of the dreaming story Gumgali. This story tells how Gumgali, the black goanna, burrowed through the escarpment beneath Korora lookout to emerge in the sea off Macauleys Headland.

The Gumgali track retells the story of Gumgali through interactive wooden sculptures, mural artwork, interpretative signage (Figure 6.34) and sound. Sculptures were crafted from locally grown brushbox (*Lophostemon confertus*), tallowwood (*Eucalyptus microcorys*) and ironbark (*E. paniculata*) by a local sculptor with the assistance of a local Gumbaynggirr woman. An audio post near the lookout tells the story of Gumgali in Gumbaynggirr language and English. In partnership with the Bularri Muurlay Nyanggan Aboriginal Corporation, Gumbaynggirr have introduced cultural shows utilising Gumgali track.

Tourism allows Aboriginal communities to revitalise language and culture, creates and drives an economy, and promotes respect and appreciation for culture. Gumgali track provides ongoing opportunities for traditional owners to share language and culture with the local community and tourists, as well as providing employment and income, and highlighting the importance of managing and caring for forests (O'Brien and Rogers 2017). Since the opening of the project in 2016, Gumgali track has won a range of awards from the National Association for Interpretation, Interpretation Australia, and the NSW Tourism Industry.

Source: FCNSW (2016c); www.forestrycorporation.com.au/about/releases/aboriginal-interpretive-walk.

Figure 6.34: Main entrance sign to Gumgali track, manufactured from locally sourced hardwoods, Orara East State Forest, New South Wales

Indicator 6.4d

The importance of forests to people

Rationale

This indicator measures the range of attitudinal values that communities and individuals place on their forests. The importance of forests to society is exemplified through the value that people place on biodiversity, clean air and water, social equity or simply the knowledge that Australia's forests exist.

Key points

- Surveys conducted between 2008 and 2017 on behalf of Forest and Wood Products Australia indicate the attitudes of Australians to a range of forest-related issues.
  - Averaged across the surveys, just under half of the respondents agreed that Australia's native forests are being managed sustainably.
  - A majority of respondents considered that wood is more environmentally friendly than alternative materials, and a large majority of respondents preferred the use of Australian trees rather than overseas trees to make wood products.
  - A majority of respondents also believed that harvesting trees is acceptable so long as the trees are replaced.
  - The level of understanding of basic facts about the role of forests and wood in carbon sequestration and storage increased markedly across the 16 surveys.

Australia's forests are recognised as one of Australia's greatest natural assets and are highly valued for the wide range of environmental and socio-economic benefits and services that they provide. Societal values and attitudes towards the natural environment and the activities that affect it change over time. This indicator monitors those attitudes in regards to community acceptance and approval of activities relating to forest management.

Attitudes towards wood and forests

Sixteen surveys conducted since 2008 for Forest and Wood Products Australia[345] provide insights into the knowledge and attitudes of the community and how these attitudes are changing. In each survey, a sample of approximately one thousand people was asked whether they agreed with a range of statements. The samples were selected with quotas placed on age, gender and location according to census data, to ensure that the samples were representative of the Australian population.

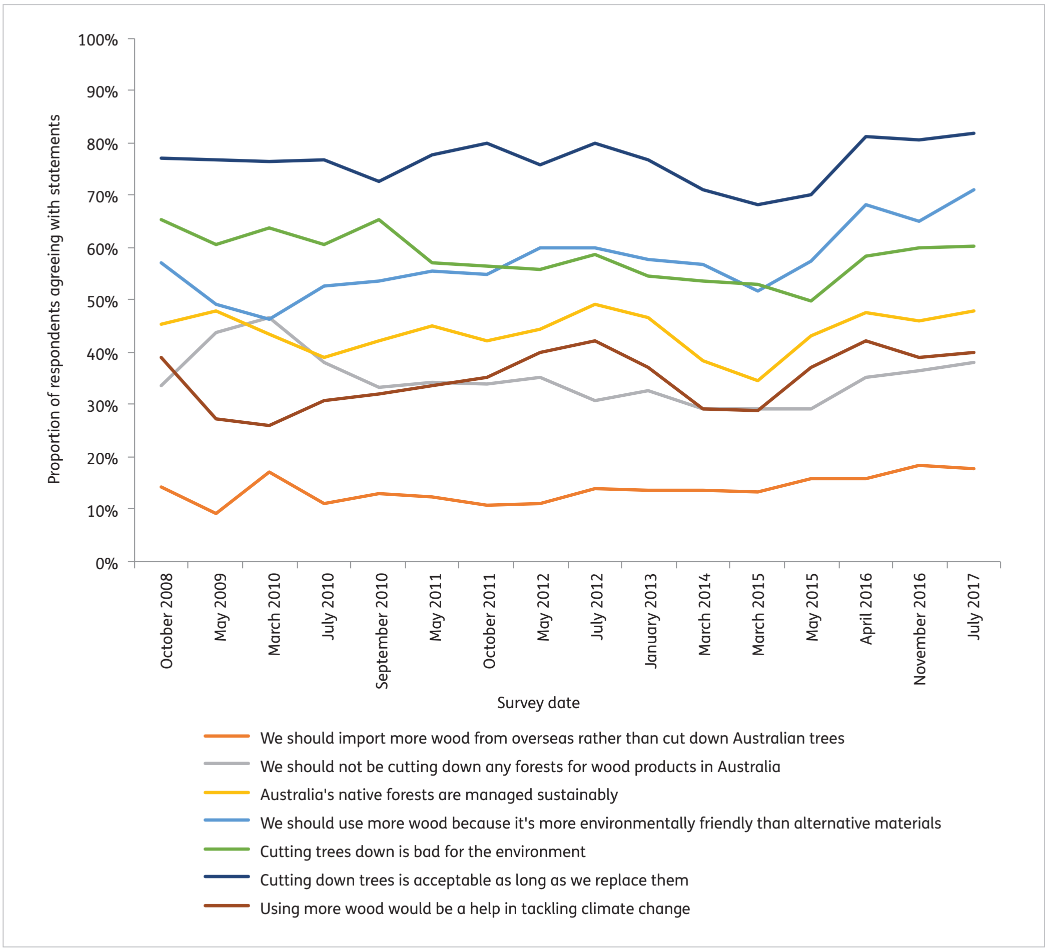
Averaged across the 16 surveys, a little under half of the respondents (44%) agreed that Australia's native forests are being managed sustainably (Figure 6.35). This proportion varied between 39% and 48% over the series of surveys, but with no apparent trend over time.

An average of 56% of respondents agreed that we should use more wood because it is more environmentally friendly than alternative materials (Figure 6.35). This proportion increased from a low of 46% in March 2010 to a high of 71% in July 2017. However, over all 16 surveys, an average of only 14% of respondents considered that Australia should import more wood from overseas rather than cut down Australian trees; individual survey results for this question ranged from 9% to 18% with a slight trend upwards over time (Figure 6.35).

A consistent proportion of people (average of 58%, with a range of 50% to 65% between surveys) agreed that cutting

[345] Forest and Wood Products Australia Limited (FWPA) is a not-for-profit company that provides national, integrated research and development services to the Australian forest and wood products industry (www.fwpa.com.au/).

Figure 6.35: Proportion of people agreeing with statements relating to tree harvesting, native forest management and wood



Notes:

'Agreeing' means the total of responses 'agree totally', 'agree strongly' or 'agree slightly'. Sample sizes are approximately 1,000. Response reliability ±3%.

Source: Forest and Wood Products Australia.

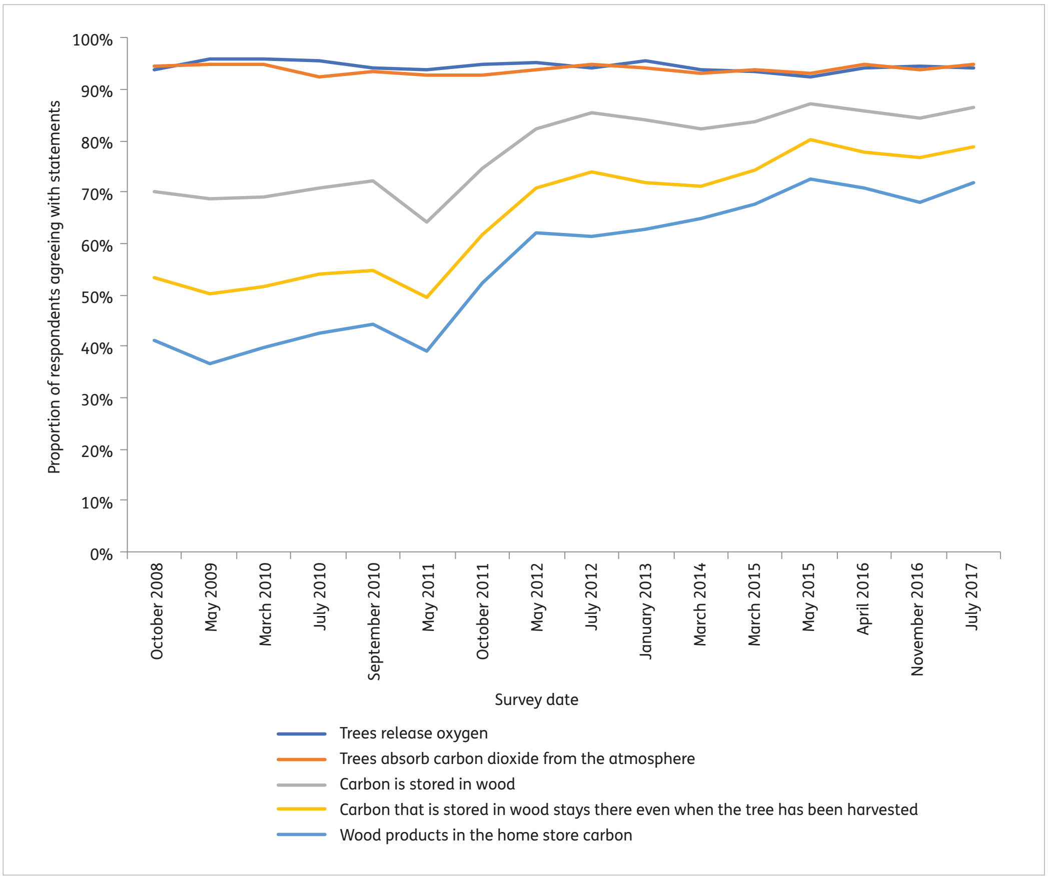
The data used to create this figure, together with other data for Indicator 6.4d, are available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

trees down is bad for the environment. However, a larger proportion of people (average of 76%, with a range of 68% to 82% between surveys) agreed that cutting down trees is acceptable as long as we replace them (Figure 6.35). This suggests that people are prepared to accept some perceived immediate environmental impact of harvesting trees when balanced against the lower long-term impacts and the environmental benefits of being able to use wood.

Respondents were also asked to respond to survey statements relating to carbon and wood (Figure 6.36). These statements are relevant to the ongoing public debate about the enhanced greenhouse effect and global warming, and the role of forests and wood products in the global carbon cycle. All the survey statements are correct, yet in initial surveys the level of agreement with three statements ('Carbon is stored in wood', 'Carbon that is stored in wood stays there even when the tree has been harvested' and 'Wood products in the home store carbon') were well below 100%. In subsequent years, the level of agreement with these statements rapidly increased, showing improving levels of understanding. A substantial majority of respondents now understand that carbon is stored in wood products. Despite that, an average of only 35% of people believed that using more wood would help tackle climate change, with that figure not increasing significantly over time (Figure 6.35).

Five surveys undertaken by the FWPA from 2015 to 2017 asked people whether they considered that various materials used in buildings and for other purposes are 'environmentally friendly'. The average results of the five surveys (Figure 6.37) show that many more respondents (an average of 74% over the five surveys) think wood is environmentally friendly, compared to an average of 13% for the other materials in the survey.

Figure 6.36: Proportion of people agreeing with statements on trees and wood



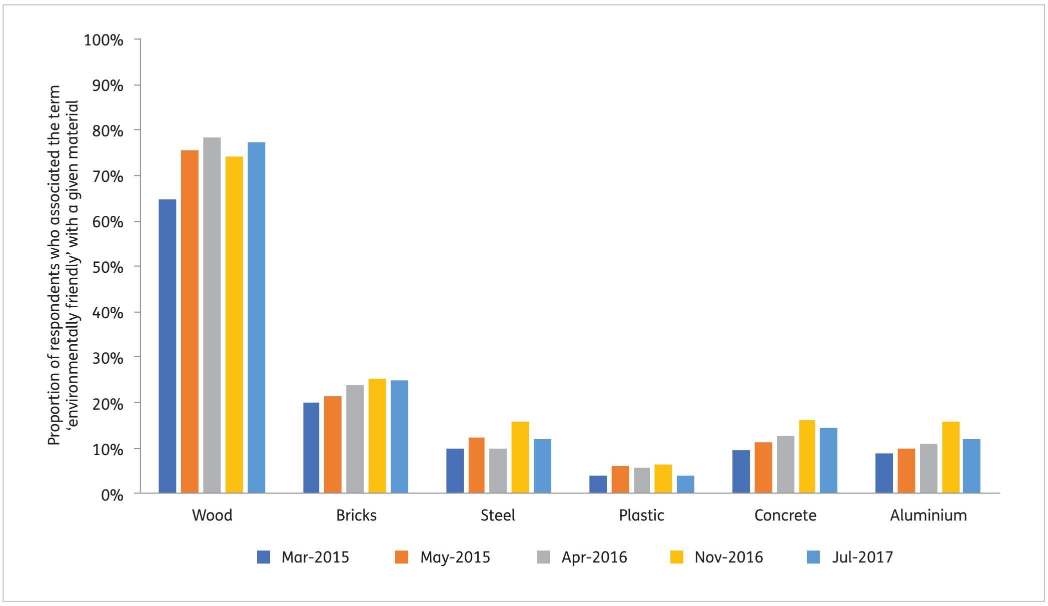
Notes:

Participants were asked to respond 'true' or 'false' to each statement. Sample sizes are approximately 1,000. Response reliability ±3%.

Source: Forest and Wood Products Australia.

The data used to create this figure, together with other data for Indicator 6.4d, are available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

Figure 6.37: Perceptions of whether materials are 'environmentally friendly'



Notes:

The histogram shows the average proportion of respondents who associated the term 'environmentally friendly' with a given material. Five surveys were conducted from 2015 to 2017. Sample sizes are approximately 1,000.

Source: Forest and Wood Products Australia.

The data used to create this figure, together with other data for Indicator 6.4d, are available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

Indicator 6.5a

Direct and indirect employment in the forest sector

Rationale

This indicator measures the level of direct and indirect employment in the forest sector. Employment is an important measure of the contribution of forests to viable communities and the national economy.

Key points

- Total national direct employment in the forest sector was estimated at 51,983 persons in 2016, down by 24% from 68,596 persons in 2011. Forest sector employment decreased in all jurisdictions except the Northern Territory during these years.
  - The decline in total direct employment reflected a 24% fall in full-time direct employment, from 56,087 to 42,733 employees, and a 23% fall in part-time direct employment, from 9,508 to 7,301 persons.
  - The total employment figures include a small number of persons employed but away from work.
  - Between 2011 and 2016, national direct employment increased in the forestry and logging subsector and the forestry support services subsector, but decreased in the larger wood product manufacturing and pulp, paper and converted paper product manufacturing subsectors.
- The key drivers for the reduction in total national direct employment in the forestry sector were consolidation of processing into larger facilities with higher labour efficiencies, and restructuring of the sector.
  - These drivers applied to direct employment in both the wood product manufacturing subsector and the pulp, paper and converted paper product manufacturing subsector.
- A study on the South West Slopes and Central Tablelands regions in New South Wales reported that, in 2016, the softwood plantation industry in these regions generated 2,769 direct jobs and 4,633 indirect jobs in these regions, and a further 1,225 indirect jobs elsewhere in New South Wales. This gave a total of 8,627 jobs generated from the softwood plantation industry in these two regions.
  - Similar studies report on indirect employment generated in 2017 by the forest sector in various Australian states and regions.
  - The estimation of indirect jobs by these studies uses multipliers to account for jobs induced by production and consumption effects, as well as broader employment categories, and thus the data are only indicative.

National data on forest sector employment presented in this indicator are derived from the Australian Bureau of Statistics (ABS) Census of Population and Housing, and are presented in four categories or subsectors: forestry and logging; forestry support services; wood product manufacturing; and pulp, paper and converted paper product manufacturing[346]. Employment in other subsectors, such as forest-based tourism, or management of forested national parks and reserves, is not captured here. Employment data are for all persons 15 years of age and over who, during the reference period: worked for at least one hour a week for pay, profit, commission or payment in kind; worked for one hour or more without pay in a family business or on a farm; or were employees who had a job but were not at work (ABS 2013b, 2016b). 'Full-time' refers to persons who usually worked 35 hours or more in a week; 'part-time' refers to persons who usually worked less than 35 hours in a week; and 'away from work' refers to persons who were employed but away from work and for whom hours worked were not reported.

Employment data for forest-dependent communities (including indirect forest employment) and Indigenous Australians are presented in Indicators 6.5c and 6.5d, respectively.

Direct employment in the forest sector

Total direct employment in the forest sector decreased between 2011 and 2016, both in the number of employees (from 68,596 to 51,983 persons, a 24% decrease) (Table 6.50, Figure 6.34) and as a proportion of total national employment (from 0.68% to 0.49%). This decline included a 24% fall in total full-time employment, from 56,087 persons in 2011 to 42,733 persons in 2016. Total part-time employment in the forest sector also fell during this period, by 23%, from 9,508 to 7,301 persons.

The key drivers for the reduction in total forestry sector employment were consolidation of processing into larger facilities with higher labour efficiencies, and restructuring of the sector. These drivers applied to both the wood product manufacturing subsector and the pulp, paper and converted paper product manufacturing subsector (Table 6.50; Schirmer 2018). Increased harvesting of plantation logs occurred (ABARES 2018), but does not necessarily create more processing activity if products are exported with minimal processing.

Table 6.50: Employment in forestry subsectors, 2006 to 2016

	Number of persons employed				
	Forestry and logging	Forestry support services	Wood product manufacturing	Pulp, paper and converted paper product manufacturing	Total forestry sector[a]
2006					
Full time	5,364	1,299	39,310	19,469	65,437
Part time	1,054	614	5,864	2,720	10,260
Away from work	458	139	2,138	1,292	4,021
Total	**6,871**	**2,050**	**47,310**	**23,479**	**79,720**
2011					
Full time	4,219	1,293	34,403	16,170	56,087
Part time	810	753	5,694	2,258	9,508
Away from work	372	116	1,575	934	2,996
Total	**5,399**	**2,168**	**41,670**	**19,364**	**68,596**
2016					
Full time	4,769	1,783	24,348	11,839	42,733
Part time	903	1,044	3,766	1,586	7,301
Away from work	355	127	922	540	1,946
Total	**6,027**	**2,957**	**29,035**	**13,962**	**51,983**

[a] Total national employment in the forestry sector includes a very small number of persons employed in external territories of Australia.

Notes: Total employment includes people employed in the sum of the following sectors: forestry and logging; forestry support services; wood product manufacturing; and pulp, paper and converted paper product manufacturing.

Total employment may be different from the sum of the three individual employment categories because the ABS randomly adjusts some small values published in the Census of Population and Housing to avoid release of confidential data.

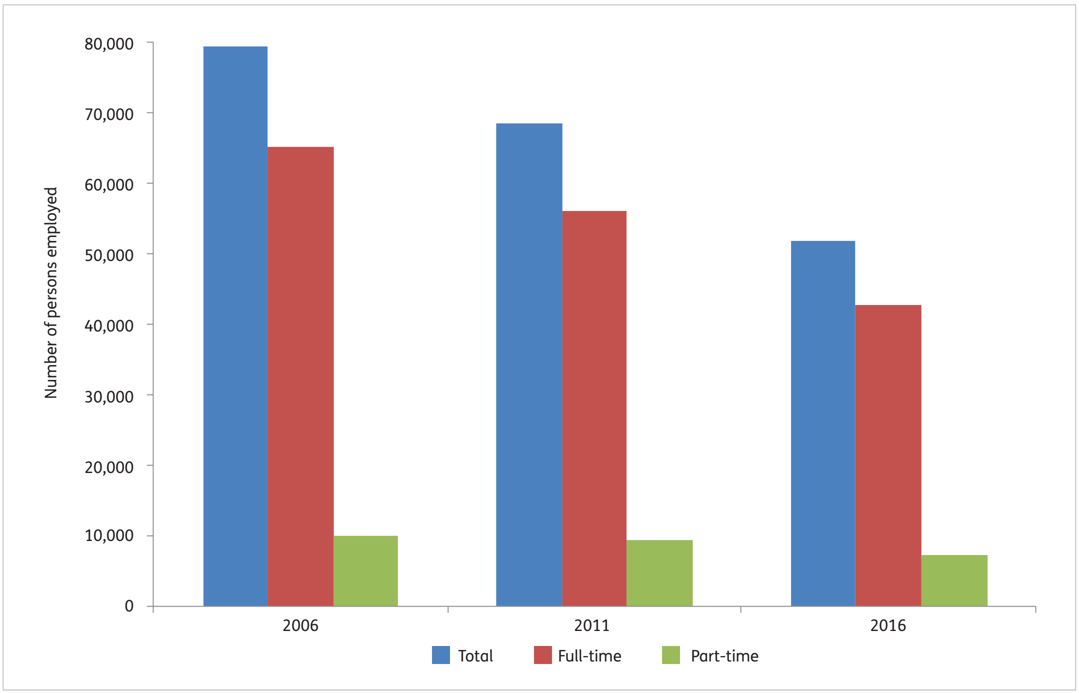
'Away from work' refers to persons who were employed but away from work and for whom hours worked were not given.

Source: ABS (2006, 2011, 2016b).

The data used to create this figure, together with other data for Indicator 6.5a, are available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

[346] These categories are from the Australian and New Zealand Standard Industrial Classification (ANZSIC) 2006 (Trewin and Pink 2006).

Figure 6.38: Total national employment in forest sector, by employment status, 2006 to 2016



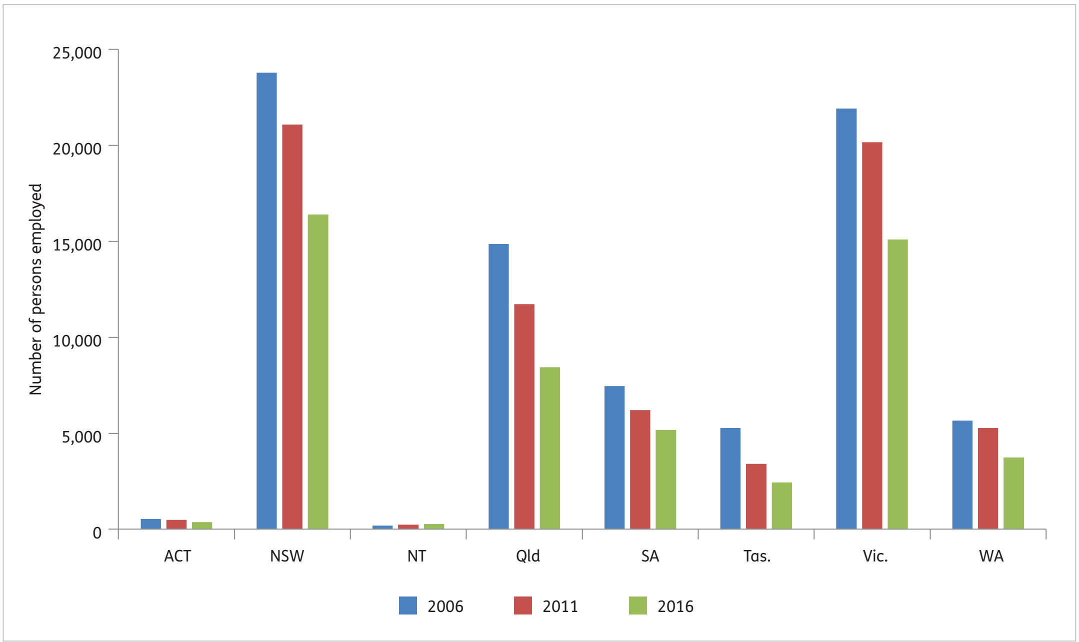
Notes: Total employment includes persons employed full-time and part-time in the following sectors combined: forestry and logging; forestry support services; wood product manufacturing; and pulp, paper and converted paper product manufacturing.

Total employment is higher than the sum of full-time and part-time employment because total employment also includes a relatively small number of persons employed but away from work (and did not state their number of hours worked). Table 6.50 shows the number of persons employed but away from work in 2006, 2011 and 2016.

Source: ABS (2006, 2011, 2016b).

The data used to create this figure, together with other data for Indicator 6.5a, are available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

Figure 6.39: Total employment in the forest sector, by jurisdiction, 2006 to 2016



Notes: Total employment includes persons employed full-time and part-time in the following sectors combined: forestry and logging; forestry support services; wood product manufacturing; and pulp, paper and converted paper product manufacturing.

Total employment is higher than the sum of full-time and part-time employment because total employment also includes a relatively small number of persons employed but away from work (and did not state their number of hours worked). Table 6.48 shows the number of persons employed but away from work in 2006, 2011 and 2016.

Source: ABS (2006, 2011, 2016b).

The data used to create this figure, together with other data for Indicator 6.5a, are available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

The number of persons directly employed in the forest sector decreased in all states and the Australian Capital Territory between 2011 and 2016 (Figure 6.39). The jurisdictions with the highest decreases in employment were Victoria (by 5,062 persons, down 25%), New South Wales (by 4,686 persons, down 22%) and Queensland (by 3,270 persons, down 28%). Proportional decreases in forest sector employment in the jurisdictions ranged between 17% (in South Australia) and 29% (in Western Australia and Tasmania). The Northern Territory was the only jurisdiction where employment increased over this period (from 241 to 278 persons, up 15%).

Direct employment in the forestry and logging subsector

The forestry and logging subsector includes businesses that grow and log timber in native and plantation forests. It also includes businesses that grow and harvest some non wood forest products.

Total employment in this subsector increased between 2011 and 2016, both in the number of employees (from 5,399 to 6,027 persons, a 12% increase) (Table 6.50) and as a proportion of total forest sector employment (from 8% to 12%). The number of persons employed both full-time and part-time increased during these years.

Direct employment in the forestry support services subsector

The forestry support services subsector includes businesses that provide silvicultural support services to forestry, such as planting, pruning and thinning trees, forest reafforestation, forest plantation conservation or maintenance; and that operate forestry planting stock nurseries.

Total employment in the subsector increased between 2011 and 2016, both in the number of employees (from 2,168 to 2,957 persons, a 36% increase) (Table 6.50) and as a proportion of total forest sector employment (from 3% to 6%). The number of persons employed both full-time and part-time increased during these years.

Direct employment in the wood product manufacturing subsector

The wood product manufacturing subsector includes businesses that manufacture rough-sawn timber and boards, woodchips, engineered wood products; and that re-saw or dress timber, timber boards and mouldings.

Total employment in the wood product manufacturing subsector decreased between 2011 and 2016, both in the number of employees (from 41,670 to 29,035 persons, a 30% decrease) (Table 6.50) and as a proportion of total forest sector employment (from 61% to 56%). The number of persons employed both full-time and part-time decreased during these years. The number of persons employed in this subsector fell by the most of any forest industry sub-sector, more than double the decrease in the pulp, paper and converted paper product manufacturing subsector.

The key drivers for the reduction in employment in the wood product manufacturing subsector were consolidation of processing into larger facilities with higher labour efficiencies, and restructuring of the subsector. More than half of the overall decrease in persons employed in this subsector between 2011 and 2016 can be attributed to a reduction in persons employed in businesses engaged mainly in manufacturing wooden structural fittings and components, such as finger-jointing, roof trusses, door and window frames.

Direct employment in the pulp, paper and converted paper product manufacturing subsector

The pulp, paper and converted paper product manufacturing subsector includes businesses that manufacture wood pulp; manufacture pulp from used paper, paper or paperboard; and manufacture paperboard containers and other paper-based products.

Total employment in the subsector decreased between 2011 and 2016, both in the number of employees (from 19,364 persons to 13,962 persons, a 28% decrease) (Table 6.50) and as a proportion of total forest sector employment (from 28% to 27%). The number of persons employed both full-time and part-time decreased during these years.

The key drivers for the reduction in employment in the pulp, paper and converted paper product manufacturing subsector were consolidation of processing into larger facilities with higher labour efficiencies, and restructuring of the subsector. More than half of the overall decrease in persons employed in this subsector between 2011 and 2016 can be attributed to a decrease in persons employed in businesses engaged mainly in manufacturing corrugated paperboard containers, sheeting or solid paperboard containers, and paper stationary.

Indirect forest employment

Indirect employment includes activities that are generated from direct employment in the forest sector. Examples are wholesale and retail trade; legal services; accounting; marketing and business services; motor vehicles; rail, pipeline and other transport services (parts, equipment, maintenance and repairs); electricity, gas and water supply; education; scientific research; technical and computer support; government administration; and media services. Limited data are available on indirect forest employment because of extensive cross-linkages with other sectors of the economy.

A study by Schirmer et al. (2018a) estimated employment generated directly and indirectly by the commercial softwood plantation industry in the South West Slopes and Central Tablelands regions of New South Wales in 2016. These two regions together represent around a quarter of Australia's commercial softwood plantation estate (Downham and Gavran 2018).

Employment data are derived from a survey of forest industry businesses operating in the two regions, the ABS 2016 Census of Population and Housing, and economic modelling.

Nangarin Timbers sawmill, Maryborough, Queensland, which closed in 2016 as part of the decline in sawmilling employment during the reporting period.

The direct employment categories used in the study are different from those used by the ABS. Direct employment includes employment generated up to the point of sale of primary processed products from softwood plantations, as well as by the wholesaling of these products. Indirect employment includes jobs generated as a result of the economic activity of the softwood plantation industry, and the estimation of indirect jobs uses multipliers to calculate jobs generated by production-induced and consumption-induced impacts[347], and thus the data are only indicative.

In the South West Slopes region in 2016, the softwood plantation industry generated 1,917 direct jobs and 3,458 indirect jobs, a total of 5,375 jobs. In the Central Tablelands region in 2016, the softwood plantation industry generated 852 direct jobs and 1,175 indirect jobs, a total of 2,027 jobs. The majority of direct jobs in both regions (66% in the South West Slopes and 73% in the Central Tablelands) were generated in the processing and wholesaling of wood and paper products.

The study also found that an additional 1,225 indirect jobs were generated elsewhere in New South Wales as a result of the softwood plantation industry in the South West Slopes and Central Tablelands regions. These jobs were generated from the demand for supplies and inputs (such as fuel and mechanical servicing), and from the spending of salaries and wages by industry workers. A total of 8,627 jobs were therefore generated in 2016 in New South Wales from the softwood plantation industry in the South West Slopes and Central Tablelands regions.

Studies using a similar methodology have also estimated employment generated directly and indirectly in 2017 by the forest industry in Queensland (Schirmer et al. 2018b), in Victoria (excluding the Green Triangle region[348]; Schirmer et al. 2018c), in Western Australia (Schirmer et al. 2017a) and the Green Triangle region (Schirmer et al. 2017b).

[347] Production-induced impacts are generated by businesses outside the forest industry that supply forest industry businesses. Consumption-induced impacts are generated when workers involved in the forest industry, and in businesses that supply the forest industry, spend their wages on goods and services (Schirmer et al. 2018a).

[348] A region that includes softwood and hardwood plantations in south-west Victoria and south-east South Australia.

Indicator 6.5b

Wage rates and injury rates within the forest sector

Rationale

This indicator measures the level of wage and injury rates in the forest sector. A sustainable industry will ensure high levels of workforce health with welfare and wage rates comparable with national averages for other occupations.

Key points

- Total wages and salaries in the forest sector varied between $4.0 and $4.3 billion between 2010–11 and 2015–16, driven mostly by changes in average wages in the pulp, paper and converted paper products subsector.
  - In 2015–16, the average annual wage in the forestry and logging subsector was $41,538. This is high compared with most other primary sectors, including agriculture, but low relative to the mining sector.
  - In 2015–16, the average annual wage in the wood product manufacturing subsector was $53,233. This is lower than in most other manufacturing sectors or subsectors.
  - In 2015–16, the average annual wages in the pulp, paper and converted paper product subsector was $94,125. This is at the upper end of wages across manufacturing sectors and subsectors.
- Between 2010–11 and 2014–15, the number of serious injury claims rose by 5% in the forestry and logging subsector (from 137 to 144), and fell by 25% in the wood and paper product manufacturing subsector (from 1,826 to 1,371).
  - Over this period, the incidence of serious injury claims per thousand employees also rose in the forestry and logging subsector, and fell in the wood and paper product manufacturing subsector.
  - From 2010–11 to 2014–15, there were four reported compensated fatalities in the forestry and logging subsector, and nine reported compensated fatalities in the wood and paper product manufacturing subsector.
  - A 2016 study on forestry work accidents in five industry partners of the Australian Forest Operations Research Alliance during the period 2004 to 2014 found that the total number of work accidents was 470, with the majority occurring in harvesting, transport and roading (176 accidents) and forest management (142 accidents).

National data on forest sector wage and salary rates presented in this indicator are derived from the Australian Bureau of Statistics, and are presented for three industry subsectors: forestry and logging; wood product manufacturing; and pulp, paper and converted paper product manufacturing. Estimates for the forestry support services subsector are not presented because of aggregation limitations within the source data.

This indicator also presents data derived from Safe Work Australia on injury and death rates in the forestry and logging subsector and the wood and paper product manufacturing subsector (which combines the wood product manufacturing subsector and the pulp, paper and converted paper product manufacturing subsector).

Wage rates

Estimates of wage rates were derived by dividing the total wages and salaries reported in a subsector by the number of full-time and part-time employees in that subsector. Wages and salaries include abnormal payments, such as severance, termination, redundancy and bonus payments, and provision expenses for employee entitlements, such as leave. They exclude payments to self-employed labourers such as consultants, contractors, and those working on commissions. Withdrawals of equity from a business by proprietors and partners are also excluded.

Total wages and salaries in the forest sector varied between $4.0 and $4.3 billion between 2010–11 and 2015–16 (Figure 6.40). Over this period, wages and salaries increased by 4% in the forestry and logging subsector and by 6% in the wood product manufacturing subsector, and fell by 1% in the pulp, paper and converted paper product manufacturing subsector by 1%.

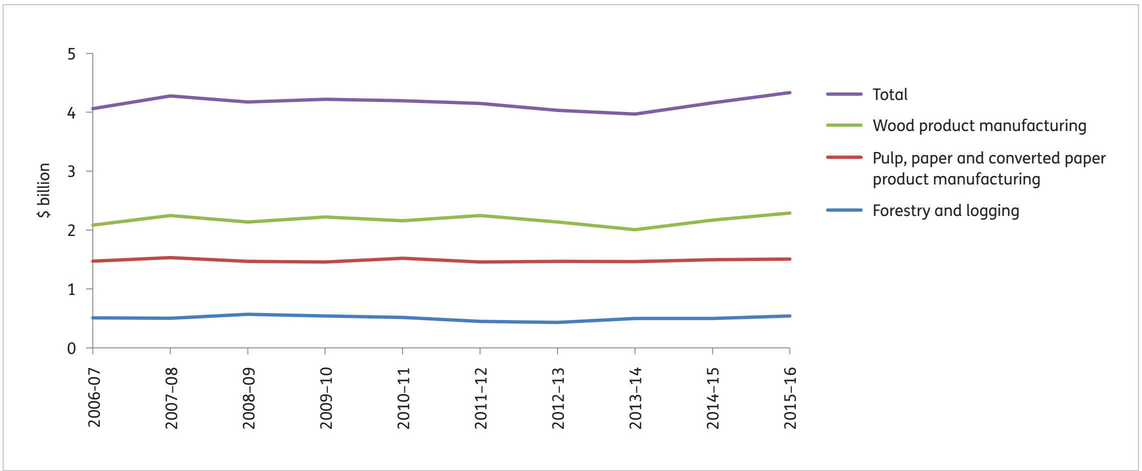
In 2015–16, the wood product manufacturing subsector constituted the largest component (53%) of total forest sector wages and salaries, while the pulp, paper and converted paper product manufacturing subsector comprised 35%, and the forestry and logging subsector 12%.

The estimated average annual wage for workers in the forestry and logging subsector increased from $34,467 to $41,538 (a 21% increase) between 2010–11 and 2015–16, and was higher than in most other agriculture, forestry and fishing sectors during this period (Figure 6.41; employment categories used for the inter-sectoral comparisons are shown in Box 6.2). By contrast, the estimated annual average wage in the mining industry increased from $117,893 to $154,043, by a higher proportion (31%) and from a much higher base.

Workers in agriculture had the lowest average wage relative to other primary sectors, due partly to the large part-time labour force that is typically recruited during harvesting seasons. The high average annual wage in the mining sector is due largely to the sector's location in remote areas of Australia – requiring higher wages to attract labour to the industry (Connolly and Orsmond 2011).

Figure 6.42 shows the estimated annual average wage in selected product manufacturing subsectors between 2006–07 and 2015–16. The estimated average annual wage in the wood product manufacturing subsector increased from $49,023 to $53,233 (by 9%) between 2010–11 and 2015–16, but was generally lower than in most other product manufacturing subsectors during this period. By contrast, the estimated annual average wage in the pulp, paper and converted paper product manufacturing subsector increased from $72,476 to $94,125 (by 30%) between 2010–11 and 2015–16, and in 2015–16 was the highest of all other reported subsectors.

Figure 6.40: Wages and salaries, forest sector, 2006–07 to 2015–16

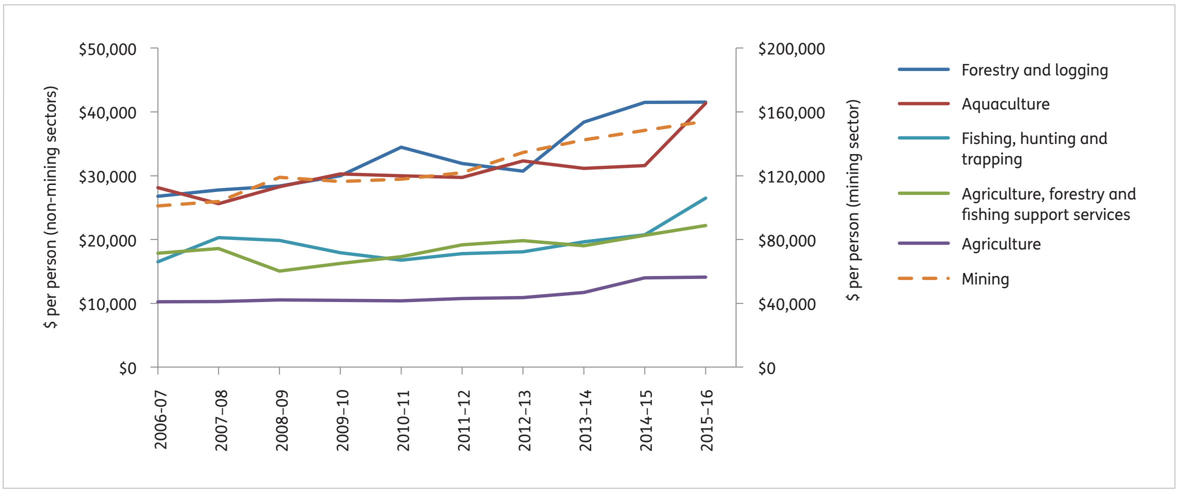


Notes: Estimates for the forestry support services subsector are not presented because of aggregation limitations within the source data. Employment categories are from the Australian and New Zealand Standard Industrial Classification (ANZSIC) 2006 (Trewin and Pink 2006) (see Box 6.2).

Source: ABS (2017b).

The data used to create this figure, together with other data for Indicator 6.5b, are available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

Figure 6.41: Annual wage per person, selected primary sectors, 2006–07 to 2015–16

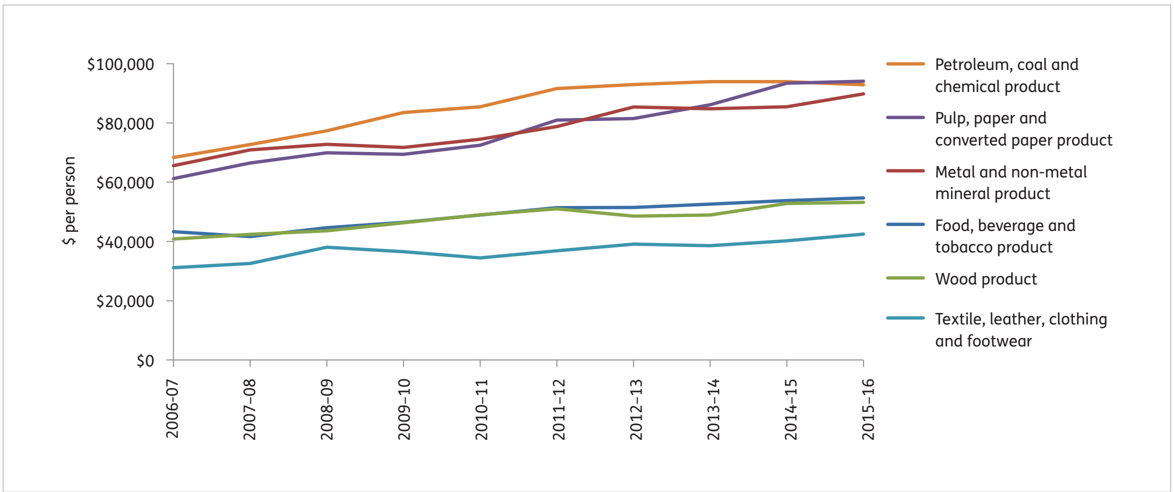


Notes: Employment categories are from the Australian and New Zealand Standard Industrial Classification (ANZSIC) 2006 (Trewin and Pink 2006); some categories are aggregated. Box 6.2 gives more detail of the forest sector-related categories.

Source: ABS (2017b).

The data used to create this figure, together with other data for Indicator 6.5b, are available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

Figure 6.42: Estimated annual wage, per person, selected product manufacturing sectors, 2006–07 to 2015–16



Notes: Employment categories are from the Australian and New Zealand Standard Industrial Classification (ANZSIC) 2006 (Trewin and Pink 2006); some categories are aggregated. Box 6.2 gives more detail of the forest sector-related categories.

Source: ABS (2017b).

The data used to create this figure, together with other data for Indicator 6.5b, are available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

Box 6.2: Forest-related employment categories used for the inter-sectoral comparisons

The following employment categories used in Figures 6.41 and 6.42 are slightly different to the employment categories used elsewhere in Indicators 6.5a-d.

Agriculture, forestry and fishing support services

This category refers to Division A, Subdivision 05 of the Australian and New Zealand Standard Industrial Classification (ANZSIC) 2006. It includes businesses that provide silvicultural support services to forestry, shearing services for livestock, and other agricultural and fishing support services, and businesses that operate forestry nurseries.

Forestry and logging

This category refers to Division A, Subdivision 03, of ANZSIC 2006. It includes businesses that mainly grow and log timber in native or plantation forests, or timber tracts; cut and/or roughly hew logs into products such as railway sleepers or posts; cut trees and scrubs for firewood; and gather forest products such as mushrooms and resin from forest environments.

Wood product manufacturing

This category refers to Division C, Subdivision 14, of ANZSIC 2006. It includes businesses that manufacture rough-sawn timber and boards; woodchips; prefabricated buildings; structural fittings and components (such as roof trusses and doors); veneers and plywood; wood boards and sheets from reconstituted wood fibres; laminated timber and non-timber materials; and businesses that re-saw or dress timber, timber boards and mouldings. It excludes businesses that manufacture timber used in furniture-making.

Pulp, paper and converted paper product manufacturing

This category refers to Division C, Subdivision 15, of ANZSIC 2006. It includes businesses that manufacture: wood pulp, pulp from used paper, paper or paperboard; paperboard containers; paper bags; paper stationery products; and sanitary paper-based products.

Businesses are classified according to their predominant activity, and can include government-owned and controlled entities such as government agencies.

The 2006 ANZSIC (Trewin and Pink 2006), was updated in 2013 (Pink and Welch 2013) with minor revisions but maintaining the scope, concepts and structure of the 2006 ANZSIC.

Injury rates

Injury and fatality rates in the forest sector reflect occupational health and safety standards, as well as the inherent danger of the forest sector.

Between 2010–11[349] and 2014–15, the number of serious injury claims rose in the forestry and logging subsector from 137 to 144 (a 5% increase) and fell in the wood and paper product manufacturing subsector from 1,826 to 1,371 (a 25% decrease) (Figure 6.43). Over the same period, the incidence of serious injury claims per 1,000 employees in the forestry and logging subsector increased marginally from 30.1 to 30.7, but decreased in the wood and paper product manufacturing subsector from 33.1 to 27.3.

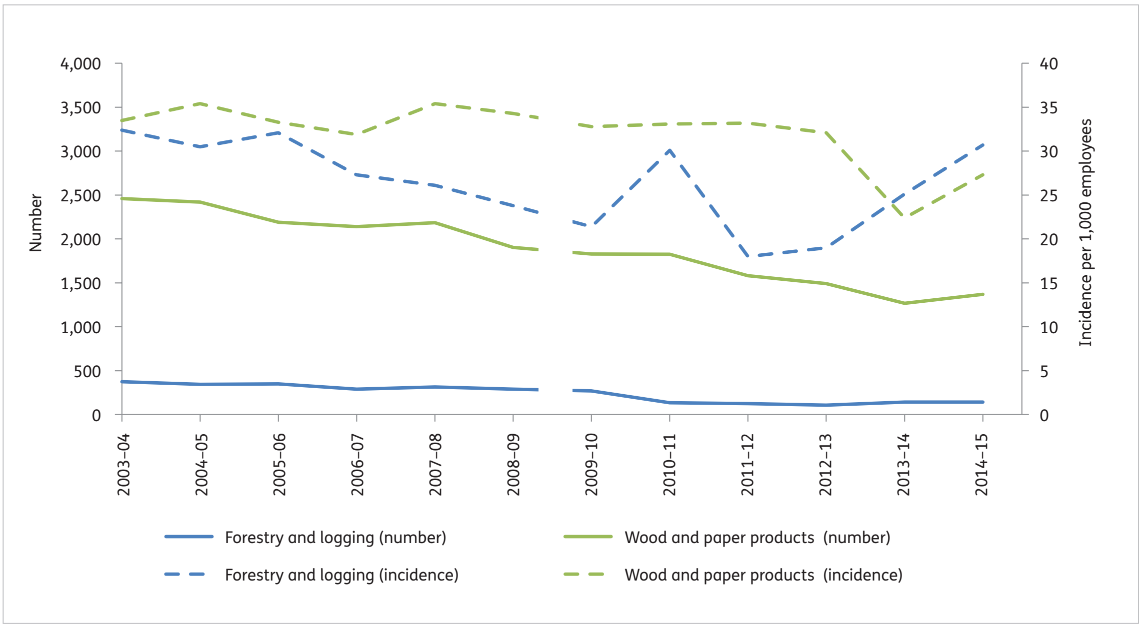
Between 2010–11 and 2014–15, there were four reported compensated fatalities in the forestry and logging subsector and nine in the wood and paper product manufacturing subsector (Figure 6.44). During the same period, the average incidence of compensated fatalities per 1,000 employees was 0.13 in the forestry and logging subsector, and 0.04 in the wood and paper product manufacturing subsector.

A study by Ghaffariyan (2016) reported on the frequency, type and root causes of work accidents that occurred within different forestry activities of five industry partners of the Australian Forest Operations Research Alliance during the period 2004 to 2014. The study found 470 work accidents during this 11-year period. The majority of accidents occurred in operational activities, such as harvesting, transport and roading (176 accidents), and forest management (142 accidents) (Table 6.51). Firefighting activities accounted for 38 accidents and 114 accidents occurred in other, unspecified forestry activities.

The main reported root causes of accidents were individual errors such as lack of personal protective equipment, operator error, poor body position, and application of poor techniques. Back and shoulder injuries were the most common. The study suggests that workers aged between 50 and 59 years have had a higher accident rate while workers older than 65 years had the lowest accident rate, although 51% of the incident reports did not record worker age.

[349] SOFR 2013 reports injury and fatality rates to 2009–10.

Figure 6.43: Serious injury claims, number and incidence per 1,000 employees, 2003–04 to 2014–15

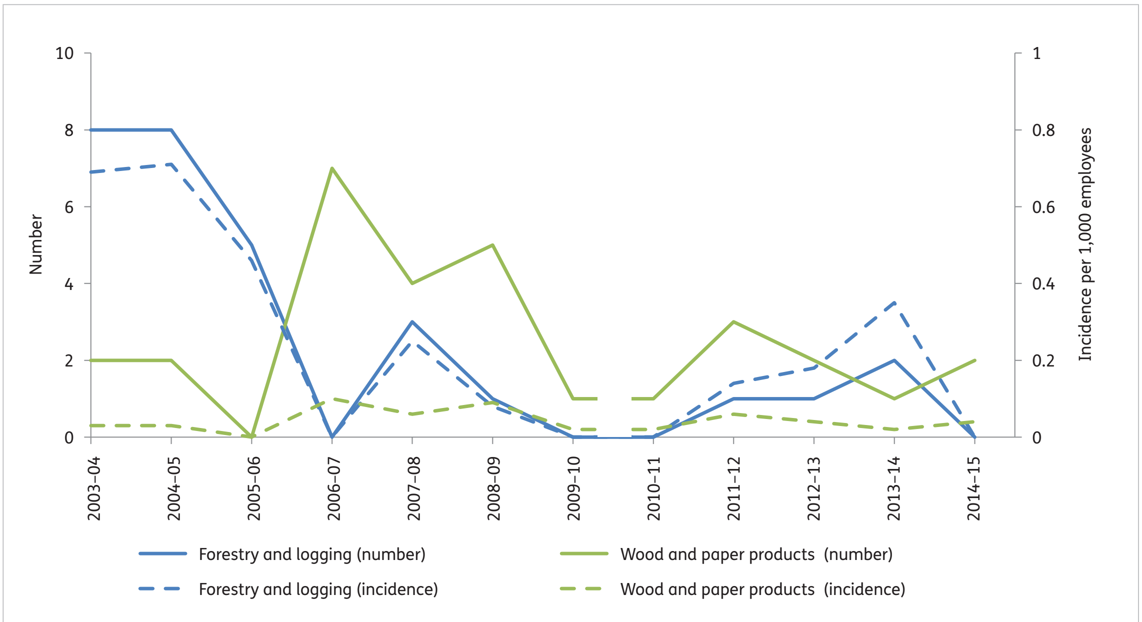


Notes: Data from 2003–04 to 2009–10 cannot be compared with data from 2010–11 to 2014–15 due to changes between those periods in both industry classification (i.e. differences between the 1993 and 2006 Australian and New Zealand Standard Industrial Classifications) and data collection. Wood and paper products includes wood product manufacturing and pulp, paper and converted paper product manufacturing.

Source: Calculated from data in Safe Work Australia (2010, 2011, 2012, unpublished).

The data used to create this figure, together with other data for Indicator 6.5b, are available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

Figure 6.44: Compensated fatalities, number and incidence per 1,000 employees, 2003–04 to 2014–15



Notes: Data from 2003–04 to 2009–10 cannot be compared with data from 2010–11 to 2014–15 due to changes between those periods in both industry classification (i.e. differences between the 1993 and 2006 Australian and New Zealand Standard Industrial Classifications) and data collection. Wood and paper products includes wood product manufacturing and pulp, paper and converted paper product manufacturing.

Source: Calculated from data in Safe Work Australia (2010, 2011, 2012, unpublished).

The data used to create this figure, together with other data for Indicator 6.5b, are available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

CRITERION 6

6.5b

Table 6.51: Work accidents by forestry activity, for five industry partners of the Australian Forest Operations Research Alliance, 2004–2014

Activity	Number of accidents	Proportion (%)
Forest management[a]	142	30
Operations[b]	176	37
Firefighting	38	8
Others	114	24
Total	**470**	**100**

[a] Includes activities such as silviculture, planting, nursery, planning, assessment, establishment and fertilisation.
[b] Includes harvesting, transport and roading.
Note: Totals may not tally due to rounding.
Source: Ghaffariyan (2016).

This table, together with other data for Indicator 6.5b, is available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

Indicator 6.5c

Resilience of forest dependent communities to changing social and economic conditions

Rationale

This indicator provides a measure of the extent to which forest dependent communities are able to successfully respond and adapt to change. Resilient forest dependent communities will adapt to changing social and economic conditions, ensuring they remain viable into the future.

Key points

- In 2016, there were 30 Local Government Areas (LGAs) rated as dependent on forest and wood products industries through having 2% or more of their working population and more than 20 workers employed in these industries. Five of these LGAs (two in New South Wales, three in South Australia) had 8% or more of their workforce employed in the forest and wood products industries.
  - Employment in forest and wood products industries declined in 21 of these 30 LGAs over the period 2011–16. With the exception of LGAs in Victoria, these declines were greater than the declines observed in total employment within each LGA.
  - Large proportional increases in forest and wood products industries employment were in LGAs in south-west Victoria (Glenelg) and northern Tasmania (George Town).
- Levels of community adaptive capacity (as represented by a combination of economic diversity, community wellbeing, and capital resources) varied considerably across the 30 LGAs rated as dependent on forest and wood products industries.
  - Levels of economic diversity varied considerably across these 30 LGAs, both between and within jurisdictions.
  - Three LGAs in Western Australia (Nannup, Manjimup and Bridgetown–Greenbushes) and two LGAs in Victoria (Alpine and Wangaratta) had higher scores for both community wellbeing and capital resources indices.
  - Three LGAs in Tasmania (Central Highlands, Dorset and Waratah/Wynyard) had lower scores for both community wellbeing and capital resources indices.
  - Bellingen (New South Wales) had a high score across all three indices of community adaptive capacity.
- In 2016, the median age of forest and wood products sector workers was from 40 to 50 years in 22 of the 30 LGAs dependent on forest and wood products industries.
  - There was a small increase in the median age of workers in the forest and wood products sector nationally between 2011 and 2016.
  - In eight LGAs dependent on forest and wood products industries, four of which were in Tasmania, the median age of workers in this sector was lower in 2016 than in 2011.
- Nationally, 54% of workers in the forest and wood products sector had non-school qualifications in 2016, compared with 65% in the total workforce. In 25 of the 30 LGAs dependent on forest and wood products industries, the proportion of workers in the forest and wood products sector with qualifications increased between 2011 and 2016.
- Nationally, 28% of households containing workers in the forest and wood products sector had weekly incomes below $800. This is slightly lower than the proportion for total workforce households.
  - The proportion of households with weekly incomes below $800 fell by more in the forest and wood products sector over the five years to 2016, than in the broader workforce.
- Communities with significant employment in Australia's forest and wood products industries thus continue to be exposed to structural changes in the sector, as well as to other influences on the local community. Changes in employment patterns, or changes in the level of employment dependence on a specific industry, can pose challenges for communities.

In a socio-economic context, the concept of resilience of a community is conceptualised and measured in different ways, sometimes interchangeably with adaptive capacity (ABARE-BRS 2010). Maguire and Cartwright (2008) clarify that resilience can occur in three different ways: as recovery, as stability and as transformation. The relationship between adaptive capacity and resilience is thus complimentary: increasing adaptive capacity will increase community resilience.

Recent industry trends that may affect communities dependent on the forest and wood products sector in Australia include changing patterns of harvesting native forests and plantations, consolidation in the sawmilling industry, and stronger export demands for processed wood products and resultant investment. The economic and social implications of these trends for such communities will depend on factors such as community size, structure, location and history. Some communities adapt to change through transformation and pursuing and taking opportunities, which enables them to 'bounce back' from stressors, adjust to unknown situations, or create a buffer against stressors through continual improvement. For other communities, change may have damaging long-term consequences (Australian Social Inclusion Board 2009).

In this indicator, a range of information is presented about the characteristics of communities and workers in the forest and wood products industries[350] that may affect their capacity to prevent, withstand, or mitigate threats resulting from changes in the industry upon which they depend. This information informs our understanding of resilience of forest-dependent communities to changing social and economic conditions.

The resilience of communities dependent on the forest and wood products sector is conceptualised in this indicator through:

- the degree of community dependence on forest and wood products industries
- community adaptive capacity, represented by a combination of:
  - economic diversity of industries that provide employment within the community
  - community wellbeing, depicting residents' confidence and perceptions about wellbeing and liveability in their community
  - the degree of social, human, financial, institutional, physical and natural capital resources available in the community.

Higher levels of economic diversity, community wellbeing, and capital resources can indicate greater adaptive capacity and resilience to industry change.

Selected characteristics that can contribute to the resilience to change at the level of individual workers are also presented.

[350] Forest and wood products industries are defined here using the Australian and New Zealand Standard Industrial Classification (ANZSIC) 2006 categories: forestry and logging; forestry support services; wood product manufacturing; and pulp, paper and converted paper product manufacturing. The forest and wood products sector is defined as the sum of these four categories.

[351] Local Government Areas (LGAs) are a suitable, small-scale geographic unit for reporting meaningful social data for the forest sector for a range of stakeholders including local governments (ABARES 2014). Nationally, there are 545 LGAs.

Dependence on forest and wood products industries

The proportion of people directly employed in an industry can indicate the level of a community's economic dependence on that industry. This indicator presents data on those directly employed in the forest and wood products industries. However, it is difficult to determine the economic dependence on forests resulting from other forest users such as apiarists, graziers, and ecotourism operators, and thus these activities are not considered in this indicator. Other business activities connected with forest and wood products industries, such as input suppliers, training providers, transport contractors and timber wholesale businesses, are also not considered.

Communities are considered to be dependent on the forest and wood products industries when direct employment in the sector is at least 2% of total workforce employment, and the community contains more than 20 workers employed in these industries. The threshold employment proportion has been reduced from the value of 4% used in SOFR 2013 so as to detect changes in more communities.

Table 6.52 shows the characteristics of the 30 Local Government Areas[351] (LGAs) that were dependent on the forest and wood products industries, as well as changes since 2001. In 2016, there were five LGAs where 8% or more of the workforce were employed in forest and wood products industries (Snowy Valleys and Oberon in New South Wales, and Mount Gambier, Wattle Range and Grant in South Australia). SOFR 2013 presented economic dependence for Statistical Local Areas, which are different geographic units to the LGAs reported here.

Figure 6.45 shows the location of the LGAs that were dependent on the forest and wood products industries, together with the locations of National Plantation Inventory (NPI) regions. The NPI regions indicate major regions of the commercial plantation estate, and can also indicate major centres of employment in the wider forestry sector.

In 2016, nationally 83% of workers in the forest and wood products sector were employed in the combined wood product manufacturing industry and pulp, paper and converted paper product manufacturing industry, 12% were employed in forestry and logging industry, and another 6% in the forestry support services industry (ABS 2016b). National forestry sector employment levels are also reported in Indicator 6.5a.

While total employment rose nationally from 2011 to 2016, total employment declined in 25 of the 30 LGAs dependent on forest and wood products industries. In 21 of these 30 LGAs, employment in forest and wood products industries also declined over this period. The decline in forest and wood products industries employment was more than 20% in eight LGAs, with the largest proportional reductions in LGAs in Tasmania. In four LGAs in Victoria employment in forest and wood products industries increased from 2011 to 2016, although total employment declined. Large proportional increases in forest and wood products industries employment occurred in south-west Victoria (Glenelg) and northern Tasmania (George Town).

Table 6.52: Characteristics of Local Government Areas dependent on forest and wood products industries

Local Government Area	Number of people employed in forest and wood products industries, 2016	Proportion of workforce employed in forest and wood products industries, 2016 (%)	Change in forest and wood products industries employment (%)[a]			Change in total employment (all industries) (%)	Adaptive capacity (2016)		
			2001–06	2006–11	2011–16	2011–16	Economic diversity index[b]	Community wellbeing index[c]	Capital resources index[d]
New South Wales									
Snowy Valleys	903	15.84	-2.3	-4.3	1.7	-7.0	0.44	0.72	0.55
Oberon	320	15.24	8.7	-9.2	-16.9	-7.0	0.47	0.75	0.60
Kyogle	92	2.99	-46.6	14.4	-31.9	-8.1	0.45	0.72	0.57
Clarence Valley	400	2.37	15.6	-12.1	-29.5	-3.0	0.88	0.72	0.57
Bellingen	97	2.06	-31.4	1.0*	-8.5*	1.3	0.85	0.80	0.57
Northern Territory									
West Arnhem	27	2.04	-100.0*	–	-12.9*	-36.1	0.46	0.70	0.53
Queensland									
Gympie	627	3.76	-0.1*	-10.4	-14.0	-1.5	0.81	0.71	0.54
South Australia									
Mount Gambier	1143	10.18	-3.3	-20.1	-6.5	-0.1	0.86	0.72	0.53
Wattle Range	456	9.40	-8.7	-33.1	-16.9	-7.4	0.35	0.80	0.54
Grant	333	8.91	-0.7*	-15.9	-8.5	-2.9	0.37	0.80	0.54
Tasmania									
Dorset	173	7.09	2.3*	-51.9	-20.3	-5.6	0.30	0.67	0.51
Derwent Valley	212	5.77	0.6*	-28.3	-15.5	-1.4	0.85	0.73	0.55
George Town	96	4.64	-25.9	7.9*	41.2	-12.3	0.72	0.69	0.53
Circular Head	144	4.18	14.9	-17.9	-38.5	-4.2	0.30	0.78	0.54
Central Highlands	27	3.43	-14.0*	-22.4	-28.9	-2.6	0.19	0.66	0.49
Huon Valley	141	2.30	-5.9	14.1	-40.0	1.2	0.61	0.73	0.55
Waratah/Wynyard	112	2.19	0.4*	-59.3	19.1	-8.1	0.77	0.68	0.51
Victoria									
Alpine	239	4.53	-20.6	-20.7	-2.4*	0.8	0.76	0.85	0.60
Latrobe	1189	4.19	11.0	-14.6	-4.9	-4.0	0.75	0.62	0.54
Colac–Otway	378	4.14	4.6	8.8	2.4*	-1.8	0.63	0.79	0.58
Benalla	178	3.29	-29.9	2.1*	-8.2	-8.2	0.77	0.72	0.58
Wellington	443	2.58	43.7	3.9	9.9	-1.9	0.64	0.74	0.56
Glenelg	190	2.40	-10.4	-55.8	52.0	-7.7	0.58	0.73	0.55
Wangaratta	253	2.09	-9.9	-9.1	9.5	-2.1	0.83	0.83	0.63

Continued

Continues

Local Government Area	Number of people employed in forest and wood products industries, 2016	Proportion of workforce employed in forest and wood products industries, 2016 (%)	Change in forest and wood products industries employment (%)[a]			Change in total employment (all industries) (%)	Adaptive capacity (2016)		
			2001–06	2006–11	2011–16	2011–16	Economic diversity index[b]	Community wellbeing index[c]	Capital resources index[d]
Western Australia									
Nannup	38	7.25	110.3	-11.5*	-29.6	-10.0	0.44	0.83	0.61
Manjimup	274	6.85	-43.9	-22.7	0.4*	-4.4	0.39	0.83	0.61
Bridgetown–Greenbushes	58	3.14	-7.0*	-30.1	-37.6	-3.1	0.53	0.83	0.61
Donnybrook–Balingup	66	2.75	13.4	-23.7	-7.0*	0.2	0.48	0.76	0.57
Dardanup	135	2.18	36.8	-17.5	2.3*	3.6	0.78	0.76	0.57
Wyndham–East Kimberley	66	2.15	106.3	127.3	-12.0*	-14.9	0.73	0.71	0.56
Australia[e,f]	**51,983**	**0.51**	**-3.4**	**-14.0**	**-24.2**	**3.9**	**1.0**	**0.75**	**0.55**

–, not calculated as previous value zero

* Change of 10 or fewer individuals.

a 2001, 2006 and 2011 data have been adjusted to align with 2016 LGA boundaries.

b The economic diversity index is calculated from ABS census data and measures the variety of employment sectors in an LGA on a scale between 0.0 and 1.0, with a score of 1.0 indicating the same diversity as the Australian economy (high diversity). Economic diversity index cannot be aggregated above LGA scale.

c Community wellbeing index scores from 2016 Regional Wellbeing Survey datasets rescaled to between 0.0 (relatively low wellbeing) and 1.0 (relatively high wellbeing).

d Capital resources index constructed by ABARES from 2016 Regional Wellbeing Survey data by averaging the scores under financial capital, human capital, institutional capital, social capital, physical capital and natural capital, for each LGA or region including the LGA (see Table 6.53). A score of 0.0 indicates relatively low capital and a score of 1.0 indicates relatively high capital.

e All LGAs in Australia, not just those dependent on forest and wood products industries.

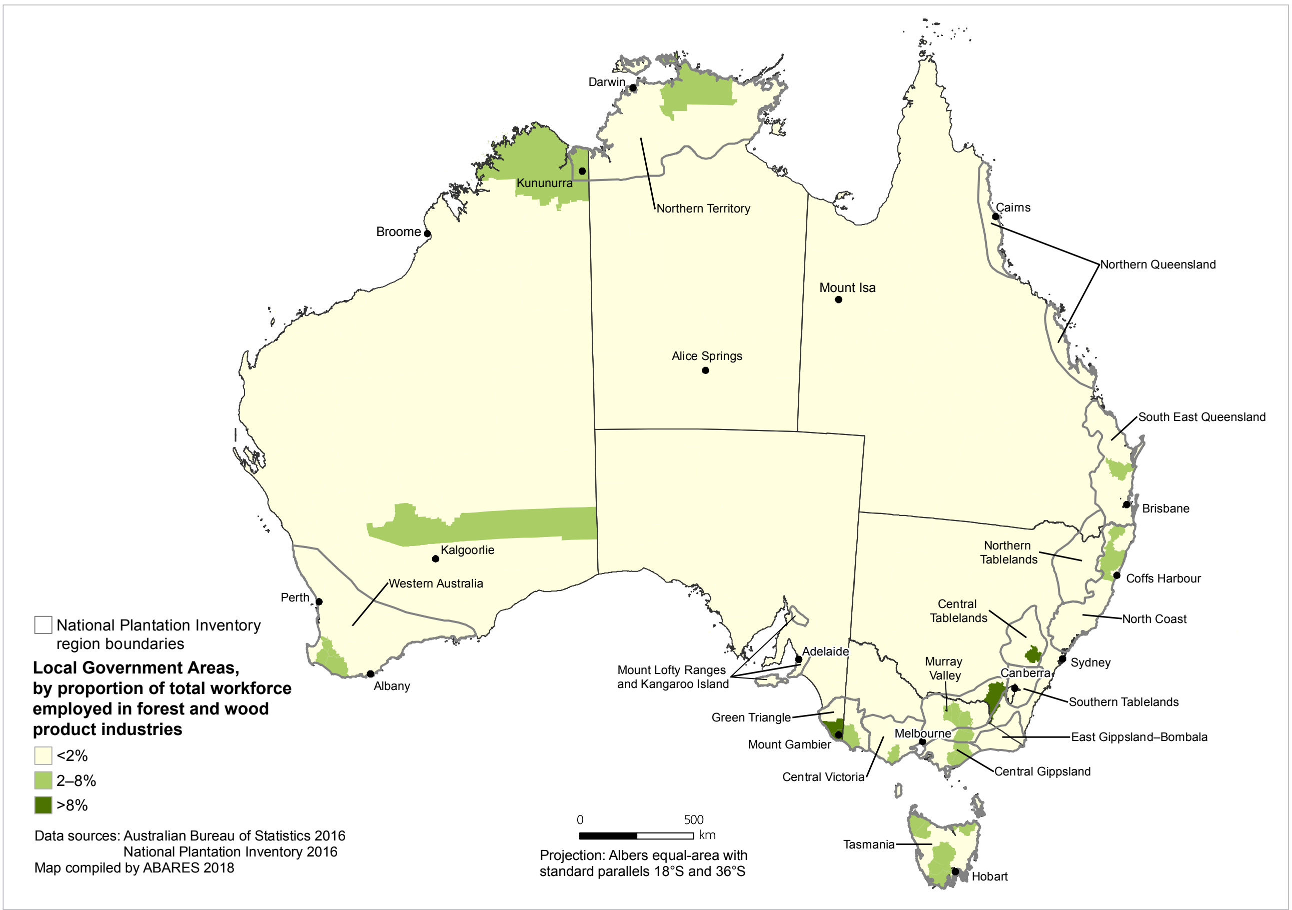
f Employment changes for 2001–06 and 2006–11 differ to those reported in SOFR 2013 because of a change in industry classification for the forest sector.

Notes: Local Government Areas (LGAs) are considered to be dependent on the forest and wood products industries when direct employment in the sector is at least 2% of total workforce employment, and the community contains more than 20 workers employed in these industries. The Australian Capital Territory is not listed because employment in forest and wood products industries is below 2% of total workforce employment (there are no LGAs within the ACT).

Source: ABARES calculations based on ABS (2016b), ABS Customised reports on census data for 2001, 2006, 2011 and 2016, and 2016 Regional Wellbeing Survey data tables (www.canberra.edu.au/research/faculty-research-centres/ceraph/regional-wellbeing/survey-results/2016-survey-results/2016-results-by-rda-and-lga).

This table, together with other data for Indicator 6.5c, is available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

Figure 6.45: Local Government Areas, by proportion of the total workforce employed in forest and wood products industries, 2016



Note: map shows all National Plantation Inventory regions and LGAs with 2% or more of the total workforce employed in forest and wood products industries, regardless of the number of individual workers in these industries in the LGA. Two mapped LGAs (Menzies in Western Australia, and Belyuen in Darwin, Northern Territory) have 20 or less workers in these industries.

Source: ABS (2016b).

A higher resolution version of this map, together with other data and maps for Indicator 6.5c, is available via www.doi.org/10.25814/5be3bc4321162

Community resilience

Community resilience is difficult to measure quantitatively, but measures of community adaptive capacity can be used as a proxy for community resilience. Three quantitative indices are used to represent the degree of adaptive capacity within a community: economic diversity, community wellbeing, and capital resources (see Box 6.3). The indices use employment data from the 2016 Australian Bureau of Statistics Census of Population and Housing (ABS CPH), and community wellbeing and capital resources data from the 2016 Regional Wellbeing Survey.

Communities are likely to be more resilient, adaptive (to change) and healthy if they have a strong economy, good access to services and infrastructure, positive social inclusion, strong institutions and governance, and positive leadership (Kais and Islam 2016; Schirmer et al. 2016). The diversity of employment sectors in a local economy is a useful indicator of the potential in a community to respond to change in one specific sector (see Box 6.3). If the forest and wood products sector sits alongside a diversity of other economic activities, this can provide communities with a more even and secure growth trajectory (Ministry for Primary Industries 2015). Economic diversity is a common component in, and one of the most influential parts of, adaptive capacity metrics that combine population information to compare communities (Productivity Commission 2017; Stenekes et al. 2012).

Resilient communities have sufficient assets and resources to facilitate their coping capacity in the short and long term (Kais and Islam 2016). Having access to the types of resources that support and positively influence wellbeing, resilience and adaptive capacity, is commonly called 'capital' – financial, human, social, physical, natural and institutional (Schirmer et al. 2016). These types of capital describe the resources that people and communities can draw on, use and transform, to achieve positive wellbeing outcomes, and hence these types of capital can also be referred to as 'determinants of wellbeing' (Schirmer et al. 2016).

Some determinants of wellbeing are more difficult to measure with census data, and surveys can provide another perspective of the experiences of residents of their local context. Good levels of the above resources can, in turn, lead residents to have a more positive view of wellbeing in their community, and its 'liveability' (Schirmer et al. 2016). A subjective index of

Box 6.3: Indicating resilience – community adaptive capacity

Economic diversity

Economic diversity is the variety of employment sectors in a local economy relative to the Australian economy. High economic diversity provides multiple income streams to a local economy and alternative employment for displaced workers, thereby potentially increasing community resilience to changes in the industry on which they depend. An Economic Diversity Index (Hachmann Index; for details see Stenekes et al. 2012) utilises data from the 2016 ABS CPH to generate scores that show diversity of employment across sectors within a location relative to that for Australia. Areas that are more economically diverse, where people are employed across more industries, are likely to be in a better position to respond to change than are less diverse areas.

Community Wellbeing Index

Community wellbeing is measured in the annual Regional Wellbeing Survey, conducted by the Centre for Research and Action in Public Health, University of Canberra, ACT. The Community Wellbeing Index is a combination of responses to five survey questions asked of residents of rural and regional Australia about liveability, in terms of how attached and positive they feel about their community and how it supports their quality of life. These questions include how well they think their local community copes with challenges, and their confidence in the future of their community. The index provides a collective measure of community wellbeing that can be compared across other areas (Schirmer et al. 2016).

Capital Resources Index

This is a composite index of the capital resources to which residents in a community have access and can draw upon to respond to change and achieve positive wellbeing outcomes. The index combines sub-components of the Regional Wellbeing Survey that measure residents' views on income and living costs (financial capital); personal health, psychological distress, and community leadership (human capital); equity and inclusion (institutional capital); volunteering rates and belonging (social capital); access to education, professional and telecommunications services (physical capital); and environmental health (natural capital). The detailed composition of these subcomponents is shown in Table 6.53.

Table 6.53: Components and measures of capital resources index

Capital resources index sub component	Measures
Financial	Household financial wellbeing; financial distress*; community economic wellbeing
Human	General health; self-efficacy; psychological distress*; community leadership and collaboration
Institutional	Having a say; equity and inclusion
Social	Spending time with friends and family; getting involved; regularly volunteer; sense of belonging
Physical	Access to health, education, aged care and child care; Access to transport; Access to food and retail shops; Access to financial and professional services; Access to telecommunications; Crime and safety; Landscape and aesthetics
Natural	Perceived environmental health

* The negative of the score for psychological distress was used in the sum of scores.

Questions used to score each measure are given in www.canberra.edu.au/research/faculty-research-centres/ceraph/regional-wellbeing/survey-results/2016-survey-results/2016-results-by-rda-and-lga community wellbeing can be used to report on the confidence of residents in a community's resilience and its future, to help understand adaptive capacity (see Box 6.3).

Of the 30 LGAs dependent on forest and wood products industries, several LGAs (Central Highlands, Dorset and Waratah/Wynyard in Tasmania, and Latrobe in Victoria) had relatively low community wellbeing scores in 2016, while other LGAs (Nannup, Manjimup and Bridgetown–Greenbushes in Western Australia, and Wangaratta and Alpine in Victoria) had higher wellbeing scores (Table 6.52). This reflects that wider influences affect wellbeing, and that wellbeing is not linked solely to employment in one sector.

The level of capital resources perceived by residents at community scale appears relatively low in several LGAs in Tasmania, in Mount Gambier (South Australia), and West Arnhem (Northern Territory). This compares with higher levels of perceived capital resources in Wangaratta and Alpine (central Victoria), Nannup, Manjimup and Bridgetown–Greenbushes (south-west Western Australia), and Oberon (New South Wales).

Across the three measures combined in this indicator to depict community adaptive capacity (Box 6.3), the LGAs of Central Highlands, Dorset and Waratah/Wynyard (Tasmania) had the lowest scores, while Wangaratta and Alpine (Victoria) and Bellingen (New South Wales) had the highest scores (Table 6.52).

Box 6.4: Individual forest industry workers – resilience

Factors that influence the individual resilience of workers can include their age, level of education and qualifications, skills and financial position.

Older workers may face greater difficulty in adapting to change. They may find it more difficult to find alternative employment, and lack the mobility to take advantage of opportunities in other geographic locations.

Measures of educational attainment and ability to meet living costs have been positively correlated with subjective wellbeing measures of life satisfaction and health in surveys of forest and wood products workers (Binks et al. 2014). A worker's skill set will also influence their ability to secure alternative employment; unskilled workers may find fewer opportunities for employment.

Equivalised household income (income to enable comparison between households of differing size and composition) is an indicator of financial position that enables comparision between different sized households. It is likely to be a better indicator of the overall ability of workers to meet living costs than individual income.

Worker characteristics

Changes in forest and wood products industries may affect workers at a personal level. An individual's ability to adapt to change is difficult to quantify and can be independent of the situation in the broader community. Table 6.54 presents selected characteristics of individual workers in forest and wood products industries that could contribute to their ability to adapt to change, using ABS CPH data (see Box 6.4).

In 2016, the median age of forest and wood products sector workers was from 40 to 50 years in 22 of the 30 LGAs dependent on forest and wood products industries (Table 6.54). There was a small increase in their median age nationally between 2011 and 2016. In eight LGAs dependent on forest and wood products industries, four of which were in Tasmania, the median age of forest and wood products sector workers was lower in 2016 than in 2011 (Table 6.54).

Qualifications and formal skills recognition can increase opportunities for workers. Nationally, 54% of forestry workers had non-school qualifications in 2016, compared with 65% in the total workforce. However, in 25 of the 30 LGAs dependent on forest and wood products industries, the proportion of forestry workers with qualifications increased between 2011 and 2016 (Table 6.54).

Workers with lower household incomes and in unskilled occupations may have fewer financial resources to assist them to meet living costs or adapt to change. Nationally, the proportion of forest sector worker households with weekly incomes below $800 was slightly lower (28%) than in total workforce households. The proportion fell by more in the forest sector over the five years to 2016, than in the broader workforce (Table 6.54). In 2016, the West Arnhem LGA (Northern Territory) had the highest proportion of forest sector households with relatively low household incomes. In many LGAs of high dependence on forest and wood products industries, more than 20% of workers in this sector were employed in unskilled jobs in 2016; the proportion nationally was similar in 2016 to 2011.

Table 6.54: Forestry worker characteristics in Local Government Areas dependent on forest and wood products industries, 2011 and 2016

	Median age (years)		Workers with non-school qualification[b]		Unskilled workers[c]		Weekly household income <$800[d]	
Local Government Area[a,b]	2016	2011	2016 (%)	Change 2011–16 (%)	2016 (%)	Change 2011–16 (%)	2016 (%)	Change 2011–16 (%)
New South Wales								
Snowy Valleys	44	42	53.9	5.1	18.2	-2.2	21.0	-16.3
Oberon	42	40	48.8	8.5	20.3	-5.2	26.4	-12.8
Kyogle	49	45	48.9	10.4	39.1	-3.0	62.5	-4.5
Clarence Valley	44	41	39.3	6.3	31.6	-4.5	48.5	-15.0
Bellingen	49	48	32.0	2.7	40.6	9.5	50.0	-11.0
Northern Territory								
West Arnhem	29	–	22.2	2.9	0.0	0.0	100.0	0.0
Queensland								
Gympie	45	44	49.4	7.9	28.7	0.8	31.9	-12.6
South Australia								
Mount Gambier	43	42	47.3	2.9	20.5	0.1	24.3	-14.4
Wattle Range	48	45	39.7	4.4	19.8	-6.3	17.6	-12.4
Grant	47	45	47.7	2.1	19.6	-0.1	26.0	-11.0
Tasmania								
Dorset	40	41	39.9	-1.1	24.9	-2.8	41.7	-16.5
Derwent Valley	46	45	43.4	4.0	18.8	-4.0	23.4	-12.5
George Town	37	33	31.3	-7.0	27.1	2.1	38.8	-14.1
Circular Head	34	42	34.0	12.7	27.3	-12.7	44.3	-15.9
Central Highlands	44	48	14.8	-16.8	37.0	12.7	53.3	-4.7
Huon Valley	45	41	36.2	3.0	25.2	-17.6	48.2	-13.8
Waratah/Wynyard	41	49	42.0	-5.9	24.3	-0.1	36.5	-15.5
Victoria								
Alpine	46	47	47.7	6.1	20.7	-11.9	35.1	-13.4
Latrobe	46	45	58.6	5.1	22.0	-0.4	14.2	-10.9
Colac–Otway	41	37	47.1	10.8	25.0	-4.4	31.1	-23.4
Benalla	40	39	43.3	5.1	18.4	-0.1	38.3	-16.9
Wellington	38	41	45.1	9.7	33.2	-6.7	32.4	-16.6
Glenelg	36	49	46.8	16.4	20.3	-9.8	28.0	-26.6
Wangaratta	45	39	49.4	-1.7	20.8	3.0	36.1	-13.6
Western Australia								
Nannup	62	54	23.7	-11.5	47.4	-11.9	31.6	-34.3
Manjimup	50	46	35.0	2.1	29.3	-3.8	27.5	-18.5
Bridgetown–Greenbushes	52	49	22.4	-7.7	26.7	-14.2	27.1	-25.5
Donnybrook–Balingup	56	52	51.5	13.5	9.1	-17.4	14.0	-27.3
Dardanup	47	45	43.7	5.1	13.4	-3.6	20.9	-12.7
Wyndham–East Kimberley	48	50	59.1	11.1	15.2	-6.2	6.3	-11.7
Australia (forest workers)[e]	**43**	**41**	**54.3**	**4.9**	**16.8**	**0.5**	**28.5**	**-12.7**
Australia (all workers)[f]	**40**	**40**	**65.3**	**6.4**	**9.4**	**0.0**	**29.9**	**-7.7**

–, insufficient data

a Based on 2016 LGA boundaries. Data for 2011 have been adjusted to align with 2016 LGA boundaries.

b Proportion of workers holding a qualification at the level of certificate, diploma or advanced diploma, bachelor's degree, graduate certificate, graduate diploma or postgraduate degree.

c Proportion of workers who identified their occupation as 'labourer'.

d Proportion of forest and wood products sector worker households with equivalised household income below $800 per week. Equivalised household income is household income data adjusted by the ABS to enable comparison between households of differing size and composition. $800 is used as the closest comparison point to the median Household Equivalised Weekly Income for Australia of $877 in 2016, and $790 in 2011.

e All LGAs in Australia, not just those dependent on forest and wood products industries.

f All LGAs in Australia, not just those dependent on forest and wood products industries, and all industries (whole-of-workforce), not just forest and wood product industries.

Notes: Local Government Areas (LGAs) are considered to be dependent on the forest and wood products industries when direct employment in the sector is at least 2% of total workforce employment, and the community contains more than 20 workers employed in these industries. The Australian Capital Territory is not listed because employment in forest and wood products industries is below 2% of total workforce employment (there are no LGAs within the ACT).

Source: ABARES calculations based on ABS (2016b) and ABS Customised reports on census data for 2011 and 2016.

This table, together with other data for Indicator 6.5c, is available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

Indicator 6.5d

Resilience of forest dependent Indigenous communities to changing social and economic conditions

Rationale

This indicator provides a measure of the extent to which forest dependent Indigenous communities are able to respond and adapt to change successfully. Resilient forest dependent Indigenous communities will adapt to changing social and economic conditions, ensuring they prosper into the future.

Key points

- Australia's Indigenous peoples have a deep connection to their ancestral landscapes, which forms a core part of their sense of wellbeing. Access to native forests enables Indigenous people to maintain or re-connect with cultural values, strengthening their connection with their community, the land and their past. This strengthens personal and community resilience.
- Forest-related employment that draws on traditional activities and knowledge delivers cultural and economic benefits. Key examples include the Indigenous ranger program that is part of the Australian Government's Working on Country initiative, and the legislative requirement for land developers to carry out cultural heritage assessments, including on land involving forests or forestry activities.
  - An estimated 337 Indigenous people are employed in conservation or park operation roles nationally in areas with forested conservation reserves.
- Participation of Indigenous workers in the forest and wood products industries can be used as an indicator of economic dependence on forests. Employment connected with forests can support livelihoods through income, skills development, and a connection with forests through services and advice, which can contribute positively to resilience.
  - In 2016, the forest and wood products industries directly employed 1,099 Indigenous people nationally.
  - In seven Indigenous Locations across Australia, more than 10% of the Indigenous workforce was employed in the forest and wood products industries.
  - Of Indigenous people directly employed in the forest and wood products industries nationally in 2016, 61% were employed in the wood product manufacturing and the pulp, paper and converted product manufacturing industries, 26% were employed in the forestry support services industry, and 13% were employed in the forestry and logging industry.

Indigenous people and communities in Australia include both Aboriginal people and communities and Torres Strait Islander people and communities.

Many Indigenous people place strong cultural significance on native forests, including activities that occur on forested land. This strengthens their cultural identity, and their connection with the land and their past (Feary 2007). Cultural dependence on forests is particularly strong when the forest involves country for which a particular Indigenous community has customary responsibility (Ganesharajah 2009). Relatedness to kin and country is embedded in complex sets of obligations that are laid out by Indigenous law and customs. The land and the associated environment therefore underpin practices that are laden with meaning and that facilitate social interactions relating to personhood, body, property, knowledge, economy and ecology (Kerins and Green 2018). The deep connection of Indigenous peoples to their ancestral landscapes therefore stands central to their wellbeing, and revolves around cultural, physical, social, spiritual and emotional elements (Kingsley et al. 2013).

Indigenous people may therefore define resilience differently than commonly occurs through the lens of a more western worldview. The latter often has at its core sustaining livelihoods through employment opportunities and income-generating activities. Instead, Indigenous communities may place high value on cultural resilience, which encompasses the capacity of a particular cultural system to absorb disturbance and re-arrange under change in order to maintain key components of the structure and identity of the particular cultural system (Healy 2006; Kerins and Green 2018). Maintaining livelihoods for Indigenous people thus often includes both tangible economic activities and intangible social and cultural dimensions (Kerins and Green 2018).

The land area managed under the Indigenous estate represents a measure of the opportunities for strengthening both cultural and economic benefits (see Indicators 6.4a and 6.4c). Over the reporting period, the opportunities for Indigenous communities to use native forests have increased as a result of increased formal recognition of native title, land rights legislation and other processes (Indicators 6.4a and 6.4c). A total of 22.9 million hectares of forest are classified as 'Indigenous owned and managed' or 'Indigenous managed', and 5.7 million hectares of forest are classified as 'Indigenous co-managed' (Indicator 6.4a). A further 40.9 million hectares of forested land is classified as 'Other special rights', which includes native title determinations and Indigenous land use agreements. Successful native title claims can contribute considerably to the social and economic wellbeing of Indigenous communities, as these claims confer land access and usage rights. However, the value that Indigenous people place on the different benefits they may derive from forests may vary depending on the local context, and the connections and values of each community.

As described in Indicator 6.5c, no single measure for resilience is possible, and measuring cultural and social aspects is complex. Publicly available data, such as census data, do not provide a national picture of the cultural aspects of resilience, so this indicator also draws on insights gained from interviews with experts, literature and case studies. This indicator is structured along a spectrum of cultural and economic dependence that supports the resilience of Indigenous communities:

- cultural dependence on forest-based activities
- economic dependence on cultural forest-based activities
- economic dependence on forest and wood products industries.

Cultural dependence of Indigenous communities on forest-based activities

The cultural use of native forests allows Indigenous people to connect with ancestral landscapes through activities such as hunting and gathering, use of fire (see Case Study 6.15), collecting materials for arts and tool-making, sharing stories and social ceremonies, and collecting bush food. Native forests are places where new generations of Indigenous people can learn traditional knowledge about country and its values, thereby contributing to the cultural resilience of their communities. This has been shown to strengthen Indigenous mental health and personal wellbeing (Feary 2008).

Economic dependence of Indigenous communities on cultural forest-based activities

Generally, the most resilient Indigenous communities are those in which economic development incorporates customary laws and values. Culture-based employment provides not only income but also benefits related to health, education, social function and wellbeing. These are particularly important in remote communities with limited access to other commercial industries (Garnett et al. 2016). Some forest-related Indigenous business models do not revolve around maximum financial gain, but have the prime objective of addressing social and family obligations (Feary 2008).

Cultural-based industries include creative industries, tourism, wildlife operations, and the sale of bush foods (Garnett et al. 2016), several of which involve activities related to native forests. For example, hundreds of Aboriginal women across South Australia and the Northern Territory participate in the harvesting of wattle seed (predominantly from gundabluie, *Acacia victoriae*) during the summer months. Wattle seed is in demand as a flavour enhancer and a cosmetic exfoliator. Wattle seeds have been or are a key part of the diet of many traditional Aboriginal communities (RIRDC 2014c).

However, it is cultural and natural resource management that is currently seen as the most vibrant industry contributing to the economic development of Australia's Indigenous people (Garnett et al. 2016). An estimated 337 Indigenous people are employed in conservation or park operation roles nationally

Case study 6.15: Cultural burning

Australia's Indigenous peoples have used fire to manage landscapes for thousands of years. In modern times, the application by Indigenous people of their landscape management skills using fire is called cultural burning. This typically involves small-scale, low intensity burning during the cooler months of the year, when fire is easily controlled (Feary 2018).

Cultural burning engenders individual and community feelings of wellbeing and satisfaction. Being embedded in millennia of traditional cultural activities, it forms a core part of Indigenous cultural identity and pride, including staying connected with the land and with each other. Using fire involves intricate traditional knowledge passed down from generation to generation, and is nested in ancient spirituality, customary laws, traditions and social organisation. Cultural burning facilitates community gatherings and collective activities, allowing for story-telling, advocating values and enacting traditional roles in communities.

The increasing application of cultural burning in Australia has been facilitated by legislative and policy changes that have improved access to land by Indigenous peoples, in combination with targeted programs. Several initiatives exist to introduce and/or maintain cultural burning by partnering with Indigenous communities, most notably the Firesticks initiative, which sets out to 'create social and ecologically resilient landscapes'. In relation to a control program for serrated tussock grass (*Nassella trichotoma*) in New South Wales, Aboriginal people said that "*if you heal country, you heal community*" (Feary 2018).

An example related to cultural burning involves Daniel Gomes, a Ranger from the Bandjalang clan for the Minyumai Indigenous Protected Area in the Upper North East region of New South Wales. This area involves mainly uncleared native forest, woodland and wetlands. During his childhood, Daniel heard stories from his late elder Lawrence Wilson about the native plants and animals that used to inhabit the region and his concerns that they might fail to return (SVA Consulting 2016a). He said "*When we burned this area, I didn't think the native plants would come back but they did. I couldn't believe it… When I see the changes I feel proud.*" The significance to Daniel of the native plants returning involved far more than mere ecological benefits. It fostered his sense of self and reconnected him with his ancestry and culture, and reminded him of the resilience of the Bandjalang people (SVA Consulting 2016a).

Rangers from the Bandjalang clan involved in cultural burning near Coffs Harbour, New South Wales.

CRITERION 6

6.5d

Table 6.55: Number of Indigenous people employed in conservation operations in Local Government Areas containing forested areas, 2016

Jurisdiction	ACT	NSW	NT	Qld	SA	Tas.	Vic.	WA	Australia
Number of people[a]	0	119	18	122	5	3	22	48	337

[a] Number of Indigenous people employed in Nature Reserves and Conservation Parks Operation in Local Government Areas (LGAs) that have nature conservation reserves containing native forest. LGAs containing forest on nature conservation reserve tenure were determined from the coverage in Indicator 1.1a. For each of these LGAs, the number of individuals who identified themselves as of Aboriginal and/or Torres Strait Islander origin and who were employed in Nature Reserves and Conservation Parks Operation was determined from 2016 ABS census data for Place of Work (ABS 2016b). A proportion of these workers may be employed in conservation roles in non-forest areas. Figures exclude areas of private forest formally managed for conservation purposes.

This table, together with other data for Indicator 6.5d, is available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

Case study 6.16: Cultural heritage assessments

A key desire for many Indigenous people is to integrate their financial independence with their socio-cultural obligations to respect and care for the country, including the associated cultural heritage. Cultural heritage assessments make a considerable contribution to fulfilling this desire, including empowering Indigenous communities to have a say in heritage management and protection. Cultural heritage involves the tangible and intangible legacies that have been passed down from generation to generation to a community or society, including places, objects, values and traditions (Feary 2008).

All Australian states and territories have legislation in place to protect Indigenous heritage, including the need for consultation with communities (Feary et al. 2010) (see Indicator 6.4a). This often leads to requirements for companies that carry out activities in forested areas, such as mining or wood harvesting, to fund cultural heritage assessments and subsequent heritage protection. For example, the Forestry Corporation of New South Wales[352], through its Aboriginal Partnerships Liaison Team, has partnered with various Aboriginal communities across the state to conserve places that have spiritual, historic, scientific or social value. This includes conducting cultural heritage assessments and jointly managing sites as part of commercial forestry operations (FCNSW 2017).

Cultural heritage assessments form an important income source for various Indigenous communities and/or organisations. This can be through short-term employment opportunities (Feary 2008), which sometimes lead to longer-term roles, such as appointment as heritage assessment officers and associated staff in Indigenous land councils (Feary 2007). Heritage assessments also enable learning opportunities for Indigenous people, either through formal training or by working with archaeologists (Feary 2008).

One cultural heritage assessment technique that has been used in co-management contexts (see Indicator 6.4c) is 'counter-mapping', which involves mapping the cultural relationships that Indigenous communities have with the land (McClean 2013). Mapping country was recently used by the Githabul community, who entered a co-management agreement for Border Ranges National Park in the Upper North East region of New South Wales (part of the Gondwana Rainforests of Australia World Heritage Area), which enabled an authentic representation of the culture of the Githabul community. This included working with elders to map traditional culture, such as stories, sites and language in traditional forms, including juraveels, places where powerful spirits exist and that form an important part of Githabul cosmology and beliefs. In addition, mapping was undertaken of places of everyday cultural significance, such as fishing spots and hunting grounds (McClean 2013). The researcher reflected on this work as follows (McClean 2013, p.96):

"For the Rangers, the mapping process we undertook was an interesting project that they were exploring for its value in their working lives, but one of its most meaningful aspects, from my observation, was that it was linked to the things they do to stay connected to their Country."

[352] Until January 2013, Forests NSW.

in LGAs that contain with forested conservation reserves (Table 6.55). These roles, which include ranger positions, provide income and may facilitate cultural connections to forested areas. Indigenous land management programs provide economic, health and wellbeing benefits to their communities (Kinglsey et al. 2013).

An example of economic dependence is the legislative requirement for cultural heritage assessments associated with forest disturbance activities. These assessments provide opportunities to Aboriginal people to earn income and to reconnect with and conserve culturally significant places (see Case Study 6.16). Another example is Australia's Indigenous ranger program (Garnett et al. 2016), as part of the Australian Government's Working on Country program (see Indicator 6.4a), which incorporates customary law and values.

Together with financial security, other benefits to an individual include strengthened self-confidence and self-esteem, better lifestyle choices, improved heath and wellbeing associated with outdoor activity, and being involved in meaningful work. The benefits of being employed extend to both an individual and often also the individual's immediate and extended families. For Indigenous people, broader community benefits include stronger community leadership, positive role models for younger generations, and stronger bonding between elders and younger generations that facilitates the passing on of traditional knowledge (Van Bueren et al. 2015).

Economic dependence of Indigenous communities on forest and wood products industries

The remainder of this indicator examines the involvement of Indigenous people in forest and wood product industries. Economic dependence on forest-based activities is difficult to quantify because of the diverse ways in which Indigenous people may be engaged in forest-related employment. The number of people directly employed in forest and wood products industries[353] is used here as an indicator of the economic dependence of Indigenous communities on forests, using ABS Indigenous Locations to define communities geographically (Table 6.56, Figure 6.46). Nationally consistent data on the economic benefits from employment in tourism or ecotourism are unavailable.

In 2016, the forest and wood products industries directly employed 1,099 Indigenous people nationally (0.64% of the total Indigenous workforce) (Table 6.56). More than 10% of the Indigenous workforce is employed in the forest and wood products industries in the Indigenous Locations of Manmoyi and Bulman-Weemol (Northern Territory), Cape York Wilderness (Queensland), Iga Warta Homeland, Raukkan and Mount Gambier (South Australia), and Manjimup (Western Australia). Many of these Indigenous Locations are small communities with a relatively high proportion of people working in forestry sector support services.

The absolute numbers of Indigenous people employed in the forest and wood products industries have increased nationally since 2006, although the proportion of the total Indigenous workforce employed in these industries decreased nationally since 2006. However, the proportion of the total Australian workforce in these industries decreased to a greater extent, and the dependence of Indigenous communities on these industries increased slightly relative to the entire workforce. In most of the Indigenous Locations with more than 0.8% of the Indigenous workforce employed in forest and wood products industries (Table 6.56), the proportion of employment in these industries increased from 2011 to 2016, although there were decreases in Indigenous Locations in Tasmania. Increases in these proportions may reflect increased opportunities to provide advice and services to commercial forestry operations, while decreases may be due to changes in the forest and wood products sector as a whole (such as more efficient technology), or the availability of employment in other industries.

Of Indigenous people directly employed in the forest and wood products industries nationally in 2016, 61% were employed in the combined wood product manufacturing and the pulp, paper and converted product manufacturing industries. Another 26% were employed in the forestry support services industry, and 13% in the forestry and logging industry (ABS 2016b). As for non-Indigenous employment, the trend is for an increasing proportion of Indigenous employment in the forestry support services industry, and a decreasing proportion in the wood and paper product manufacturing industries. The forestry support services industry made up 6% of Australian employment in the forest and wood products sector workforce in 2016 (Indicator 6.5c).

[353] Forest and wood products industries are defined using the Australian and New Zealand Standard Industrial Classification (ANZSIC) 2006 categories of forestry and logging; forestry support services; wood product manufacturing; and pulp, paper and converted paper product manufacturing. The forest and wood products sector is defined as the sum of these four categories.

Table 6.56: Characteristics of Indigenous communities and workers in Indigenous Locations with more than 0.8% of the Indigenous workforce employed in forest and wood products industries, 2016

		Community characteristics – employment dependence				Characteristics of Indigenous workers in forest and wood products industries			
Indigenous Location[a]	Proportion of Indigenous people in population (%)	Number of Indigenous people employed in forest and wood products industries[b]	Proportion of Indigenous workforce employed in forest and wood products industries (%)	Change in proportion of Indigenous workforce employed in forest and wood products industries, 2011–16 (%)	Proportion of total workforce employed in forest and wood products industries (%)	Median age (years)	Secondary school qualification[c] (%)	Non-school qualification[d] (%)	Unskilled workers (labourers) (%)
New South Wales									
Tumut	4.8	10	9.17	4.09	16.30	–	42.9	–	100.0
Upper Murray	3.0	9	4.11	1.36	2.30	–	33.3	0.0	50.0
Grafton	8.4	14	3.63	-0.80	3.34	–	0.0	25.0	72.7
Bulahdelah	5.2	8	3.57	1.41	1.87	–	0.0	100.0	0.0
Snowy–Monaro	2.3	8	2.88	0.93	1.30	–	0.0	0.0	–
Bathurst	5.8	13	2.35	1.24	1.69	28	33.3	42.9	57.1
Wyong–North-East	5.8	16	1.19	0.39	1.11	–	0.0	23.5	33.3
Wyong–South-West	4.4	11	1.14	1.14	0.90	–	57.1	55.6	0.0
Shoalhaven	4.4	9	1.13	-0.45	0.59	–	0.0	0.0	100.0
Northern Territory									
Manmoyi	100.0	9	64.29	14.29	64.29	–	50.0	50.0	0.0
Bulman–Weemol	96.6	10	18.18	18.18	16.13	–	0.0	–	0.0
Gunbalanya	91.7	14	9.59	9.59	6.60	–	45.5	33.3	0.0
Queensland									
Cape York Wilderness	14.3	8	12.12	5.87	1.77	–	100.0	100.0	0.0
Cooloola	3.5	9	5.59	0.21	4.12	–	100.0	66.7	0.0
Maryborough	5.1	9	4.84	-2.26	4.42	–	0.0	50.0	100.0
South Australia									
Iga Warta Homeland	88.2	11	84.62	84.62	47.83	48	–	40.0	0.0
Raukkan	100.0	8	50.00	20.00	47.06	–	–	100.0	–
Mount Gambier	2.4	20	13.33	4.94	10.17	–	50.0	15.0	41.2
Limestone Coast	1.7	10	4.95	2.27	4.66	33	0.0	33.3	21.4

Continued

Continues

Indigenous Location[a]	Proportion of Indigenous people in population (%)	Number of Indigenous people employed in forest and wood products industries[b]	Proportion of Indigenous workforce employed in forest and wood products industries (%)	Change in proportion of Indigenous workforce employed in forest and wood products industries, 2011–16 (%)	Proportion of total workforce employed in forest and wood products industries (%)	Median age (years)	Secondary school qualification[c] (%)	Non-school qualification[d] (%)	Unskilled workers (labourers) (%)
	Community characteristics – employment dependence					Characteristics of Indigenous workers in forest and wood products industries			
Tasmania									
Circular Head–King Island	14.5	28	6.11	-3.60	3.41	–	0.0	24.0	25.9
Wynyard	8.2	9	3.69	3.69	2.20	28	0.0	42.9	40.0
Huonville–South Cape	8.8	9	2.08	-2.73	2.27	–	25.0	0.0	57.1
Burnie	7.4	8	1.87	1.87	1.22	–	0.0	44.4	44.4
Launceston	3.9	9	1.41	-1.94	1.06	–	0.0	30.8	57.1
Western Australia									
Manjimup	3.6	11	14.10	7.85	6.85	–	100.0	0.0	57.1
Australia 2016[e]	**3.0**	**1099**	**0.64**	**NA**	**0.51**	**33**	**33.1**	**43.4**	**28.3**
Australia 2011[e,f]	**2.7**	**1053**	**0.74**	**NA**	**0.70**	**33**	**24.3**	**31.8**	**33.9**
Australia 2006[e,f]	**2.3**	**990**	**0.86**	**NA**	**0.90**	**33**	**21.3**	**27.6**	**40.7**

–, data insufficient

[a] Indigenous Locations are geographical units used by the Australian Bureau of Statistics that generally represent small Indigenous communities with a minimum population of 90 usual Indigenous residents, and that are designed to allow the production and analysis of statistics relating to Indigenous peoples with a high level of spatial accuracy, while also maintaining the confidentiality of individuals. There are 1,115 Indigenous Locations in Australia. Indigenous Locations with fewer than 8 forest sector workers are not included in this table because of data unreliability due to ABS randomisation. Indigenous Locations are mapped in Figure 6.46.

[b] Employees are counted under the Indigenous Location that is their place of usual residence. People are not necessarily employed within the geographic area of the Indigenous Location that is their place of residence.

[c] Secondary school qualification is Year 12 or equivalent as highest year of school completed.

[d] Certificate, diploma or advanced diploma, bachelor's degree, graduate certificate or graduate diploma, or postgraduate degree.

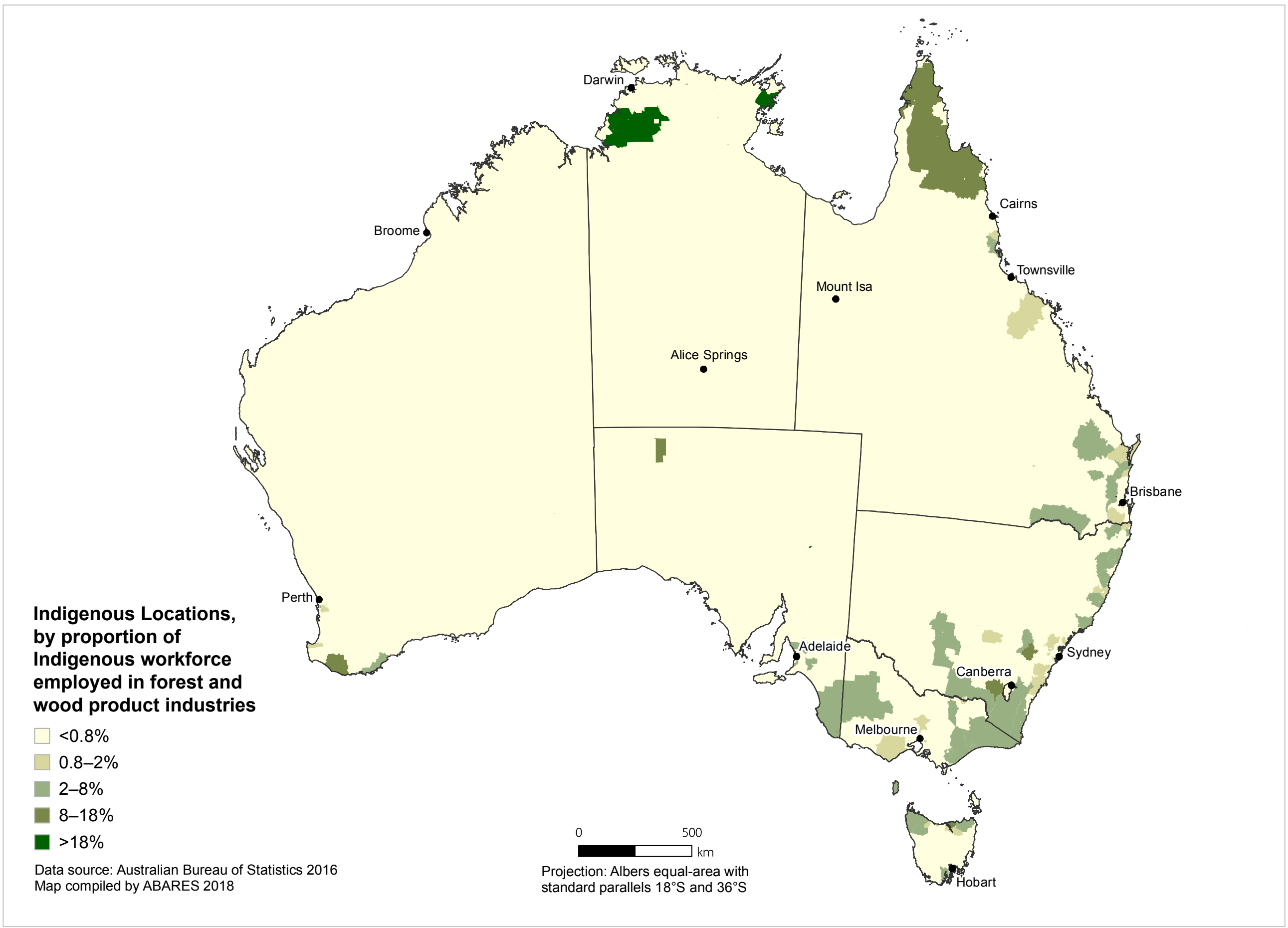
[e] Data for whole of Australia.

[f] Australia figures for 2006 and 2011 differ to those reported in SOFR 2013 because of a change in industry classification used to represent the forest sector.

Source: ABARES, based on ABS census data (ABS 2011, 2016b).

This table, together with other data for Indicator 6.5d, is available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

Figure 6.46: Indigenous Locations, by proportion of the Indigenous workforce employed in forest and wood products industries, 2016



Note: Data for Indigenous Locations where more than 0.8% of the total Indigenous workforce are employed in forest and wood products industries are given on Table 6.56.

Source: ABS (2016b).

A higher resolution version of this map is available via www.doi.org/10.25814/5be3bc4321162

Characteristics of Indigenous workers

As for the nation generally, there is a strong link between increased education levels, and improved employment and health outcomes, for Indigenous people (Commonwealth of Australia 2018). Employment is associated with improved wellbeing and living standards, and benefits individuals, associated families and broader communities. Factors such as an individual's skills, age, education and financial resources are key influences that support adaptability and positive wellbeing outcomes.

Demographic information about Indigenous people employed in the forest and wood products industries (Table 6.56) can therefore be used to understand an individual's resilience to change in forest and wood product industries. For Indigenous Locations with more than 0.8% of the Indigenous workforce employed in forest and wood products industries in 2016:

- The median age of this workforce across Australia was 33, unchanged from 2011. This compares with a median age of 43 in the Australian forest sector workforce as a whole. In general, younger employees can find it less challenging than older people to find alternative employment and adapt to change.
- In the Indigenous Locations of Wyong-South-West (New South Wales), Manmoyi and Gunbalanya (Northern Territory), Cape York Wilderness and Cooloola (Queensland), the combination of higher rates of secondary school completion and lower proportions of unskilled workers in the forest and wood products industry, compared with other locations and with national figures, may positively influence resilience.
- Workers had the highest levels of non-school qualifications such as certificates and diplomas in Queensland locations, Wyong-South-West and Bulahdelah (New South Wales), Raukkan (South Australia) and Manmoyi (Northern Territory). This could indicate a greater capacity to take opportunities within the forest sector, or potentially other sectors.
- Nationally, Indigenous workers had lower rates of non-school qualifications (43%) than those in the forest sector workforce as a whole (54%) (see Indicator 6.5c). However, the proportion of Indigenous workers in forest and wood products industries with non-school qualifications, or who had completed secondary school, increased between 2011 and 2016 to a greater extent than for workers in the

forest sector workforce as a whole. Higher levels of formal education are typically associated with increased rates of employment, and tend to indicate a greater capacity to respond to workplace change.

- The proportion of Indigenous workers in unskilled (labourer) occupations fell nationally by 5% from 2011 to 2016, while it increased slightly for the forest sector workforce as a whole (see Indicator 6.5c). Working in higher skilled jobs can increase opportunities and increase financial resources to assist adapting to change

Training and skills development

Training in practical skills for the forest and wood products sector, or for broader roles involving forests in the wider forest sector, can increase future employment opportunities and enhance personal resilience. ForestWorks, a not-for-profit skills development organisation, works with Skills Impact, the government-endorsed Skills Service Organisation, to develop and manage skills standards and qualifications under two training packages, the national Forest and Wood Products (FWP) and the Pulp and Paper Industry Manufacturing Industry training packages (ForestWorks 2018). Training is delivered by a range of registered training providers in areas such as forest management, sawmilling and processing, harvesting and haulage, and frame manufacturing.

Enrolments by Indigenous students in government-funded forestry-related training packages declined after 2011, in line with declines for all students in these training packages and in traineeship commencements across all industries. As noted in Indicator 7.1b, declines can be linked to two factors: more focus on less formal in-house approaches to skill development not requiring external payments to service providers; and increased industry preference for fee-for-service short courses and broader training than the technical skills previously delivered by registered training organisations. Other data on total Vocational Education and Training (VET) activities, which are only available since 2014, suggests a rise in Indigenous enrolments since 2014, including for training delivered in the Northern Territory (NCVER 2018).

The number of Indigenous students completing government-funded FWP training package awards has fallen since a peak in 2010 and 2011. That was a period when there were high numbers for all students in forestry-related training packages (see Indicator 7.1b). Since 2012, the majority of completions for Indigenous students completing government-funded forestry-related training programs have been in Victoria and New South Wales (Table 6.57). Around 55% of program completions by Indigenous students were at Certificate III level, with the remainder at Certificate II.

The skills and work experience gained in forest-based enterprises or occupations often assist Indigenous people to obtain employment in other sectors. For example, Indigenous ranger programs have contributed to preparing Indigenous people for their subsequent careers (Van Bueren et al. 2015).

Although it is difficult to measure the number of people who obtain employment in other industries as a result of the transferable skills that they obtain by undertaking training courses in the forest sector, the participation of Indigenous people in such training is likely to help build individual and community resilience.

Table 6.57: Completions of Forest and Wood Products (FWP) training package awards by Indigenous students, 2006 to 2016

	Completions[a]											
Jurisdiction	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017[b]**
ACT	0	0	0	0	0	0	0	0	0	0	0	0
NSW	6	5	0	0	8	6	12	2	6	5	3	5
NT	10	0	0	7	0	0	0	0	0	0	0	4
Qld	5	14	3	0	158	167	33	1	2	0	0	0
SA	0	0	0	4	2	0	0	0	0	0	0	0
Tas.	4	3	2	7	0	0	0	0	0	0	0	0
Vic.	0	0	0	5	5	0	6	6	5	7	3	12
WA	0	0	3	6	0	3	0	0	0	1	0	0
Total	**26**	**18**	**14**	**19**	**169**	**172**	**45**	**11**	**9**	**14**	**12**	**19**
Indigenous completions as proportion of all completions	**7%**	**8%**	**5%**	**6%**	**32%**	**35%**	**9%**	**4%**	**3%**	**4%**	**4%**	**9%**

[a] Completion of all awards (certificate level I to IV, Diploma or higher).

[b] Figures for 2017 are preliminary.

Notes:

The FWP training package covers topics including harvesting technologies, forest management innovation, timber processing optimisation, wood machining and timber product development. There were no Indigenous student completions in the Pulp & Paper Manufacturing Industry training package from 2006 to 2017.

Figures may differ from those published in SOFR 2013 due to a change in scope of government-funded activity data published by the National Centre for Vocational Education Research.

Source: National Centre for Vocational Education Research, VOCSTATS, VET program completions 2003–2016 database (government-funded training delivered by TAFE, university, other government providers, and private training providers) (www.ncver.edu.au/resources/vocstats.html), extracted 4 July 2018.

This table, together with other data for Indicator 6.5d, is available in Microsoft Excel via www.doi.org/10.25814/5bda972cd76d9

Criterion 7

Legal, institutional and economic framework for forest conservation and sustainable management

Plantation and native forest, Queensland.

Criterion 7 Legal, institutional and economic framework for forest conservation and sustainable management

The five indicators in this criterion report on the extent to which the legal, institutional and economic frameworks in Australia support sustainable forest management, specifically the conservation, maintenance or enhancement of the forest attributes described in Criteria 1-6. The indicators also report on the extent to which these frameworks support the capacity to monitor change and to conduct and apply research and development to forest management.

Effective legal, institutional and economic frameworks are critical for sustainable forest management. The legal framework presented in Indicator 7.1a defines and allocates legal and regulatory responsibilities, describes provision for public participation, and outlines the protection of conservation values in forests. Indicator 7.1b describes the institutions that provide mechanisms for policy-making and decision-making, and for the engagement of the wider community in continuous improvement of forest management. National economic policies on investment, taxation and trade that influence the level of investment in forest conservation, in forest growing, and in the wood-processing industries are addressed in Indicator 7.1c.

Indicator 7.1d describes Australia's forest measurement and monitoring programs, and how these programs provide the basis for planning to support sustainable forest management. The extent to which relevant and up-to-date information about forest condition is available to forest managers provides a measure of the capacity for continuous improvement of forest management. Reporting on the capacity to measure change provides forest managers with the opportunity to revise and prioritise data collection so that future measurement and monitoring are more relevant and informative.

Lastly, Indicator 7.1e assesses Australia's capacity to conduct and apply forest research and development. A scientific understanding of the characteristics and functions of forest ecosystems is needed to underpin their sustainable management. Research and development provide the basis for biological and wood inventories, forest health surveillance, improvements in operational forest management and silviculture, and effective forest monitoring. Research and development also underpin the expert advice required to inform decision-making and policy development. Changes in the institutional capacity for forest research and development, and the magnitude of investment in this, can indicate changes in research investment priorities and delivery mechanisms.

This icon indicates data, maps or graphics from *Australia's State of the Forests Report 2018* that are available for electronic download. Data used in figures and tables in this criterion are available via www.doi.org/10.25814/5bda99c8d76da.

Indicator 7.1a

Extent to which the legal framework supports the conservation and sustainable management of forests

Rationale

This indicator outlines the support that the legal system gives to the sustainable management of forests. A legal system that ensures transparency and public participation in policy and decision-making processes supports the continuous improvements in sustainable forest management.

Key points

- All states and territories and the Australian Government have legislation that supports the conservation and sustainable management of Australia's forests.
- Australia's public native forests, including those held in nature conservation reserves and those available for wood production, are governed and managed under state or territory regulatory frameworks and management plans.
  - Many of these frameworks and plans are prescribed in legislation.
  - Management of forests on private land is also regulated under various Acts.
  - As at 2016, 43 million hectares (32% of Australia's forests) were covered by management plans relating to their conservation and sustainable management. Management plans are in place for 19 million hectares of forest in the National Reserve System (57% of the area of forest in the National Reserve System).
- Codes of forest practice vary in their legal status and coverage, but generally provide specific operational guidance for sustainable forest management practices in public and private forests available for wood production, including in commercial plantations.
  - In Tasmania, there is a code of practice for the management of nature conservation reserves, including forested nature conservation reserves.

This indicator provides an overview of the support that the legal framework provides for the conservation and sustainable management of Australia's forests. An effective framework of legislation and legal mechanisms ensures transparency in land ownership, management planning and operational implementation, and enables public participation and the inclusion of Indigenous perspectives (perspectives of Aboriginal and Torres Strait Islander peoples) in policy development and decision-making processes. An effective regulatory framework also promotes continuous improvement in the sustainable management of forests across tenures. Public participation, including Indigenous participation, is covered in more detail at Indicator 7.1b.

Legal framework for forest management

In Australia, primary responsibility for land management, including forest management, lies at the state and territory level. At the national level, the Australian Government also has certain powers and responsibilities.

All states and territories have Acts, and dependent Regulations, that are designed to ensure the conservation and sustainable management of forests. Some of this legislation is administered jointly by, and requires coordination between, state or territory and local governments, statutory authorities and regional management authorities. State and territory legislative provisions cover planning and review, public participation, and the regulation of forest management activities in multiple-use public forests, public nature conservation reserves and, to a lesser extent, private and leasehold forests. In most states and territories there is also a legislative requirement to apply best practice standards to forest management activities, in multiple-use public forests, nature conservation reserves, and private and leasehold forests.

Table 7.1 lists key legislation at the national and state and territory levels relating to the conservation and sustainable management of Australia's forests, active during the SOFR 2018 reporting period 2011–16.

Table 7.1: Key legislation relating to the conservation and sustainable management of Australia's forests, by jurisdiction, active during the SOFR 2018 reporting period 2011–16

Jurisdiction	Legislation	Purpose
National		
	Environment Protection and Biodiversity Conservation Act 1999	To provide a legal framework to protect and manage, among other things, nationally and internationally important flora, fauna, ecological communities and heritage places – defined in the Act as matters of national environmental significance.
	Regional Forest Agreements Act 2002	To give effect to Commonwealth obligations under Regional Forest Agreements, which are 20-year plans for the conservation and sustainable management of Australia's native forests in the regions in which they apply. The legislation also requires the establishment of a comprehensive and publicly available source of information for national and regional monitoring and reporting in relation to all of Australia's forests, to support decision-making in relation to all of Australia's forests.
	Aboriginal and Torres Strait Islander Heritage Protection Act 1984	To provide for the preservation and protection from injury or desecration of areas and objects in Australia and in Australian waters, being areas and objects that are of particular significance to Aboriginals in accordance with Aboriginal tradition.
	Illegal Logging Prohibition Act 2012	To support the domestic and international trade in legally harvested wood and wood products by giving consumers and businesses greater certainty about the legality of the wood products they purchase.
Australian Capital Territory		
	Nature Conservation Act 2014 (replaced *Nature Conservation Act 1980*)	To make provision for the protection, conservation, enhancement and management of nature in the ACT, and for the management of reserves.
	Environment Protection Act 1997	To establish an environmental duty of care in relation to water quality and other environmental pressures, and to protect soil and water quality during harvesting through the application of a pollution control licence.
	Public Unleased Land Act 2013	To protect the amenity and natural value of, and to facilitate use of, unleased territory land that the public is entitled to use or is open to, or used by, the public, including nature conservation reserves and wilderness areas.
New South Wales		
	Forestry Act 2012[a] (replaced *Forestry Act 1916* and *Forestry and National Park Estate Act 1998*)	To provide for the dedication, management and use of State forests and other Crown-timber land for forestry; to constitute the Forestry Corporation of New South Wales as a statutory State-owned corporation and to specify its objectives and functions; to provide for forest agreements; and to provide for integrated forestry operations approvals for licensing operations in State forests and other Crown-timber lands for a period not exceeding 20 years.
	National Parks and Wildlife Act 1974, as amended[b]	To conserve nature, including threatened species; conserve objects, places and features of cultural value; and foster public appreciation, understanding and enjoyment of nature and cultural heritage and their conservation.
	Environmental Planning and Assessment Act 1979	To encourage the proper management, development and conservation of natural and artificial resources, for the social and economic welfare of the community and a better environment; to promote and co-ordinate the orderly and economic use and development of land; to protect the environment, including the protection and conservation of native animals and plants, including threatened species and ecological communities, and their habitats; ecologically sustainable development; to promote the sharing of the responsibility for environmental planning between the different levels of government in the State, and to provide increased opportunity for public involvement and participation in environmental planning and assessment.
	Native Vegetation Act 2003[c]	To provide for, encourage and promote the management of native vegetation on a regional basis in the social, economic and environmental interests of the State, and to prevent broad-scale clearing unless it improves or maintains environmental outcomes, protect native vegetation of high conservation value, improve the condition of existing native vegetation, encourage the revegetation of land, and the rehabilitation of land, with appropriate native vegetation, in accordance with the principles of ecologically sustainable development.
	Protection of the Environment Operations Act 1997[d]	To protect, restore and enhance the quality of the environment in New South Wales, having regard to the need to maintain ecologically sustainable development.
	Plantations and Reafforestation Act 1999	To facilitate the reafforestation of land, and to promote and facilitate development for timber plantations on essentially cleared land, and to codify best practice environmental standards, and provide a streamlined and integrated scheme, for the establishment, management and harvesting of timber and other forest plantations.
Northern Territory		
	Environment Assessment Act 1994	To provide for the assessment of the environmental effects of development proposals and for the protection of the environment.
	Territory Parks and Wildlife Conservation Act 2006	To provide for the establishment and management of parks and reserves (including sanctuaries and joint management parks or reserves), and the study, protection, conservation and sustainable use of wildlife. Also controls commercial harvesting of native vegetation throughout NT, not just in national parks and reserves.
	Pastoral Land Act 1992, as amended[e]	To make provision for the conversion and granting of title to pastoral land and the administration, management and conservation of pastoral land.
	Planning Act 1999	To provide for appropriate and orderly planning and control of the use and development of land. Also establishes the NT Planning Scheme, which specifies performance criteria for the clearing on native vegetation.

Continued

Continues

Jurisdiction	Legislation	Purpose
Queensland		
	Forestry Act 1959	To provide for forest reservations; the management, silvicultural treatment and protection of state forests; the sale and disposal of forest products and quarry material, which are the property of the Crown in state forests and timber reserves, and on other lands; and to grant exclusive rights to state plantation forests through a plantation licence.
	Nature Conservation Act 1992	To conserve nature using an integrated and comprehensive conservation strategy for the whole state while allowing for the involvement of indigenous people in the management of protected areas in which they have an interest under Aboriginal tradition or Island custom.
	Vegetation Management Act 1999	To regulate the clearing of vegetation in a way that conserves remnant vegetation, conserves vegetation in declared areas, ensures that clearing does not cause land degradation, prevents the loss of biodiversity, maintains ecological processes, manages the environmental effects of clearing and reduces greenhouse gas emissions.
South Australia		
	Forestry Act 1950	To provide for the creation, management and protection of state forest reserves, including the conservation, development and management of native forest reserves.
	National Parks and Wildlife Act 1972	To provide protection measures for endangered and vulnerable plants and animals, and to provide for the establishment of reserves for public benefit and recreation.
	Native Vegetation Act 1991	To preserve native vegetation, including through legislative controls on native vegetation clearance.
	Natural Resources Management Act 2004[f]	To promote the sustainable and integrated management of the state's natural resources and make provision for the protection of the state's natural resources, including the control of significant plantation water use through licensing or a forest permit system.
	Environment Protection Act 1993	To promote the principles of ecologically sustainable development based on sound environmental practices and policies that protect, restore and enhance the quality of the environment.
Tasmania		
	Forest Management Act 2013 (replaced *Forestry Act 1920*)	To provide for the declaration of Crown land as permanent timber production zone land required for the supply of forest products, and its management.
	Forest Practices Act 1985	To establish the Forest Practices Code and forest practices system to provide for the sustainable management of forests on any land subject to forest operations; and to enable the establishment of private timber reserves on private land to provide security of long-term forestry use for landowners.
	Nature Conservation Act 2002	To provide for the declaration of national parks and other reserved land, and set out the values and purposes of each reserve class with respect to the conservation and protection of fauna, flora and geological diversity.
	National Parks and Reserves Management Act 2002	To provide for the management of national parks and reserves under the *Nature Conservation Act 2002*, according to management objectives for each reserve class.
	Forestry (Rebuilding the Forest Industry) Act 2014 (replaced *Tasmanian Forests Agreement Act 2013*)	To provide for future potential production forest land and its possible conversion to permanent timber production zone land, and to provide for special species timber harvesting, including requiring the preparation of a special species management plan within three years of commencement of the Act.
Victoria		
	Forests Act 1958, as amended[g]	To provide for the management of state forests, including timber harvesting and fire management; for timber harvesting to comply with a code of practice; and for the protection of state forests and forest produce as property of the Crown.
	National Parks Act 1975, as amended[h]	To provide a framework for the establishment and management of national parks, and to make provision for certain other parks, including harvesting in selected parks.
	Conservation, Forests and Lands Act 1987	To provide a framework for a land-management system and to make necessary administrative, financial and enforcement provisions.
	Flora and Fauna Guarantee Act 1988	To provide the framework for the conservation of threatened species and ecological communities and management of processes threatening Victoria's native flora and fauna[i].
	Catchment and Land Protection Act 1994	To set up a framework for the integrated management and protection of catchments, including forested catchments.
	Sustainable Forests (Timber) Act 2004[j]	To provide a framework for sustainable forest management and sustainable timber harvesting in state forests.

Continued

Continues

Jurisdiction	Legislation	Purpose
Western Australia		
	Conservation and Land Management Act 1984, as amended[k]	To make provision for the use, protection and management of certain public lands and waters, and their flora and fauna, and to establish responsible authorities.
	Forest Products Act 2000	To provide for the harvesting and sale of forest products from native forests and plantations on state forest and timber reserves, and their regeneration or replanting, in specified areas in the south west of the state.
	Environmental Protection Act 1986	To provide for the assessment of the environmental impacts of forest management proposals, and to set conditions on implementation of proposals to moderate adverse impacts; and to provide offences for unlawful environmental harm, including the clearing of native vegetation.
	Sandalwood Act 1929[l]	To regulate the quantity of sandalwood to be pulled or removed from Crown and other land, with sandalwood being the wood of any tree of the genera *Santalum* or *Fusanus*, and any other species of aromatic wood which is or may be used as a substitute for sandalwood.
	Wildlife Conservation Act 1950[l]	To provide for the conservation and protection of wildlife, with wildlife being flora and fauna native to the state.

[a] The NSW *Forestry Regulation 2012* also replaced the *Forestry Regulation 2009* when the *Forestry Act 2012* replaced the *Forestry Act 1916*.

[b] Amended in (October) 2011, to amend the *National Park Estate (South-Western Cypress Reservations) Act 2010*, to delay the commencement of certain reservations.

[c] The NSW *Native Vegetation Regulation 2013* commenced on 23 September 2013.

[d] The NSW *Protection of the Environment Operations (General) Regulations 2009* was amended in March 2014 to allow residues from authorised clearing and timber harvesting to be burnt for electricity generation, consistent with other states.

[e] Amended in 2016 to allow parts of the lease to be used for non-pastoral uses such as agriculture, horticulture, aquaculture, tourism or forestry, while also subject to land clearing guidelines specified in this Act and the NT *Planning Act 1999*.

[f] Amended in 2014 to provide for the introduction of forest water licencing in the south-east of the state.

[g] Amended in 2012 to provide for cutting and taking away fallen or felled trees in State forest and certain regional parks for domestic use as firewood without a licence or permit.

[h] Amendments in 2013, 2015, 2016 relating to leasing powers and terms, environmental assessments, and prohibiting cattle grazing.

[i] An Action Statement must be prepared for each species, ecological community, and potentially threatening process, following a listing under this Act.

[j] Amended in 2013 in relation to allocation orders, the management of timber resources, and the management and conduct of timber harvesting.

[k] Various amendments from 2011 to 2016, including replacing the Conservation Commission of Western Australia with the Conservation and Parks Commission.

[l] The *Sandalwood Act 1929* and the *Wildlife Conservation Act 1950* were both replaced by the *Biodiversity Conservation Act 2016*, which received assent on 21 September 2016 and provides for the conservation and protection of biodiversity and biodiversity components, and the ecologically sustainable use of biodiversity components in Western Australia.

Source: State, territory and Australian Government agencies.

Forest management plans

Australia's public native forests, including those held in nature conservation reserves and those available for wood production, are governed and managed under state or territory regulatory frameworks and strategic management plans. Many of these frameworks and plans are prescribed in legislation. A small number of nature conservation reserves are governed and managed by the Australian Government under Commonwealth legislation and management plans prescribed in that legislation. Australia's publicly managed plantation forests are also governed and managed under state or territory regulatory frameworks and management plans.

Management plans provide guidance for sustainable forest management practices. Examples of management plans prescribed in legislation for the conservation and sustainable management of forests are listed in Table 7.2 and described in Case studies 7.1 and 7.2.

As at 2016, a total of 43 million hectares (32% of Australia's forests) were covered by management plans relating to their conservation and sustainable management (Table 7.3). This has increased from 22% of Australia's forests since SOFR 2013. Within this area, management plans are in place for 19 million hectares of forest in the National Reserve System. This is 57% of the area of forest in the National Reserve System (see Indicator 1.1c).

A forest area with a management plan is an area for which there is a long-term, documented and periodically reviewed management plan containing defined management goals. Management plans can take many forms, such as the examples listed in Table 7.2, as well as natural resource, environment and water catchment management plans that cover forests, and the components of strategic management planning systems required for forest management certification. Forests covered by a management plan are mostly public forests, but also include some privately owned or managed forests covered by a forest certification scheme.

Table 7.2: Examples of management plans prescribed in legislation for the conservation and sustainable management of Australian forests

Plan	Purpose	Coverage
Management plans for all national parks – required under relevant legislation in each jurisdiction	To provide a framework of objectives, principles and policies to guide the long-term management of the broad range of values contained in national parks.	All state, territory and nationally managed national parks.
Australian Capital Territory *Tidbinbilla Nature Reserve Plan of Management 2012* – required under the *Planning and Development Act 2007*	The plan is a legal document that outlines how the Tidbinbilla precinct is to be managed.	Tidbinbilla precinct, which contains special-purpose reserve areas and national park areas, including Tidbinbilla Nature Reserve.
New South Wales regional ***Forest Management Plans*** and ***Ecologically Sustainable Forest Management Plans***[a] – required under the *Forestry Act 2012*	To publicly document the broad strategies, ecological principles, performance indicators and measurable outcomes for forest management, and commitment to Ecologically Sustainable Forest Management.	New South Wales State forests and other Crown-timber lands.
New South Wales *Special Areas Strategic Plan of Management 2015* – required under the *Water NSW Act 2014* (see Case study 7.1)	Provides the strategic framework for the planning, delivery and reporting of land management activities within the Special Areas by WaterNSW and NSW National Parks and Wildlife Service. It is a long-term plan to secure high-quality water for the storages, maintenance of ecosystem integrity, and the management of cultural values within the Special Areas.	Special Areas comprise the 364,778 hectares of lands (forest and non-forest) that surround and protect water supply storages for Sydney, the Illawarra, Blue Mountains, Southern Highlands and Shoalhaven regions.
South Australia *State Natural Resources Management Plan 2012–2017* and ***Regional Natural Resources Management Plans*** – required under the *Natural Resources Management Act 2004*	To establish direction for South Australia in its management of natural resources by providing the framework for regional Natural Resource Management (NRM) boards working with state government agencies to develop regional NRM plans and programs.	Statewide and region-by-region natural resources in South Australia.
Victoria regional ***Forest Management Plans*** – required under the *Forest Act 1958*	To ensure that state forest is managed in an environmentally sensitive, sustainable and economically viable manner, while being responsive to changing community expectations and expanding knowledge of the forest ecosystem.	State forests in Victoria's 12 Forest Management Areas.
Western Australia *Forest Management Plan 2004–2013* and ***Forest Management Plan 2014–2023*** – required under the *Conservation and Land Management Act 1984* (see Case study 7.2)	To set out the actions to be taken to conserve biodiversity; sustain the health, vitality and productive capacity of ecosystems; and produce the social, cultural and economic benefits valued by the community, taking account of the principles of ecologically sustainable forest management.	Forests on public land in the south-west of Western Australia that is vested in the Conservation Commission of Western Australia[b].

[a] The regional *Ecologically Sustainable Forest Management Plans* for the Upper and Lower North East, Southern Region – South Coast, and Southern Region – Tumut and Eden, were replaced in December 2016 by the *Forest Management Plan for the Coastal Forests of NSW*, a management plan required under the *Forestry Act 2012*.

[b] From October 2015, the Conservation and Parks Commission of Western Australia.

Source: State, territory and Australian Government agencies.

Table 7.3: Forest areas covered by management plan ('000 hectares)

	ACT	NSW	NT	Qld	SA	Tas.	Vic.	WA	Australia
Forests with a management plan									
Primarily conservation[a]	113	4,862	4,582	1,450	1,255	972	2,814	3,136	19,183
Multiple values including wood production[b]	0	2,414	0	18,236	352	1,195	512	1,378	24,087
Total forests with a management plan	**113**	**7,276**	**4,582**	**19,686**	**1,607**	**2,167**	**3,326**	**4,514**	**43,270**
Forests without a management plan	**29**	**13,092**	**19,153**	**32,144**	**3,453**	**1,531**	**4,897**	**16,467**	**90,767**
Total forest area	142	20,368	23,735	51,830	5,060	3,699	8,222	20,981	134,037

[a] 'Primarily conservation' comprises forest areas in the Collaborative Australian Protected Areas Database (www.environment.gov.au/land/nrs/science/capad) with an existing, identified management plan (see Table 7.14).

[b] 'Multiple values including wood production' includes total areas of multiple-use public native forests and commercial plantations covered by management plans or certification.

Sources: Collaborative Australian Protected Areas Database and publicly accessible data on Australian certified forests from Responsible Wood (www.responsiblewood.org.au) and Forest Stewardship Council (info.fsc.org).

This table, together with other data for Indicator 7.1a, is available in Microsoft Excel via www.doi.org/10.25814/5bda99c8d76da

Case study 7.1: *Special Areas Strategic Plan of Management 2015*, New South Wales

Special Area lands declared under the *Water NSW Act 2014* comprise 364 thousand hectares of lands that surround and protect drinking water supply storages for Sydney, the Illawarra, Blue Mountains, Southern Highlands and Shoalhaven regions (Figure 7.1). The Special Areas primarily comprise intact native forest; the remainder is other native vegetation, wetlands, river systems, heritage sites, water storages and associated infrastructure, active and historic farmland, active and derelict mines, roads, utility corridors and water supply facilities.

Under the *Water NSW Act 2014*, WaterNSW and the NSW National Parks and Wildlife Service (NPWS) are required to jointly manage the Special Areas. The *Special Areas Strategic Plan of Management 2015* fulfils Section 52 of the Act that requires the joint sponsors (WaterNSW and NPWS) to prepare a plan of management for the Special Areas. Section 53 of the Act requires the joint sponsors to implement the plan.

NPWS is the primary conservation agency in NSW and is also the land manager of conservation reserves within the Special Areas that have been gazetted under the *National Parks and Wildlife Act 1974*, totalling 67% of the Special Areas land. WaterNSW has responsibility for the quality of water in Greater Sydney's drinking water catchment areas, and is the freehold owner of 19% of the Special Areas land (including the water storages). The remaining 14% of the land is privately owned or other tenure, including other Crown land, however the plan does not direct actions on privately owned land declared as Special Areas. To maintain water quality, WaterNSW encourages best-practice sustainable land use by private landholders and developers in the urban water supply catchments through a mix of incentives, shared information, education and regulation. (Indicator 4.1e provides more information on water quality in forests.)

The *Special Areas Strategic Plan of Management 2015* provides the strategic framework for the planning, delivery and reporting of land management activities within the Special Areas by WaterNSW and NPWS. It is a long-term plan to secure high-quality water for the storages, the maintenance of ecosystem integrity, and the management of cultural values within the Special Areas.

Special Areas land has been classified into two water quality protection schedules. Public access to the Special Areas is regulated in accordance with these schedules.

Schedule 1 lands are lands immediately surrounding the water storages, and into which public entry is generally not permitted, although some visitor facilities and walking corridors do exist with WaterNSW's consent. Schedule 2 lands are a second-tier buffer zone that generally adjoins Schedule 1 lands. While some public entry and activities are permitted on Schedule 2 lands, restrictions apply. Access restrictions do not apply to privately owned land and public roads within the Special Areas.

Figure 7.1: Map of Special Areas managed under the NSW *Special Areas Strategic Plan of Management 2015*

Source: NSW *Special Areas Strategic Plan of Management 2015*.

Case study 7.2: Forest Management Plan, Western Australia

The Conservation Commission of Western Australia[354] is the controlling body in which Western Australia's conservation estate is vested, including national parks, conservation parks, nature reserves, state forests and timber reserves, and marine reserves.

Under Western Australia's *Conservation and Land Management Act 1984*, public forests in the south-west of Western Australia are managed according to a forest management plan. The current plan is the *Forest management plan 2014–2023*[355] (Figure 7.2), published in December 2013 by the Conservation Commission of Western Australia through the Department of Parks and Wildlife, which succeeded the *Forest Management Plan 2004–2013*[356]. These plans provide a framework for managing forest areas for a range of environmental, social and economic uses, and are based on a modified set of Montreal Process criteria of sustainability as the framework for identifying management actions in line with the principles of ecologically sustainable forest management. The criteria used are conservation of biodiversity, maintenance of productive capacity, maintenance of ecosystem health and vitality, conservation and maintenance of soil and water, maintenance of forests' contribution to the global carbon cycle, maintenance of heritage and maintenance of socio-economic values (CCWA 2013).

The Commission's overall goal in formulating Western Australia's Forest Management Plans is for biodiversity to be conserved; the health, vitality and productive capacity of ecosystems to be sustained; soil and water resources to be protected; the contribution to global carbon cycles to be sustained; and the social, cultural and economic benefits valued by the community to be produced in a manner that takes account of the principles of ecologically sustainable forest management. Western Australia's Department of Parks and Wildlife[357] manage the land to which the Plan applies, while the Forest Products Commission (Western Australia) are responsible for the harvest and regeneration of forests within the areas available for timber production.

Figure 7.2: The forest management plan for 2014–2023 for Western Australia

Source: CCWA (2013).

[354] From October 2015, the Conservation and Parks Commission of Western Australia.

[355] www.dpaw.wa.gov.au/images/documents/conservation-management/forests/FMP/20130282_WEB_FOREST_MGT_PLAN_WEB.pdf

[356] www.dpaw.wa.gov.au/images/documents/conservation-management/forests/FMP/preparing_FMP_2014-23/20120329_forest_management_plan_20042013_end_of_term_audit_performance_final_30_march_2012_ccwa.pdf

[357] From July 2017, the Department of Biodiversity, Conservation and Attractions.

Forest management codes of practice

Forest management codes of practice provide specific guidance for sustainable forest management practices in public and private production native and plantation forests in each state and territory, and in nature conservation reserves in Tasmania. In production forests the codes cover a range of issues, such as forest planning; forest access and roads; forest harvesting; the conservation of non-wood values; pest, weed and fire management; and the harvesting of non-wood forest products. The codes vary in their legal status and coverage as summarised in Table 7.4.

Plantation forestry codes of practice are referred to in the *Export Control (Unprocessed Wood) Regulations* made under the *Export Control Act 1982* (Cth). The Regulations declare certain types of unprocessed wood, including unprocessed wood from a plantation, to be prescribed goods and therefore in need of an export licence. However, in those states where the minister has found that its plantation forestry code of practice protects environmental and heritage values, this declaration does not apply and a licence is not required. Codes of practice are assessed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) against the *Forest Practices Related to Wood Production in Plantations: national principles*. Plantation forestry codes of practice for most states and territories were approved by the minister in 2013, and for Queensland in 2016[358].

Tasmania is the only Australian jurisdiction with a code of practice for the management of nature conservation reserves. The *Tasmanian Reserve Management Code of Practice* (2003) complements other codes, including Tasmania's *Forest Practices Code 2015*. It is the result of a commitment under

Table 7.4: Forest management codes of practice, their legal status and coverage, by jurisdiction

Jurisdiction	Title	Legal status	Coverage
ACT	*Code of Forest Practice* (2005)	No legal status	Public plantations
NSW	Integrated Forestry Operation Approvals[a]	Required under the *Forestry Act 2012*	Forestry operations in public native forests in State forests or other Crown timber lands
	Plantations and Reafforestation (Code) Regulation 2001	Prescribed in the *Plantations and Reafforestation Act 1999*	Public and private plantations
	Private Native Forestry Code of Practice (2008)[b], *Private Native Forestry Code of Practice* (2013)[c]	Prescribed in the *Native Vegetation Act 2003*	Private native forests and native forests on Crown tenures that are not Crown-timber land under the *Forestry Act 2012*.
NT	*Codes of Practice for Forestry Plantations* (2004)	No legal status	Public and private plantations
Qld	*Code of practice for native forest timber production on the* Queensland Parks and Wildlife Service *forest estate 2014*	Defines minimum standards to meet requirements of the *Forest Act 1959* and other associated legislation.	Public native forests
	Code applying to a native forest practice on freehold land (2005)	Prescribed in the *Vegetation Management Act 1999*	Private native forests
	Managing a native forest practice: A self-assessable vegetation clearing code (2014)	Prescribed in the *Vegetation Management Act 1999*	Private native forests
	Timber Plantation Operations Code of Practice for Queensland (2015)	No legal status	Public and private plantations
SA	*Guidelines for Plantation Forestry in South Australia 2009*	No legal status but includes references to mandatory requirements.	Public and private plantations
Tas.	*Forest Practices Code 2015*	Prescribed in the *Forest Practices Act 1985*	Public and private native forests and plantations
	Tasmanian Reserve Management Code of Practice 2003	A commitment under the Tasmanian Regional Forest Agreement 1997	Public native forests in conservation reserves
Vic.	*Code of Practice for Timber Production 2014*	Prescribed in the *Conservation Forests and Lands Act 1987*	Public and private native forests and plantations
WA	*Code of Practice for Timber Harvesting in Western Australia* (1999)	No legal status	Public native forests
	Code of Practice for Timber Plantations in Western Australia (2014)	No legal status	Public and private plantations

[a] IFOAs are in place for the following regions: Upper North East, Lower North East, Eden, Southern, South Western Cypress, River Red Gum, and Brigalow–Nandewar.
[b] For Southern, River Red Gum, Cypress and Western Hardwood regions
[c] For Northern region

[358] Further information on the assessments is available at www.agriculture.gov.au/forestry/australias-forests/plantation-farm-forestry/principles

the 1997 Tasmanian Regional Forest Agreement to develop and implement a code of practice to cover all environmental practices in reserves. The code provides information and guidance for best-practice operational standards for management activities in Tasmania's nature conservation reserves.

Regulations governing firewood collection

Firewood is wood used for residential heating, whereas fuelwood is wood or wood products used as industrial fuel or for bioenergy production. Firewood is one of the most commonly utilised wood products, and is collected from plantations, agricultural lands and native forests. Its use is an important segment of the forest sector, and important to regional communities. Industrial fuelwood includes wood waste generated during wood processing. Data on firewood and fuelwood consumption (use) are provided in Indicator 6.1d.

Regulations are in place across Australia to protect threatened species and ecological communities from the impacts of firewood collection. Many states and territories regulate the personal and commercial collection of firewood by permit systems. Regulatory controls on the clearing of native vegetation also restrict firewood collection. A *National Approach to Firewood Collection and Use in Australia* was developed and endorsed by governments in 2001 (ANZECC 2001), and in August 2005 the Natural Resource Management Ministerial Council agreed to a *Voluntary Code of Practice for Firewood Merchants* (NRMMC 2005). From 2005, a scheme operated by the Firewood Association of Australia (FAA) certified compliance of firewood merchants and suppliers with the voluntary code of practice, but the scheme ceased in 2011, although FAA members continue to adhere to the voluntary code of practice as an ongoing condition of their membership (DSEWPaC 2011a; FAA 2018).

Regional Forest Agreements

Regional Forest Agreements (RFAs) are 20-year plans for the conservation and sustainable management of Australia's native forests in the regions in which they apply. Ten RFAs were negotiated bilaterally between the Australian Government and four of the six state governments (New South Wales, Tasmania, Victoria and Western Australia), and commenced between 1997 and 2001. A map (Figure I.vi) in the Introduction shows the 10 regions to which RFAs apply. Davey (2018a) describes the origins and development of Australia's regional forest agreements.

Each RFA was the result of a Comprehensive Regional Assessment (CRA) involving substantial scientific study, consultation and negotiation, covering a diverse range of stakeholder interests. Information was gathered on the social, economic, environmental, and cultural and natural heritage values of each region's forests, and a science-based methodology was used to determine forest allocation for different uses and forest management strategies. RFAs are

Habitat tree, East Boyd State Forest, Eden, New South Wales. Habitat trees are retained within logged areas to provide fauna roosting and nesting sites.

designed to provide stability for forest-based industries, certainty for forest-dependent communities, and conservation for forest ecosystems through a Comprehensive, Adequate and Representative (CAR) reserve system. The *Regional Forest Agreements Act 2002* gives effect to certain obligations of the Commonwealth under RFAs, including public reporting.

Under the *Regional Forest Agreements Act 2002*, five-yearly RFA reviews on the performance of each RFA are to be reported and tabled in the Australian Parliament by the Australian Government minister with responsibility for forestry. The status of each five-yearly review is detailed in Table 7.12 of Indicator 7.1d.

In October 2013, the Australian Government committed to maintaining its support for long-term RFAs by seeking to extend and establish 20-year 'rolling lives' for each RFA. The initial 20-year periods of the 10 RFAs expire between 2017 and 2021. As at December 2018, the Tasmanian RFA and the three New South Wales RFAs have been extended for a further 20 years following assessment processes.

Commonwealth Government export licencing requirements under the *Export Control Act 1982* (specifically, the *Export Control (Hardwood Wood Chips) Regulations 1996* and the *Export Control (Regional Forest Agreements) Regulations*) do not apply to the export of wood and wood chips from native forests in a region covered by an RFA.

Environment Protection and Biodiversity Conservation Act 1999

Australia's *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) applies to matters of national environmental significance, such as World Heritage properties and Natural Heritage places, wetlands of international importance, nationally listed threatened species and ecological communities, internationally listed migratory species, and water resources.

Part 4, Division 4, section 38(1) of the EPBC Act states that Part 3 of the Act does not apply to forestry operations undertaken in accordance with a Regional Forest Agreement (RFA); this does not apply to World Heritage listed areas or to Ramsar wetlands. This provision recognises that RFAs have already met the normal requirements for assessment and approval of operations because conservation values in each region were assessed as part of Comprehensive Regional Assessments before each RFA was signed, with the RFAs providing a substitute system and an equivalent level of protection to that provided by Part 3 of the EPBC Act. Davey (2018a) discusses the interrelationship between RFAs and the EPBC Act.

Requirements for assessment and approval under the EPBC Act still apply to forestry operations in forests outside an RFA region.

Illegal logging

Australia's *Illegal Logging Prohibition Act 2012* aims to support the trade in legally harvested wood and wood products by giving consumers and businesses greater certainty about the legality of the wood products they purchase. The Act makes it a criminal offence to intentionally, knowingly or recklessly import or process illegally logged timber or timber products, including domestically grown raw logs.

The *Illegal Logging Prohibition Regulation 2012* prescribes due diligence requirements to minimise the risk of obtaining illegally logged wood, and lists the wood products subject to those requirements. The due diligence requirements are for use by importers of the listed wood products and by processors of domestically grown raw logs. The requirements are estimated to annually affect approximately 20,000 businesses and individuals.

State-specific guidelines were developed and released during the reporting period to help processors better understand the legal frameworks used in New South Wales, Queensland, South Australia, Tasmania, Victoria and Western Australia to regulate the harvesting of wood.

Indicator 7.1b

Extent to which the institutional framework supports the conservation and sustainable management of forests

Rationale

This indicator examines the institutional frameworks that support sustainable forest management. Institutional frameworks provide mechanisms for engagement of the wider community in the process of continuous improvement and sustainable forest management.

Key points

- A well-established policy framework, guided by a *National Forest Policy Statement*, supports the conservation and sustainable management of Australia's forests, both nationally and in all states and territories.
- Codes of forest practice and externally certified environmental management systems are used by forest managers to provide a structured approach to the planning and management of protection of the environment.
- At June 2018, a total of approximately 8.9 million hectares of native forests and plantations were certified for forest management under either the Responsible Wood Certification Scheme or the Forest Stewardship Council scheme. Some forests and plantations were certified under both schemes.
- At June 2018, a total of 189 chain-of-custody certificates for tracking wood from the forest to the final product were issued under the Responsible Wood Certification Scheme, and 258 chain-of-custody certificates were issued under the Forest Stewardship Council scheme.
- A range of training and education qualification options continues to be available in Australia across all areas relevant to sustainable forest management, from operational competency certificates, to coursework certificates and diplomas, and graduate and postgraduate degrees. Over time, there has been a decreasing trend in undergraduate degree completions, and an increasing trend in postgraduate degree completions.

Institutional frameworks provide mechanisms for policy-making and decision-making, and for engagement of the wider community in sustainable management of forests and in the processes of continuous improvement. Such frameworks provide for and support sustainable forest management through policies that promote good forest management, planning, monitoring and assessment, and community engagement and awareness. They also encourage the adoption of voluntary forest management certification schemes and environmental management systems, and the maintenance of appropriate levels of human resource skills in forest management.

Australia's forest policy framework

The management of Australia's forests is guided by a *National Forest Policy Statement* (Commonwealth of Australia 1992). The statement outlines 11 broad national goals (see Introduction, Box 1.i). The three goals most relevant to this indicator are integrated and coordinated decision-making and management; employment, workforce education and training; and public awareness, education and involvement. Through this statement and other policy mechanisms, Australia's national, state and territory governments are committed to the sustainable management of all Australia's forests, whether the forest is on public or private land, or within a conservation reserve or a production forest.

Through the *National Forest Policy Statement*, the governments of Australia agreed to *Forest Practices Related to Wood Production in Native Forests: National Principles* (Standing Committee of the Australian Forestry Council 1991) and *Forest Practices Related to Wood Production in Plantations: National Principles* (Ministerial Council on Forestry, Fisheries and Aquaculture 1995). The governments agreed that the principles should be applied to the management of all public and private native forests and plantations in Australia. These principles provide for a consistent and scientific basis for sound forest management to which all states and territories are committed.

The Forestry and Forest Products Committee (FFPC) is an intergovernmental body consisting of officials from the Australian, state, territory and New Zealand governments. FFPC provides advice to the Forestry Ministers Meeting and the Agriculture Senior Officials Committee on matters relevant to forests and forestry. Three working groups are established under the FFPC: the Montreal Process Implementation Group for Australia, the National Forest Inventory Steering Committee, and the Forest Fire Management Group.

Most state and territory government organisations and agencies responsible for forest management operate under long-term national and state or territory non-legislative policies, strategies and charters that influence the sustainable management of Australia's forests (Table 7.5). The extent to which these arrangements provide for sustainable forest management varies among states and territories. Generally, these arrangements apply comprehensively in public forests (except those under leasehold), but to a lesser extent in private and leasehold forests.

Much of Australia's production native forests and plantation forests are owned and/or managed by large public or private organisations. The operations of these organisations are usually conducted through recognised forest management systems, using policies, guidelines, protocols and other instruments that promote the sustainable management of forests and the engagement of the wider community. Their policies are stated publicly, generally relate to sustainability, forest stewardship and environmental awareness, and guide their forest management planning and operational practices.

Table 7.5: Key non-legislative policies, strategies and charters influencing the sustainable management of Australia's forests, July 2011 to June 2016

Jurisdiction	Non-legislative policy, strategy or charter	Purpose
National		
	National Forest Policy Statement	Outlines agreed objectives and policies for Australia's public and private forests, based on 11 national goals to be pursued within a regionally based planning framework that integrates environmental and commercial objectives so that provision is made for all forest values, including opportunities for effective public participation in decision making.
	National Indigenous Forestry Strategy	Encourages Indigenous participation in the forest industry and contributes to the overall sustainable development of Indigenous land and communities, addressing areas such as natural resource management, business development, cultural heritage, education, employment and training.
	Australian Forestry Standard (AS 4708-2007) *The Australian Standard for Sustainable Forest Management* (AS4708-2013)	Provides criteria and requirements from a credible standard which allows a forest manager to demonstrate sustainable forest management, including proactive stakeholder engagement, through independent, accredited, third-party certification.
	Australia's Native Vegetation Framework	Guides the ecologically sustainable management of Australia's native vegetation. Guides government, the community and the private sector, and engage all Australian and Indigenous peoples, in native vegetation management across Australia.
	Australia's Biodiversity Conservation Strategy 2010–2030	Provides a guiding framework for conserving Australia's biodiversity over the coming decades for all sectors – government, business and the community – by engaging all Australians – the public, businesses, Indigenous peoples, private landholders, non-government organisations and all levels of government.
	Australia's Strategy for the National Reserve System 2009–2030	Provides national guidance for improved cross-jurisdictional coordination, and supports collaborative action by protected area managers and key stakeholders to enhance the National Reserve System, including through strengthened partnerships and increased community support.
ACT		
	Nature Conservation Strategy 2013–2023	Guides a coordinated and integrated approach to nature conservation for all land management, planning, business and community sectors in the ACT, for the management of open spaces, rural and urban areas, riverine corridors and nature reserves, including strengthening community engagement in nature conservation.
NSW[a,b]		
	Environment Protection Authority *Crown Forestry Compliance Strategy 2013–2016*	Provides a comprehensive and transparent framework for regulating the environmental impacts of forestry operations in State forests and on other Crown timber lands.
	Forestry Corporation of NSW *Forest Management Policy*[c]	Provides a commitment to sustainably manage its plantation and native forest estate to produce a range of forest products, services and environmental benefits, and to create opportunities to engage with affected and interested stakeholders to understand their views and inform decisions made about management of the forest estate.
NT		
	Territory Natural Resource Management Plan	Promotes a shared vision that draws together the activities of all involved in natural resource management in the Territory. Provides clear strategies and goals for the management of the unique natural resources across the NT, which draws on scientific, Indigenous and community-based knowledge.

Continued

Continues

Jurisdiction	Non-legislative policy, strategy or charter	Purpose
Qld		
	Department of Agriculture and Fisheries, Forest Products *Forest Management Policy Statement*	Provides a commitment to a range of measures, including the responsible management of state land allocated to native forest production, and proactively communicating with and considering the views of interested and affected stakeholders.
	Queensland Forest and Timber Industry Plan	Provides an overarching vision of sustained business growth and innovation in Queensland's forest and timber industry through the implementation of specified actions. Strategic priorities include the responsible management of state forests for timber production and other commercial activities, recreation and conservation outcomes, and identifying and engaging with key stakeholders.
SA		
	Forest Industry Strategy: Vision 2050 Strategic Directions 2011–2016	Sets out a vision and targets, articulates key directions and strategies, and identifies major opportunities for industry to work with government and the community to strengthen the development of a sustainable future for the forest industry in South Australia.
	Blueprint for the Future South Australian Forest and Wood Products Industry (2014–2040)[d]	Provides direction for activities to achieve significant economic, social and environmental outcomes, and seeks to build upon key South Australian Government initiatives, including the *Cellulose Fibre Value Chain Study*, the *South East Forestry Partnerships Program*, and the *South Australian Forest Industry Strategy*.
	ForestrySA *Policy for Sustainable Forest Management*	Provides for a commitment to sustainable forest management, compliance with relevant legislative requirements, standards and codes, and proactively engaging and considering the views of stakeholders, and the community.
	No Species Loss: A Nature Conservation Strategy for South Australia 2007–2017	Promotes strategic and creative thinking by government, industry and urban, rural and Indigenous communities about how best to achieve biodiversity conservation and sustainable management in South Australia, through engagement partnerships.
Tas.		
	Permanent Native Forest Estate Policy[e]	Aims to maintain an extensive and permanent native forest estate to ensure that Tasmania's native forests are maintained in the long-term for all their various conservation, production and amenity values. The Forest Practices Authority has powers under the *Forest Practices Act 1985* to ensure compliance with this Policy.
	Forestry Tasmania *Sustainable Forest Management Policy and Sustainability Charter*[f]	Provides a commitment to continual improvement and to ensuring that the forest resource is managed sustainably through practices that are environmentally sound, socially acceptable and economically viable.
Vic.[g]		
	Sustainability Charter for Victoria's State Forests	Sets objectives for the sustainability of public native forests and of the timber harvesting industry on public land in Victoria, and promotes community involvement in how state forests are managed to enhance their diverse values and uses.
	VicForests *Ecologically Sustainable Forest Management Policy*	Provides a commitment to ensuring that state forests vested in the care of VicForests are managed to the highest possible standards to support the range of interests and rights of all stakeholders, and commits to stakeholder engagement.
	Environmental Sustainability Framework	Establishes three fundamental directions to drive environmental sustainability in Victoria: maintaining and restoring natural assets, using resources more efficiently, and reducing everyday environmental impacts.
	Timber Industry Action Plan	Provides the conditions for a productive, competitive and sustainable timber industry, and for a new strategic approach to biodiversity management.
WA		
	Forest Products Commission *Forest Management Policy*	Commits the commission to ensuring that renewable timber resources are managed sustainably through the implementation of forest management practices that are environmentally sound, socially acceptable and economically viable. Also commits to liaising with internal and external stakeholders on forest management issues and performance.

a In August 2016, the NSW government released its *NSW Forestry Industry Roadmap*. A whole-of-government approach for reforming the NSW forestry industry with the aim of ensuring the forestry industry is economically viable and sustainable into the future.

b During the reporting period, *NSW 2021* was implemented as the overarching framework of the NSW Government. *NSW 2021* included goals for protecting NSW's natural environment and a strategic framework for protecting high value conservation land, native vegetation, biodiversity and water habitats.

c The *Forest Management Policy* is one of four elements with the Forestry Corporation of NSW 'Sustainability Framework' that sets out priorities in terms of environmental, community, staff and business sustainability.

d A *South Australian Forest and Wood Products Industry Policy Statement* was the first step in implementing recommendations from the *Blueprint for the Future South Australian Forest and Wood Products Industry 2014 to 2040*. The statement reaffirmed the South Australian Government's commitment to the management of South Australia's plantation forests for all South Australians.

e A full review of Tasmania's *Permanent Native Forest Estate Policy* from 2015 to 2017 led to the release of an updated version in June 2017.

f From July 2017, Sustainable Timber Tasmania.

g A Forest Industry Taskforce was formed in Victoria in 2015, with major stakeholders aiming to make long-term recommendations to government on the future of the forest industry.

Source: Australian Government Department of Agriculture and Water Resources; Australian Government Department of the Environment and Energy; state and territory agencies.

Public participation and awareness

Australia has well-established non-legislative mechanisms for public participation and for raising awareness of forest management planning (Table 7.5), in addition to those prescribed in legislation (see Indicator 7.1a). These non-legislative mechanisms include the provision of information on forest resources, impacts, uses and values; discussion papers on alternative plans; invitations to provide comment or written submissions; and discussion forums and public meetings.

At the national level, the Australian Government coordinates the *Australia's State of the Forests Report* series and the *Australia State of the Environment* report series, which provide periodic status updates based on available information for defined reporting periods. Key online sources of national forest information include the Forests Australia website[359], the Forest Learning website[360], and the Forest Education Foundation website[361].

All public forest management agencies publish forest-related information, such as annual reports and technical papers on research and matters of interest, and seek community engagement on issues of community concern. Some states and territories also publish their own state of the forests (or equivalent) reports (see Indicator 7.1d).

Many public forest management agencies provide forest education and awareness resources, and run formal education and awareness programs for schools, community groups and the general public. Examples of these resources and programs in New South Wales include those provided by the Office of Environment and Heritage[362] and the National Parks and Wildlife Service[363]. As well, the Forestry Corporation of NSW[364] runs curriculum-aligned school excursions at Cumberland and Strickland State forests; between 2,271 and 3,585 children undertook excursions to these forests each financial year during the period 2011–16.

Many public forest management agencies also maintain visitor information centres, promoting public participation, education and awareness. Examples of these include those provided by ForestrySA in South Australia, at the Mt. Crawford Forest Information Centre and the Kuitpo Forest Information Centre.

Government agencies also engage in lengthy public consultation processes. For example, South Australia's Primary Industries and Regions SA (PIRSA) worked closely with stakeholders from industry and the local communities to determine a way forward for the state's Mid North Forests, an area regarded as the birthplace of plantation forestry in Australia. Bushfires destroyed 427 hectares of commercial plantations at Bundaleer in 2013 and 1,776 hectares of commercial plantations at Wirrabara in 2014. PIRSA sought and evaluated proposals from stakeholders for a range of commercial and recreation activities for the future of these forest areas.

A broad range of community volunteer programs that encourage public participation in, and raise awareness of, environmental management issues affecting forested landscapes are facilitated and supported in various ways by local, state, territory and Australian governments. Programs work towards rectifying environmental issues through a range of management activities including tree planting, wildlife and water quality monitoring, protection of soil from erosion, and the control of pests and weeds. Examples include Landcare, ParkCare, and regional catchment groups, such as those supported by the Australian Capital Territory Government Environment, Planning and Sustainable Development Directorate.

Nationally coordinated associations such as Australian Forest Growers represent and promote private forestry and commercial tree growing interests around Australia. Active branches in each of the states promote awareness and education in forests to landholders and the community through field days, conferences and promotional material.

Indigenous community participation and awareness

Raising awareness and increasing Indigenous community participation in forest management is encouraged as a key objective of the *National Indigenous Forestry Strategy*[365] (see also Indicator 6.4c). The strategy specifically encourages Indigenous community participation in the forest and wood products industry by forming business partnerships that provide long-term benefits both to Indigenous communities and to the forest and wood products industry. The level of Indigenous community participation varies between states and territories and organisations.

The Forestry Corporation of NSW (FCNSW) employs an Aboriginal Partnerships Liaison Team to work with Aboriginal communities throughout NSW state forests, to conserve the qualities and attributes of places that have spiritual, historic, scientific or social value. FCNSW has worked in partnership with Aboriginal communities for many years on a range of activities including carrying out cultural heritage surveys; jointly managing culturally significant sites; providing forest products for cultural purposes, such as bark for canoes; and developing a First Peoples interpretative walk (see also Indicator 6.5d).

The NSW National Parks and Wildlife Service (NPWS) is also committed to working in collaboration with local Aboriginal groups to manage New South Wales national parks and reserves. One example is through Aboriginal joint management of national parks and reserves, sharing responsibility for management by having the opportunity to participate in planning and decision making. Many New South Wales national parks and reserves are now managed in this way, with Aboriginal management facilitated by an Aboriginal Joint Management Network.

Indicators 6.4a and 6.4c report on the level of Indigenous management, use and rights on Australia's forests.

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359 www.agriculture.gov.au/abares/forestsaustralia
360 forestlearning.edu.au/
361 www.forest-education.com/
362 www.environment.nsw.gov.au/education-resources
363 www.nationalparks.nsw.gov.au/education-services
364 Until January 2013, Forests NSW.
365 www.agriculture.gov.au/forestry/policies/nifs

Monitoring of compliance with forest management codes and systems

The monitoring of compliance with forest management codes of practice, and with the regulatory framework deriving from state and territory legislation, is generally conducted by regionally based officers and field staff within an agency that has responsibility for enforcement and compliance. The highest levels of monitoring occur for wood harvesting in Australia's multiple-use public forests.

State agencies responsible for wood production from native forests give high priority to compliance with legislation, regulations, management plans, and codes of practice in their management of multiple-use public forests. Accordingly, compliance is generally high. In addition, most of these agencies are externally regulated.

Tasmania's forest practices system operates with the objective of achieving sustainable management of public and private forests, with due care for the environment. The forest practices system was set up through the *Forest Practices Act 1985*. Tasmania's Forest Practices Authority (FPA), an independent statutory body established under this Act, is responsible for monitoring compliance under Tasmania's forest practices system, and taking appropriate enforcement action. Monitoring of compliance under Tasmania's forest practices system is carried out at three levels:

1) Routine monitoring of operations is undertaken by Forest Practices Officers[366] employed by forest managers. This level of monitoring is often included in formal environmental management systems and forest management certification, which also involve independent third-party audits.
2) Formal reporting on compliance is required for all Forest Practices Plans (FPPs) under section 25A of the *Forest Practices Act 1985*. This is performed by Forest Practices Officers.
3) Independent monitoring of a representative sample of FPPs, in accordance with the *Forest Practices Act 1985*, is performed annually by the FPA.

Under the *Forest Practices Act 1985,* certificate of compliance reports must be lodged with the FPA within 30 days of the completion of each phase of operations prescribed within a Forest Practices Plan (see Case study 7.3). FPA monitoring showed that the compliance rate rose steadily after the introduction of the Forest Practices Code, and remained within the range of 85–95% over the 15 years to 2012 (Wilkinson et al. 2014).

The New South Wales Office of Environment and Heritage (OEH), which works with the NSW Environment Protection Authority (EPA), has wide monitoring and compliance responsibilities under the NSW *Native Vegetation Act 2003*. The EPA also administers NSW Forest Agreements and Integrated Forestry Operations Approvals (IFOAs), under which the native forest operations of the Forestry Corporation of NSW are regulated. The NSW EPA's *Crown Forestry Compliance Strategy 2013–2016* provides the framework for regulating the environmental impacts of forest operations in State forests and on other Crown timber lands. The results of compliance audits on these land tenures are compiled annually and tabled in the NSW Parliament. FCNSW also has legal instruments in place to monitor and penalise people who conduct authorised and unauthorised operations on State forests and other Crown land.

Private native forestry (PNF) in New South Wales is defined as the management of native vegetation on privately owned land to obtain forest products on a sustainable basis. Under the NSW *Native Vegetation Act 2003*, harvesting and associated forestry operations conducted for the purposes of PNF requires an approved PNF Property Vegetation Plan (PVP). PNF operations under a PVP must be conducted in accordance with the NSW PNF Code of Practice, which also requires detailed forest operation plans and annual reporting by landholders, and EPA audits of forest operations. During 2013–14, the EPA undertook 69 operational inspections and 74 audits of PNF operations. Twenty-two reports about non-compliance or unauthorised PNF operations were received and investigated by the EPA during the period.

The NSW Department of Primary Industries Plantations Assessment Unit monitors compliance of plantations operations with the regulatory framework established under the *Plantations and Reafforestation Act 1999* and the *Plantations and Reafforestation (Code) Regulation 2001*. During the period 2011–16, the Plantation Assessment Unit conducted a total of 106 audits; 50 of these were conducted on plantations managed by Forestry Corporation of NSW, and 56 were conducted on privately managed plantations.

VicForests is the Victorian government business with responsibility for the sustainable harvest and commercial sale of wood from defined areas of Victoria's State forests. The Department of Environment, Land, Water and Planning[367] (DELWP) is the environmental regulator responsible for conducting audits of commercial wood harvesting activities in Victoria's state forests. DELWP has the responsibility for ensuring that all wood harvesting operations are undertaken in compliance with relevant legislation and with Victoria's *Code of Practice for Timber Production 2014*. Compliance is required under the *Conservation, Forests and Lands Act 1987*.

The Victorian forest audit program is designed to allow for the independent examination of a range of activities associated with wood harvesting. The audit program also aims to assess the effectiveness the state's regulatory framework and the effectiveness of the DELWP as the regulator.

In Queensland, under the *Forestry Act 1959*, application of a code of practice for production forestry is a condition attached to sales permits from Crown land, and from some freehold land where forest consent areas exist. Monitoring of compliance is conducted through audits by the Forest Products division, Department of Agriculture and Fisheries[368], and by the Queensland Parks and Wildlife

366 The FPA accredits Forest Practices Officers, who have legislative authority under the *Forest Practices Act 1985* to undertake compliance and enforcement activities across all tenures under the Act or the *Forest Practices Code 2015*.

367 Until January 2015, the Department of Environment and Primary Industries.

368 Before February 2015, the Department of Agriculture, Fisheries and Forestry.

Service, as the custodians of State forests and timber reserves in Queensland.

In Western Australia, monitoring of compliance in forest management is prescribed in the *Forest Management Plan 2014–2023*[369], which was prepared under the *Conservation and Land Management Act 1984* for land vested in the Conservation Commission of Western Australia[370]. Under the plan, the Western Australian Department of Parks and Wildlife[371] and the Forest Products Commission, in consultation with the Conservation and Parks Commission of Western Australia, develop an annual audit program to monitor the extent to which land to which the plan applies is managed in accordance with the plan. The Conservation and Parks Commission of Western Australia also undertakes independent audits to assist it in assessing the extent to which land is managed in accordance with the plan.

Monitoring management of nature conservation reserves is generally less intensive than monitoring of multiple-use public forests. The exception is Tasmania, which is the only state or territory with a code of practice for the management of nature conservation reserves — the *Tasmanian Reserve Management Code of Practice* (2003) (see Indicator 7.1a). Enforcement of legislation and regulations on reserved land in Tasmania is primarily conducted by authorised officers in the Tasmanian Parks and Wildlife Service, who coordinate compliance activities throughout the state with respect to breaches of legislation on reserved land.

Certification of forest management

Forest management certification is the voluntary, independent assessment of forest management activities and operations in a particular area of forest against a credible standard that has criteria, requirements and indicators encompassing environmental, economic, social and cultural values. Certification schemes can require forest management practices to be more stringent than required by law alone. Forest certification assures consumers, governments and enterprises that the forest and wood products they buy are legally harvested from sustainably managed forests. It also provides for community consultation in the management of forests covered by certification.

The certification of the management of a forest area is carried out by an accredited, third-party certification body against standards set out by a forest certification scheme. Two forest certification schemes operate in Australia: the Australian Forest Certification Scheme (AFCS), renamed the Responsible Wood Certification Scheme (RWCS) in November 2017[372], and a scheme operated by the Forest Stewardship Council (FSC)[373]. Both the AFCS/RWCS and the scheme operated by FSC Australia have forest management standards and chain-of-custody standards. Forest management standards establish thresholds for sustainable forest management through a range of economic, social, environmental and cultural criteria and requirements for wood production in native and plantation forests. A chain-of-custody standard has criteria and requirements to assess the process for tracking wood and forest products originating in certified forests through all phases of ownership, transportation and manufacturing, from a defined forest area to the final product and delivery to the consumer.

The area of forest certified in Australia under either scheme has remained relatively stable since 2008–09, except for the years 2015–16 and 2016–17 (Figure 7.3). At June 2018, a forest area of 8.8 million hectares was covered by RWCS certification, and 1.2 million hectares by FSC certification. Approximately 1.1 million hectares of forests are certified under both certification schemes; allowing for this overlap, as at June 2018 a combined forest area of 8.9 million hectares was covered by forest management certification in Australia.

Changes in the procedure used by the Queensland Department of Agriculture and Fisheries to account for leasehold land within its Defined Forest Area[374] (DFA) resulted in this DFA increasing from 3.8 million hectares to 20.6 million hectares in early 2015 and 17.9 million hectares in late 2016, before decreasing to 3.0 million hectares in early 2017. These changes were reflected in the area of forest reported as certified across Australia under the AFCS/RWCS, which increased from 10.4 million hectares in June 2015 to 26.7 million hectares in June 2016 and 24.1 million hectares in June 2017, before decreasing to 8.8 million hectares in June 2018 (Figure 7.3).

At June 2018, a total of 189 chain-of-custody (CoC) certificates were issued under the RWCS, and 258 CoC certificates were issued under the FSC scheme (Figure 7.4). The number of CoC certificates issued under the FSC and AFCS/RWCS peaked in 2013–14 and 2014–15 respectively, and has gradually decreased since then (Figure 7.4). This decrease is partly due to some forest managers consolidating their CoC certificates for wood originating from multiple certified forest sites into a single CoC certificate.

In addition to forest certification, most multiple-use public forests and some private forests and plantations are managed in accordance with codes of forest practice (see Indicator 7.1a), as well as recognised environmental management systems (EMSs). EMSs are independently certified by accredited, third-party certification bodies to the International Organization for Standardization (ISO) standard 14001 *Environmental Management Systems—Requirements with Guidance for Use*. An EMS under ISO 14001 is a tool for

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369 And the prior *Forest Management Plan 2004–2013*.

370 From October 2015, the Conservation and Parks Commission of Western Australia.

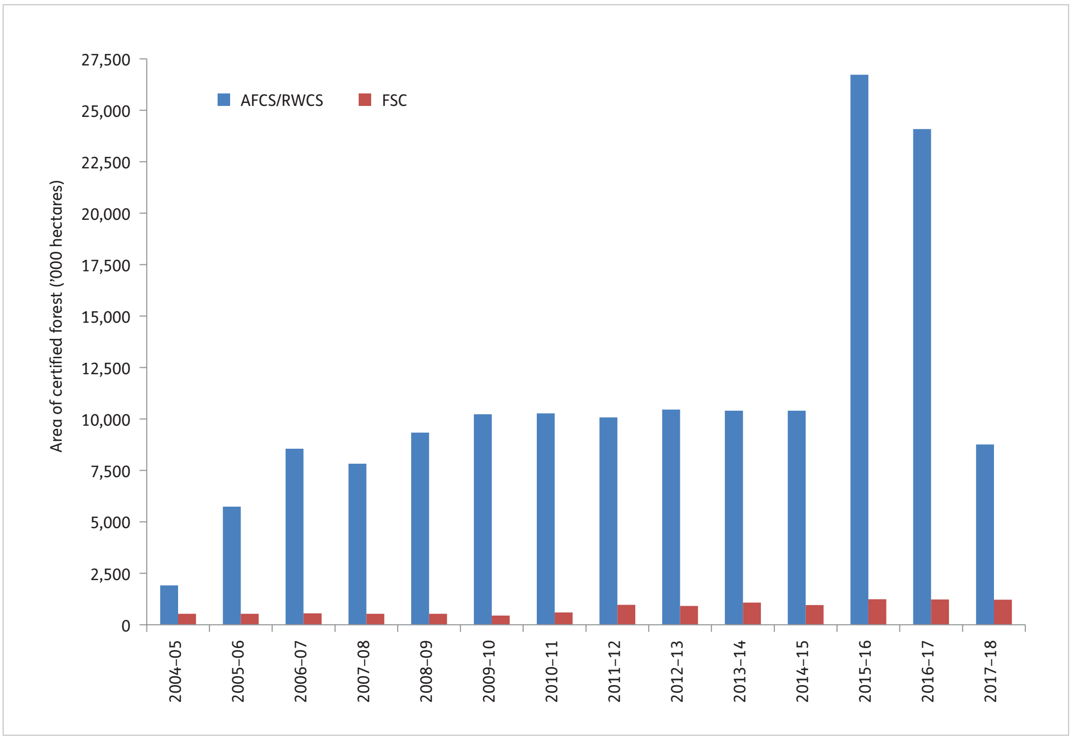
371 From July 2017, the Department of Biodiversity, Conservation and Attractions.

372 www.responsiblewood.org.au/

373 au.fsc.org/en-au

374 "Defined Forest Area" is defined in the Australian Standard for Sustainable Forest Management AS 4708-2013 (www.responsiblewood.org.au/standards/australian/australian-standards-4708-forest-management/) as "An area of forest (including land and water) to which the requirements of this Standard are applied, and to which the forest manager can demonstrate management control, which allows them to achieve the requirements of this Standard".

Figure 7.3: Area of certified forest management in Australia, 2003–18



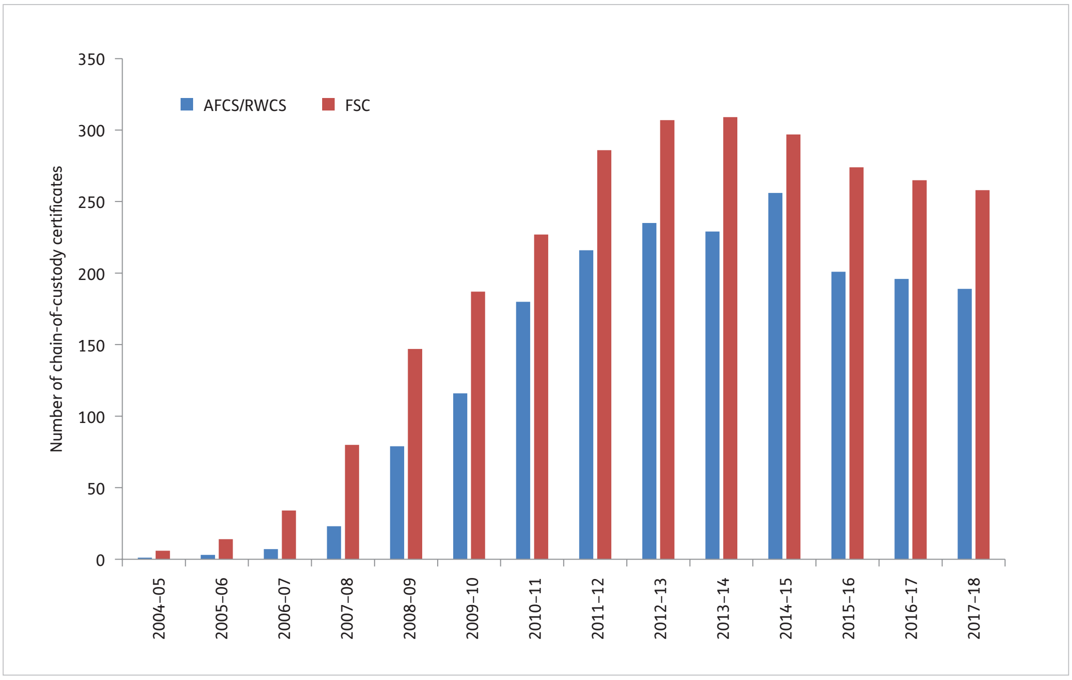
AFCS, Australian Forest Certification Scheme; RWCS, Responsible Wood Certification Scheme; FSC, Forest Stewardship Council.

Note: AFCS/RWCS numbers are for June each year. FSC numbers are for March 2004, January 2005, February 2006, March 2007, January 2008–2011 and June 2012–2018. Some areas of forest have both AFCS/RWCS and FSC certification.

Source: AFCS, RWCS, Forest Stewardship Council (FSC) International.

The data used to create this figure, together with other data for Indicator 7.1b, are available in Microsoft Excel via www.doi.org/10.25814/5bda99c8d76da

Figure 7.4: Chain-of-custody certificates issued in Australia, 2004–18



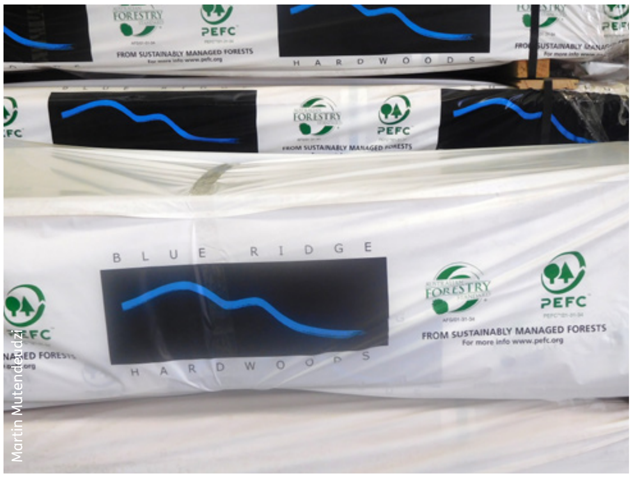
AFCS, Australian Forest Certification Scheme; RWCS, Responsible Wood Certification Scheme; FSC, Forest Stewardship Council

Note: AFCS/RWCS numbers are for June for each year. FSC numbers are for January 2005, February 2006, March 2007, January 2008–2011 and June 2012–2018.

Source: AFCS, RWCS, Forest Stewardship Council Australia.

The data used to create this figure, together with other data for Indicator 7.1b, are available in Microsoft Excel via www.doi.org/10.25814/5bda99c8d76da

Chain-of-custody certified hardwood sawlog, Eden, NSW.



Certified timber, Blue Ridge Sawmill, Eden, NSW.

managing the impacts of an organisation's activities on the environment, and provides a structured approach to the planning and implementation of environmental protection measures. Some public agencies and private forestry companies have EMSs in place alongside forest management certification.

Human resources and education

A range of options for training and educational qualification continues to be available in Australia across areas relevant to sustainable forest management. The levels of training and education available include operational competency certificates, coursework certificates and diplomas, and graduate and postgraduate degrees.

Tertiary education

The Southern Cross University offers the undergraduate forestry degree 'Bachelor of Forest Science and Management'. The Australian National University undergraduate course 'Bachelor of Science (Forest Sciences)' ceased to be offered during the reporting period, but that university continues to offer post-graduate courses and forestry-related subjects as part of environmental science courses. The University of Melbourne offers a Forest Science major as part of a Bachelor of Science and a Bachelor of Science (Extended). Post-graduate forest-related degrees are also offered at each of the above universities, and at the University of the Sunshine Coast. These degrees and postgraduate degrees (including graduate diplomas) continue to deliver graduates in forest-specific and forest-related study areas.

Over time, there has been a decreasing trend in undergraduate degree completions, and an increasing trend in postgraduate degree completions (Figure 7.5).

Fellowships and awards also provide professional development opportunities in the forest industry. The Joseph William Gottstein Memorial Trust Fund was established in 1971 as a national education trust to promote the development of Australia's forestry and forest products industry. The fellowship and award programs provided by the Gottstein Trust enable people working in the forestry and forest products industry to acquire knowledge and skills that benefit themselves, their employers and the industry as a whole. The Gottstein Forest Industry Scholarship is for undergraduate or postgraduate students studying approved courses in forestry, forest science or wood science[375].

Vocational education and training

The ForestWorks Industry Skills Council (ForestWorks) is an industry-owned, not-for-profit organisation offering skills development services for the forestry industry and the wood and paper products industry. ForestWorks is also contracted by the Australian Government to develop, maintain and continuously improve the Forest and Wood Products (FWP) (formerly Forest and Forest Products) training package and the Pulp and Paper Manufacturing Industry (PPM) training package. These packages offer vocational education and training in technical qualifications at certificate level and at diploma level, to support those sectors of industry.

Course enrolments in government-funded Vocational Education and Training (VET) across both training packages were stable for several years up to 2011, then in 2012 enrolments decreased by 40%. Enrolments declined by a further 12% in 2013, to levels below half of the 2011 enrolments. This decline in enrolments was in line with the decline in overall apprenticeship and traineeship commencements across all industries in Australia after 2011. Tighter budgets led to reduced demand for training with accredited qualifications, with more focus on informal in-house approaches to skill development not requiring external payments to service providers. Industry also

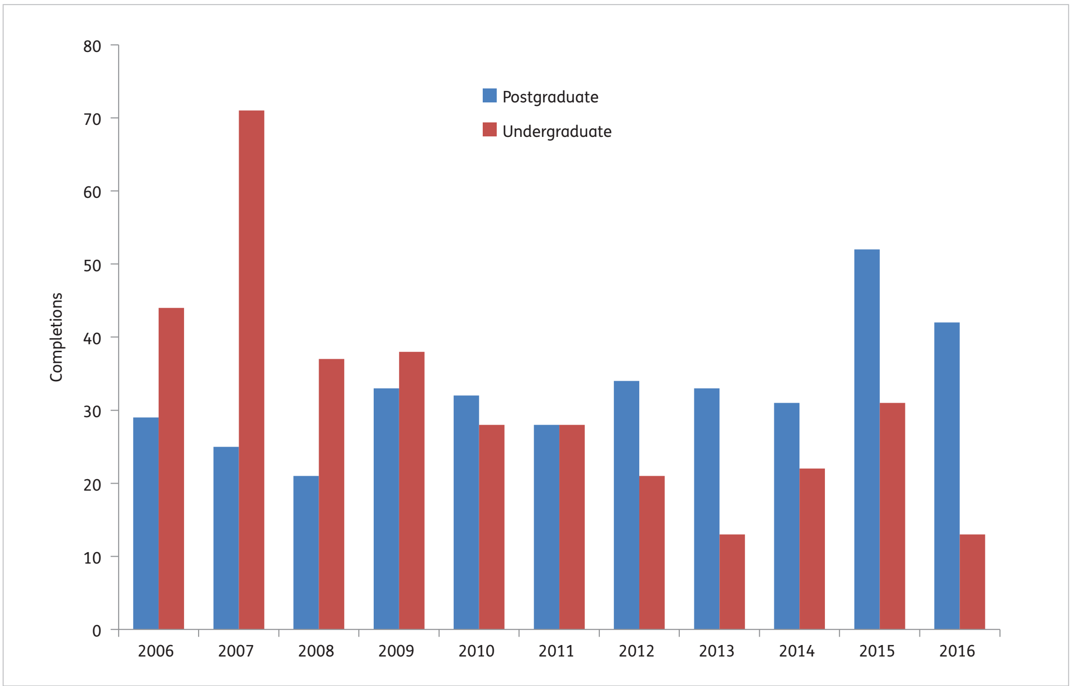
375 gottsteintrust.org/

developed an increased preference for fee-for-service short courses and training in a broader range of skills than the technical skills previously delivered by registered training organisations. Such training is not captured by the National Centre for Vocational Education Research (NCVER) data collection (ForestWorks 2016).

As a result of these changes, several Technical and Further Education (TAFE) institutions removed or reduced their offerings of Forest and Forest Products qualifications. However, despite the significant reductions in enrolments in the FWP and PPM training packages, course completions have remained reasonably stable (Table 7.8), demonstrating a sustained level of interest in improved skills in the workforce. From 2016, the NCVER excluded all "fee-for-service" activity (including that delivered by TAFE and other government providers) from the scope of the "government-funded activity" data that it publishes, and only data for training activity funded by Commonwealth and state and territory governments are published. Data according to the new scope have been back-dated to 2003 (Table 7.8) (NCVER 2017), and so these completion data differ from those published in SOFR 2013.

In Tasmania, the not-for-profit Arbre Forest Industries Training and Careers Hub was launched in March 2016. This organisation was created to promote careers within the forest industry, by providing a clear entry and learning path for potential employees, and by introducing potential employees to employers.

Figure 7.5: Australian university degree completions in forest-related studies, 2006–16



Note: Postgraduate degree completions include graduate diplomas.

Source: Australian Government Department of Education and Training, Higher Education Statistics Collection, 2017.

The data used to create this figure, together with other data for Indicator 7.1b, are available in Microsoft Excel via www.doi.org/10.25814/5bda99c8d76da

CRITERION 7

7.1b

Case study 7.3: Monitoring and compliance of native forest operations in Tasmania, 2011–16

Tasmania's Forest Practices Authority (FPA) has legislative authority to investigate and measure compliance against Tasmania's legal forest management instruments. The FPA undertakes annual audits of forest practices plans (FPPs), and investigates all potential breaches under the *Forest Practices Act 1985*. Under the *Forest Practices Act 1985*, the FPA must investigate all complaints relating to alleged breaches or poor practice (Table 7.6). It has the authority to apply sanctions where breaches of the *Forest Practices Code 2015* have been identified. Formal legal investigations by the FPA are undertaken into serious breaches, sometimes in consultation with the Tasmanian Police. The majority of breaches can generally be attributed to human error or lack of knowledge about the requirements of the forest practices system, and are dealt with by 'corrective actions'.

Under the *Forest Practices Act 1985,* certificate of compliance reports must be lodged with the FPA within 30 days of the completion of each phase of operations prescribed within a FPP (Table 7.7). Certificate of compliance reporting provides evidence that a FPP:

- fully complied with all provisions of the plan; or
- did not fully comply with all the provisions of the plan, with:
  - no further action required. This generally involves a change in the operation which did not result in adverse long term environmental harm
  - the matter being resolved through corrective action. This generally means a non-compliance was detected, a notice of compliance was issued, and a corrective action was taken to ensure compliance with the plan
  - further action required. This generally involves a non-compliance issue that requires further investigation and action by the FPA.

Generally, the level of compliance has been high, with the majority of operations not requiring a corrective action or further investigation for the reporting period 2011–2016.

Table 7.6: Number of investigations completed by the Forest Practices Authority 2011–12 to 2015–16

Year	Total number of formal investigations	Investigated and no breaches identified	Number of minor breaches	Number of major breaches
2011–12	92	25	52	15
2012–13	36	10	17	9
2013–14	55	17	30	8
2014–15	44	12	26	6
2015–16	32	11	12	9

Notes: Minor breaches include notices to rectify and warnings, but no further action. Major breaches include penalties, legal action and breaches where no action was pursued due to insufficient evidence and/or legislative time constraints.

This table, together with other data for Indicator 7.1b, is available in Microsoft Excel via www.doi.org/10.25814/5bda99c8d76da

Table 7.7: Certificates of compliance lodged with the Forest Practices Authority

				Compliance of lodged certificates			
					Not fully complied		
Year	Certificates of compliance due	Certificates of compliance lodged	No activity	Fully complied	No further action required	Corrective action required	Further investigation required
2011–12	970	835	n.d.	702	122	2	8
2012–13	747	696	29	591	66	0	10
2013–14	1270	1096	71	928	85	2	9
2014–15	1079	1056	78	834	134	1	9
2015–16	1609	1371	108	1240	100	2	6

n.d., no data

Notes: Data prior to 2013 report on lodgement of final certificates of compliance only. Data from 2013 onwards report on individual discrete operational phases, e.g. roading, harvesting or reforestation, which may all be covered by the one forest practices plan. 'No activity' was added as a category in 2012–13 to reflect instances where an FPP expired and no operations took place.

This table, together with other data for Indicator 7.1b, is available in Microsoft Excel via www.doi.org/10.25814/5bda99c8d76da

Table 7.8: National completions in government-funded forestry-related vocational education and training (VET), 2006–16

Jurisdiction	VET Program	Completions										
		2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
ACT	FWP	0	0	0	0	0	0	0	0	0	0	0
	PPM	0	0	0	0	0	0	0	0	0	0	0
NSW	FWP	111	56	72	63	76	101	114	37	68	37	39
	PPM	0	2	0	0	0	0	0	0	3	32	0
NT	FWP	10	0	0	2	0	0	0	0	0	0	0
	PPM	0	0	0	0	0	0	0	0	0	0	0
Qld	FWP	25	20	9	17	191	230	83	23	27	138	71
	PPM	0	0	0	0	0	0	0	0	0	0	0
SA	FWP	28	2	25	21	10	26	10	14	3	17	22
	PPM	0	0	0	0	0	0	0	0	0	0	0
Vic.	FWP	55	33	47	28	83	47	195	204	105	75	93
	PPM	0	0	0	0	0	0	14	0	0	0	0
Tas.	FWP	64	40	52	69	44	34	22	2	3	17	27
	PPM	0	0	0	0	6	0	0	0	2	0	3
WA	FWP	73	88	90	95	120	56	63	33	48	61	48
	PPM	0	0	0	0	0	0	0	0	0	0	0
Total	FWP	368	227	298	291	527	492	483	314	259	342	301
	PPM	0	2	0	0	6	0	14	0	6	32	3
Grand total		**368**	**229**	**298**	**291**	**533**	**492**	**497**	**314**	**265**	**374**	**304**

FWP, Forest and Wood Products training package; PPM, Pulp and Paper Manufacturing Industry training package.

Notes: FWP includes the former Forest and Forest Products Industry (FPI) training package. Values for 2016 are preliminary (as at 29 June 2018). All values are indicative only, because the National Centre for Vocational Education Research relies on providers to supply data.

Source: National Centre for Vocational Education Research, VOCSTATS, VET program completions 2003–2016 database.

This table, together with other data for Indicator 7.1b, is available in Microsoft Excel via www.doi.org/10.25814/5bda99c8d76da

CRITERION 7

7.1b

Indicator 7.1c

Extent to which the economic framework supports the conservation and sustainable management of forests

Rationale

This indicator examines the extent to which government policies support the conservation and sustainable management of forests. Government policies on investment, taxation and trade influence the level of investment in forest conservation, forest establishment and timber processing.

Key points

- The effectiveness of government policies in promoting conservation and sustainable management of production forests and conservation reserves was assessed as effective or very effective by the *Australia State of the Environment 2016* report.
- At 30 June 2016, the asset value of wood ('standing timber') in Australia's production native forests was estimated by the Australian Bureau of Statistics as $1.8 billion, and the asset value of wood ('standing timber') in Australia's commercial plantations was estimated as $10.2 billion.
  - Throughout the period 2011 to 2016, the value of Australia's total standing timber assets varied between 0.19% and 0.26% of the total value of Australia's environmental assets.
- Bilateral trade agreements signed since 2011 are designed to ensure tariff-free entry for Australia's manufactured wood products into key export markets.
- Between 2010–11 and 2014–15, funding for new commercial plantations was increasingly sourced from institutional investors. Institutions have also been involved in purchases of established commercial plantations.
  - In 2014–15, institutional investors owned 50% of Australia's commercial plantations, compared to 31% in 2010–11. During the same period, farm foresters and other private owners increased their area share of total commercial plantation area from 8% to 21%.
  - This shift reflects the increasing contribution of private investment capital to the growth and development of the sector.
  - Further structural adjustment and consolidation of the sawmill industry also occurred.
  - The domestic softwood sawmill industry is becoming significantly more capital-intensive, and larger in scale.
- Various Australian Government policies and programs that commenced during the reporting period were aimed at reducing greenhouse gas emissions or promoting other environmental services from forests. The Australian Government and various state and territory governments also made investments to improve natural resource management, and encouraged private and community-based involvement in this sector.

In this indicator, 'economic framework' refers to the economic commitments and policy mechanisms of governments that promote the conservation and sustainable management of forests. 'Conservation' refers to the protection of forests to allow ongoing ecosystem functions and maintain the natural and cultural significance of forests (Jackson et al. 2016). 'Sustainable management' refers to the use of natural resources in a way that does not adversely affect the needs and interests of future generations.

Effectiveness of the economic framework

The *Australia State of the Environment 2016* report, published by the Australian Government Department of the Environment and Energy, assessed the effectiveness of government policies in promoting conservation and sustainable management in the period 2011–16. The report rated five categories (understanding, planning, inputs, processes, and outputs and outcomes) across four criteria (production forests, bushfire, management of conservation reserves, and Indigenous-managed lands) (Table 7.9). Production forests, and management of conservation reserves, were rated 'effective' or 'very effective'; bushfire was rated 'effective' except in regards to management inputs; and Indigenous-managed lands were rated 'partially effective' in all categories. The *Australia State of the Environment 2016* report also reported an improving trend in conservation reserve and bushfire planning, and an improving trend in outputs and outcomes for Indigenous-managed lands and bushfire, but a deteriorating trend in management inputs for production forests and conservation reserves.

Value of Australia's environmental assets

The concept of environmental assets can include subsoil assets, both mineral and energy; land; soil resources; timber resources; aquatic resources, both cultivated and natural; water resources; and other biological resources. The Australian Bureau of Statistics defines environmental assets as comprising land; mineral and energy assets; native forest standing timber; and plantation standing timber (ABS 2017a).

The Australian national balance sheet recorded $13,800 billion in assets on 30 June 2016, of which $6,100 billion (44%) were classed as environmental assets (ABS 2016a, 2017a) (Table 7.10). The estimated value of Australia's environmental assets increased in the period 2011 to 2016 (Table 7.10), and is now the largest share of the nation's capital base.

The valuation for 'standing timber' in native forests is based on the net present value of the future stream of income from the estimated net area of forest available for wood production on private and public land, over the estimated rotation cycle of the forests. The discount rate applied is based on the average cost of forest industry borrowing. On this basis, in the 5 years to June 2016, the estimated value of Australia's native standing timber decreased by 5%, to $1.8 billion (Table 7.10).

The valuation for 'standing timber' in commercial plantations is based on an insured asset value that is derived from ABARES data on plantation forest area and plantings, and industry insurance schedules[376]. On this basis, in the 5 years to June 2016, the estimated value of Australia's commercial plantation standing timber increased by 5% to $10.2 billion (Table 7.10).

Since the Australian Bureau of Statistics (ABS) uses different methodologies and assumptions to estimate the asset value of wood ('standing timber') in Australia's native forests and in commercial plantations (ABS 2015a), the valuations for these forestry assets cannot be compared with each other. Moreover, these asset values include only the value of wood available for harvesting, and not the value of other benefits from native forests or plantations, such as biodiversity, carbon sequestration, prevention of soil erosion, or production of non-wood forest products.

Throughout the period 2011 to 2016, the estimated value of Australia's total standing timber assets varied between 0.19% and 0.26% of the total value of Australia's environmental assets.

Table 7.9: Assessment of understanding, planning, inputs, processes, outputs and outcomes associated with conservation and sustainable management of forests, 2011–16

Category	Production forests	Bushfire	Management of conservation reserves	Indigenous-managed lands[a]
		Assessment grade and recent trend[b]		
Understanding	Very effective —	Effective ↑	Very effective —	Partially effective —
Planning	Very effective —	Effective ↑	Effective ↑	Partially effective —
Inputs	Effective ↓	Partially effective —	Effective ↓	Partially effective —
Processes	Effective —	Very effective —	Effective —	Partially effective —
Outputs and outcomes	Effective —	Effective ↑	Effective —	Partially effective ↑

a 'Indigenous-managed lands' is equivalent to the land categories 'Indigenous owned and managed' and 'Indigenous managed' in Indicators 6.4a and 6.4c.
b 'Recent trend' refers to the direction of change at the time of assessment (2016): ↑, improving ; ↓, deteriorating ; —, stable.
Source: *Australia State of the Environment 2016* (Metcalfe and Bui 2017).

This table, together with other data for Indicator 7.1c, is available in Microsoft Excel via www.doi.org/10.25814/5bda99c8d76da

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[376] These schedules are compiled by Australian Forest Growers: www.afg.asn.au.

Table 7.10: Estimated value of environmental assets, 2006–16 ($ billion)

Time point	Land	Mineral and energy assets	Native forest standing timber	Plantation standing timber	Total
June 2006	2,714	229	2.1	7.9	2,953
June 2007	3,096	272	2.1	8.4	3,378
June 2008	3,311	358	2.1	9.7	3,681
June 2009	3,224	604	1.9	9.3	3,840
June 2010	3,896	586	1.8	9.4	4,492
June 2011	3,866	612	1.9	9.7	4,489
June 2012	3,732	772	1.7	9.8	4,515
June 2013	3,910	950	1.6	9.9	4,871
June 2014	4,276	1084	1.6	9.9	5,372
June 2015	4,847	1150	1.7	10.0	6,009
June 2016	5,105	1021	1.8	10.2	6,138

Note: Totals may not tally due to rounding.
Source: ABS (2017a).

This table, together with other data for Indicator 7.1c, is available in Microsoft Excel via www.doi.org/10.25814/5bda99c8d76da

Overview of the economic framework

The World Bank publishes indicators of the general investment environment across countries. These apply to the economy as a whole, and incorporate various regulatory and financial measures, such as property registration, ease of obtaining credit, and the institutional capacity to enforce contracts. On the basis of these indicators, Australia was ranked 15th out of 190 countries in 2016 for the ease of doing business (World Bank 2017).

Australia's strong economic framework can be attributed partly to reforms that increase the competitiveness of Australian products. A key reform was the National Competition Policy (NCP): a program of economic reforms undertaken by all Australian governments between 1997 and 2006 aimed at prohibiting anti-competitive activities and promoting competitive neutrality (NCC 2007). The NCP introduced several reforms that affect the competitive climate for Australian forest-based industries. For example, the principle of competitive neutrality requires commercial state-owned forest entities that compete with private sector entities to be exposed to similar expenses and costs (Ferguson et al. 2010).

Trade policy

Australia's trade policy focuses on trade liberalisation to improve access for Australian exports in global markets, and Australian access to imports. Global and multilateral efforts, including international treaties such as free trade agreements (FTAs), facilitate improved market access. Australia is a member of the World Trade Organization (WTO), which facilitates multilateral trade negotiations and ensures that the rules of international trade are correctly applied and enforced. Australia's rights and obligations under the WTO underpin its market access negotiations, and WTO rights and obligations are a minimum for Australia's bilateral and plurilateral[377] free trade agreements.

Australia entered into four bilateral trade agreements between 2011 and 2016: the Malaysia–Australia FTA (MAFTA) 2013; the Korea–Australia FTA (KAFTA) 2014; the Japan–Australia Economic Partnership Agreement (JAEPA) 2015; and the China–Australia FTA (ChAFTA) 2015.

FTAs reduce barriers to trade and investment, for example by eliminating tariffs and simplifying compliance measures, such as the need to apply for export licences; by liberalising services; and by addressing other issues, such as intellectual property, e-commerce and government procurement.

Japan and China are two of Australia's largest export markets, both for raw commodities and for manufactured products. JAEPA provides tariff-free entry for Australia's wood products, such as medium-density fibreboard, particleboard and structural laminated timber. Before JAEPA, Japan applied general tariffs of up to 30% on some manufactured products. Duty-free access continues for Australian exports of woodchips and paper products to Japan (DFAT 2017a).

ChAFTA locked in existing 0% Chinese tariffs on logs and a range of manufactured products, including woodchips and certain paper products. Tariffs on medium-density fibreboard (MDF) made from radiata pine were eliminated upon this agreement coming into force. Tariffs on some other products will be eliminated from 01 January 2019. Exclusions from tariff concessions also apply to a small number of products considered sensitive in China's economy or culture, including some fertilisers, wood and paper products (DFAT 2017b).

[377] Under WTO rules, all WTO members are party to *multilateral* agreements, but only some members need to be party to *plurilateral* agreements.

Investment in plantations

Significant changes have occurred between 2010–11 and 2014–15 in the ownership structure of the commercial plantation estate. These changes reflect the restructuring towards institutional ownership, and the increasing contribution of private investment capital to the growth and development of the forestry sector.

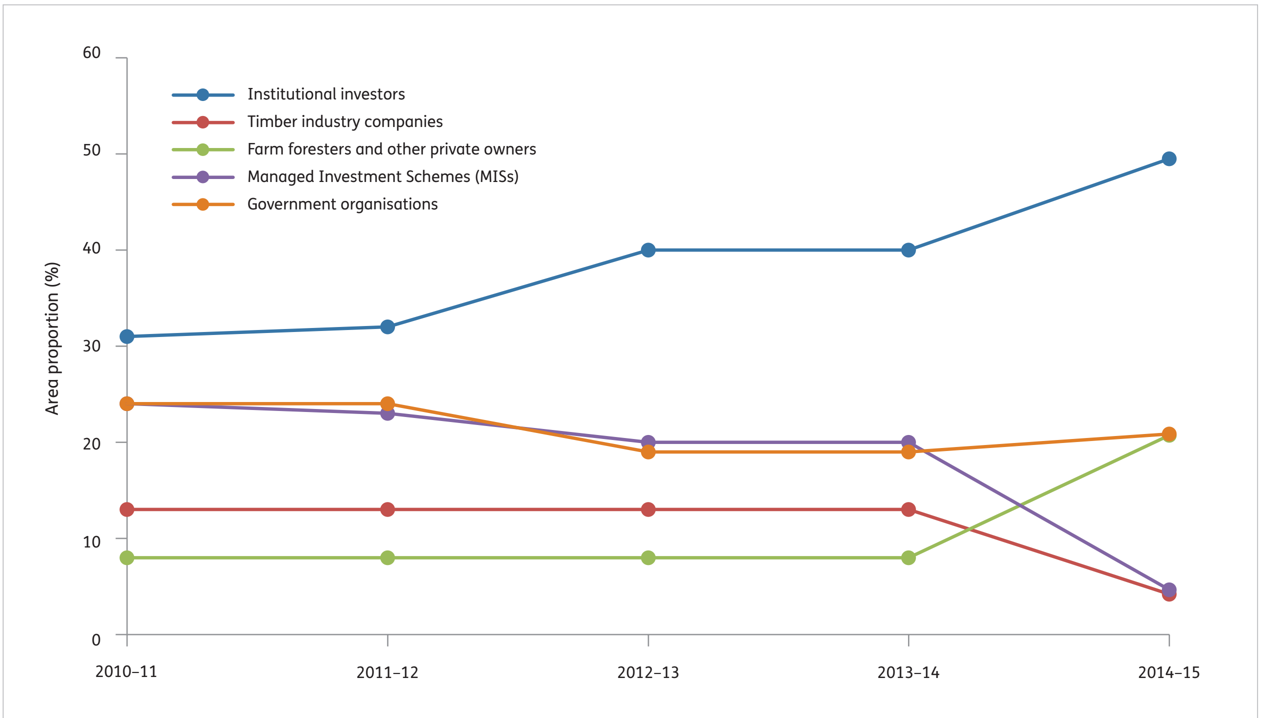
Figure 7.6 shows the change in area proportion of commercial plantations by ownership category (ownership data refer to ownership of trees, not land). In 2014–15, institutional investors owned 50% of Australia's commercial plantations, compared to 31% in 2010–11. During the same period, farm foresters and other private owners increased their area share of total commercial plantation area from 8% to 21%, as a result of plantations that were previously owned by Managed Investment Schemes (MISs) primarily under lease arrangements reverting back to the landowner. In contrast, the proportion owned by timber industry companies fell from 13% to 4%, and the proportion owned by government organisations fell from 24% to 21%.

Following the many challenges faced by agribusiness MISs during the previous reporting period[378], many MIS management companies became commercially unviable. In 2014–15, MISs owned 5% of Australia's commercial plantations, compared to 24% in 2010–11 (Figure 7.6). During this period, ownership of these MIS forestry assets transferred largely to institutional and private investors (including international superannuation funds).

In New South Wales, a number of Forestry Plantation Authorisations were cancelled during the period 2012–13 to 2015–16, and some areas of plantations planned to be established under MISs were converted into other land uses[379]. Some poorly grown plantations were cleared, and the properties converted to agricultural use; a few such plantations had been harvested for woodchip or small logs before cancellation of authorisations. Some of the cancelled authorisations were attached to land that had never been planted.

Indicator 6.2a also discusses investment in new public and private forest plantations, and Indicator 2.1b reports separately on ownership of plantation trees and ownership of plantation land.

Figure 7.6: Change in commercial plantation ownership over time



Notes: Ownership data refer to ownership of trees. Joint venture arrangements between government agencies and private owners are included under 'Government organisations' where government is the manager of the plantation resource. Totals may not tally due to rounding.
Source: Gavran (2013, 2014); ABARES (2016b).

Data for this figure, together with other data for Indicator 7.1c, is available in Microsoft Excel via www.doi.org/10.25814/5bda99c8d76da

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[378] These challenges included the global financial crisis, reduced investor confidence in MISs generally, an inability to raise further capital, and regulatory changes that affected sales of MISs products.

[379] DPI Forestry, Plantation Assessment Unit, February 2017.

Investment in wood processing

The main drivers of current investment in wood processing in Australia are resource availability, forest management practices, and economies of scale. Consolidation of sawmilling operations, driven by the increased sourcing of wood from commercial plantations and a reduction in the availability of logs from native forests, has continued.

The ABARES National Wood Processing Survey 2012–13 (Gavran et al. 2014) reports further structural adjustment and consolidation of the sawmill industry since the 2006–07 and 2010–11 surveys. The number of sawmills in Australia fell significantly between 2006–07 and 2012–13 (by 60% for hardwood sawmills, and by 25% for softwood sawmills). The domestic softwood sawmill industry has become significantly more capital-intensive and larger in scale, which has limited the reduction in total log processing despite the decline in number of sawmills. These adjustments also reflect continued changes in Australia's forest management practices, including further restrictions or reductions in availability of logs from public native forests in some states, tighter regulation of private native forests, and the ongoing privatisation of public plantations.

Forest and Wood Products Australia (FWPA) provides results of its research projects to the forest and wood products industry, including research on hardwood and softwood sawmilling and processing, and research on increasing wood performance and yield. Omega Consulting and FWPA (2017) reported on the level of investment between July 2012 and June 2017 by selected softwood sawmilling, hardwood sawmilling, panel and plywood operations in the timber industry. During this period, a combined total of $473 million was invested by the operations surveyed, across approximately 70 individual processing locations. The report found a high level of focus on scanning and optimisation technologies to support higher recovery, improved productivity and improved grade yield, so as in turn to reduce manual interaction with the materials handling process. Not all capital items were reported as investment in new activities: some capital items were identified as major replacements or upgrades to current plant, and a significant quantity of capital expenditure was associated with replacement or upgrading of product transfer equipment.

Government departments at the national, state and territory levels also administer programs that directly promote investment in wood processing, or provide funding for wood processing enterprises. For example, in October 2013 the Australian Government committed a total of $21.8 million of funding for wood processing projects as part of the Economic Growth Plan for Tasmania. This funding was for several enterprises, including the milling of plywood, and the production of laminated timber and wood panels (DIRDC 2015).

In South Australia, the South East Forestry Partnerships Program (SEFPP), a state government assistance package, allocated $27 million in grants over three rounds between November 2012 and June 2015. SEFPP aimed to encourage a viable and strong timber sawmilling industry and create and secure jobs. Grants were available to applicants who provided a dedicated service to, or were located or intending to locate in, the state's south-east. Primary Industries and Regions South Australia (PIRSA) is overseeing 13 projects that are expected to generate over $63 million of total investment in this region's forestry industry (PIRSA 2017). Most of these projects replace and upgrade existing sawmilling plant and equipment with modern technology and processes to increase processing volumes and improve efficiency. In Victoria, the Regional Growth Fund committed a total of $620,000 in grants to a number of wood processing enterprises in 2013–14 (DSDBI 2014).

Indicator 6.2a also discusses investment in harvesting and wood product manufacturing.

Investment in environmental services

A number of Australian Government policies and programs that commenced during the reporting period and that aimed to reduce Australia's greenhouse gas emissions represent investment in environmental services based on forests and wood products.

The Australian Government established the Clean Energy Finance Corporation (CEFC) in 2012 to invest in the clean energy sector[380]. The CEFC invests commercially in projects with the strongest potential for emissions reduction, including low-carbon electricity generation (such as solar, wind, storage and bioenergy), energy efficiency, and low-emissions technologies (CEFC 2017a).

Since its inception, the CEFC has committed over $1.4 billion in finance to investments in clean energy projects valued at over $3.5 billion. For example, in November 2015 the CEFC provided $100 million towards the Australian Bioenergy Fund (ABF), an equity fund for bioenergy and energy from waste. The ABF will invest in a range of technologies including biomass-to-energy projects (e.g. using plantation timber residues and sawmill waste) and wood pelletisation. The ABF aims to benefit a broad cross-section of the economy, including local government, mining, forestry and agriculture (CEFC 2017b).

In August 2011, the Australian Parliament passed the *Carbon Credits (Carbon Farming Initiative) Act 2011*. The Act established the Carbon Farming Initiative (CFI), a voluntary scheme that allowed eligible farmers and land managers to earn tradeable carbon credits by storing carbon or reducing greenhouse gas emissions on their land. The CFI operated between September 2011 and December 2014, when it was integrated with the Emissions Reduction Fund (ERF)[381] (DoEE 2017a).

The ERF is the central component of the Australian Government's suite of policies designed to reduce emissions, and operates alongside programs such as the Renewable

380 The CEFC is a statutory authority established under the Commonwealth *Clean Energy Finance Corporation Act 2012*. The Act creates the CEFC Special Account that is credited with $2 billion each 1 July, for five years from 1 July 2013.

381 Amendments to the CFI legislation that implemented the ERF came into effect in December 2014.

Energy Target and the National Carbon Offset Standard (DoEE 2017c). The ERF is a voluntary scheme that allows eligible participants to earn Australian carbon credit units for projects that store carbon or avoid emissions. These credits can be sold either to the Government (through a carbon abatement contract) or in the secondary market, to generate income. 'Methods' developed under the ERF define the types of projects that can be undertaken under the ERF, and specify project activities and methodologies for measuring the resulting reductions in emissions. Methods relating to the land sector include plantation forestry, increasing soil carbon, expanding opportunities for environmental and carbon sink plantings, reforestation and revegetation, and protecting native forest or vegetation that is at imminent risk of clearing (CER 2017a, 2017b).

The Australian Government is also contributing to carbon reduction and supporting local environmental outcomes by working with the community to re-establish green corridors and urban forests through planting 20 million trees by 2020. The Government has committed funding of $70 million over six years from 2014–15 to the 20 Million Trees program as part of the National Landcare Program. As at 30 April 2017, $42.9 million has been approved across 166 projects to plant more than 13.4 million trees, with the majority of trees funded to date under the program expected to be planted between 2017 and 2019 (NLP 2017a).

In New South Wales, the Biodiversity Banking and Offsets Scheme, known as BioBanking, which commenced in July 2008, addresses the loss of biodiversity values (including threatened species) due to habitat degradation, land clearing and development. BioBanking is a legislated[382], voluntary scheme that enables landowners and developers[383] who commit to enhance and protect biodiversity values on their land to generate 'biodiversity credits' to offset their operations. These credits can be sold to those seeking to invest in conservation outcomes, including philanthropic organisations and governments. On 25 August 2017, BioBanking was replaced by the Biodiversity Offsets Scheme under the *Biodiversity Conservation Act 2016* (NSW OEH 2017).

Investment to improve natural resource management

Australia's national system of natural resource management has developed over several decades into a unique social and organisational infrastructure involving governments, industry groups, local communities and land managers that implement programs to support natural resource management, including of forests, on privately held lands.

Australian Government investment

Between 2008 and 2013, the Australian Government invested more than $2 billion in the Caring for our Country program. The program provided grants for regional organisations to deliver projects that helped to meet priorities relating to the environmental management of Australia's natural resources. Caring for our Country included Landcare, a national grass-roots movement that started in the 1980s and that consists of groups and individuals focused on sustainable natural resource management. The Caring for our Country and Landcare programs were merged in 2014 to form the National Landcare Program, an Australian Government initiative[384] to support local environmental and sustainable agriculture projects, and to support management practices that maintain or enhance Australia's natural resource base.

The Australian Government invested $1 billion over four years from July 2014 to June 2018 for Phase One of the National Landcare Program, including support for the Landcare Networks, 20 Million Trees program and Australia's 56 regional natural resource management organisations. Local programs funded from 2014–15 to 2016–17 include $15 million to protect threatened bushland in the Cumberland Plain of Greater Western Sydney area, and $3 million to improve the environmental health of Victoria's Dandenong Ranges. The National Landcare Program Phase One also continues investment for programs that commenced before 2014–15, including World Heritage Grants totalling $40 million over 2013 to 2018 for projects to ensure that World Heritage property management is in accordance with the World Heritage Convention commitment. Funding is available for the management of properties including the Tasmanian Wilderness, Greater Blue Mountains, and Gondwana Rainforests of Australia World Heritage Areas.

The Australian Government has also committed to investing more than $1 billion for Phase Two of the National Landcare Program. The majority of this investment will be delivered over a period of five years, from July 2018 to June 2023, and will include a $450 million Regional Land Partnerships component to deliver national priorities at a regional and local level.

As the funding towards Caring for our Country was not all designated for specific areas, it is difficult to estimate the total investment in forest management. However, investment data is available on in the Environmental Stewardship Program (ESP) (see Case study 7.4) that was developed as part of the Caring for our Country program, and that continues under the National Landcare Program. The ESP provides long-term support for private landholders to maintain and improve the condition of targeted matters of national environmental significance. The total area managed under the ESP is 52,123 hectares across various threatened ecological communities, including forests, in New South Wales, South Australia and Queensland. Total payments between 2011–12 and 2015–16 to ESP grantees were $59.4 million.

[382] The scheme is implemented through Part 7A of the *Threatened Species Conservation Act 1995*, the Threatened Species Conservation (Biodiversity Banking) Regulation 2008 and the BioBanking Assessment Methodology.

[383] As well as other organisations, including government agencies such as NSW Roads and Maritime Services.

[384] Jointly administered by the Australian Government Department of the Environment and Energy and the Department of Agriculture and Water Resources.

Case study 7.4: Environmental Stewardship Program and Box Gum Grassy Woodland Monitoring Project

In 2007–08, the then Australian Government Department of Sustainability, Environment, Water, Population and Communities[385] developed the Environmental Stewardship Program (ESP). The objective of the program is to maintain and improve the extent and condition of targeted matters of national environmental significance under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*.

Participating land managers are contracted for up to 15 years to conduct management activities to protect and enhance the condition of the threatened ecological community(s) on their land. Activities may include grazing management, weed and pest animal control, and maintenance of buffer zones. Land managers are required each year to submit annual progress reports that include the results of monitoring undertaken. The Box Gum Grassy Woodland ecological community, which is listed as critically endangered, was the first matter of National Environmental Significance targeted by the ESP.

The Australian National University (ANU) has established a network of long-term biodiversity monitoring sites on 157 properties in New South Wales and Queensland.

The ANU is funded to manage areas of Box Gum Grassy Woodland under the first four rounds of the ESP, and has been monitoring the condition of these sites since 2010. The main objective of the ANU monitoring is to develop a large-scale, long-term dataset which can highlight the influence of the ESP on the current and future condition of the Box Gum Grassy Woodland ecological community and its associated fauna.

Interim and annual reports[386] document the progress and results of the ANU Environmental Stewardship BGGW (Box Gum Grassy Woodland) Monitoring Project. The 2016 annual report is positive, stating that overall, the "ESP represents the most comprehensive, cost-effective, and rigorously designed agri-environment scheme implemented in Australian history. With 6 years of existing monitoring data, the program is in an excellent position to extend the monitoring program so that the long-term values of Environmental Stewardship in preserving and maintaining BGGW condition can be discerned".

Source: Florance et al. 2016

A patch of Box-Gum Woodland ecological community on a private property near Murrumbateman, New South Wales.

[385] From July 2016, the Australian Government Department of the Environment and Energy.

[386] www.nrm.gov.au/national/continuing-investment/environmental-stewardship

In 2015, the Australian Government committed to investing $700 million over four years to the Green Army program as part of the Agricultural Competitiveness White Paper. The Green Army is an environmental action program that supports local environment and heritage conservation projects across Australia that are hosted by community organisations, Landcare groups, natural resource management organisations, environment groups, Indigenous organisations and local councils. From the commencement of the Green Army program until its closure on 30 June 2018, there will have been an estimated 1264 projects across Australia, many of which aimed to improve the condition of privately owned forests.

Investment by state and territory governments and industry groups

State and territory governments also fund and administer programs that encourage private and community-based natural resource management in their jurisdictions. Extension programs encourage private sector and community participation in natural resource management activities through education, technology transfer, and support programs.

Industry groups such as the Australian Forest Products Association, as well as government departments at the national, state and territory levels, also provide the community with information on sustainable natural resource management.

Case study 7.5: Government investment related to forest conservation and resource management in New South Wales

In New South Wales, the *Biodiversity Conservation Act 2016* established the NSW Biodiversity Conservation Trust (BCT), which will oversee the new Private Land Conservation program across the state and has a key role in the new Biodiversity Offsets Scheme discussed above. The BCT will invest $240 million over the next five years to support working with landholders, farmers and other organisations that wish to participate in private land conservation (New South Wales Government 2017).

The Conservation Partners Program, administered by the New South Wales Office of Environment and Heritage, supports landholders in voluntarily protecting and managing native vegetation, wildlife habitat, geological features, historic heritage and Aboriginal cultural heritage on their properties. Landholders can choose from a range of protection options, which recognise and formalise their commitment to conservation on their properties. In turn, the government provides support matched to the level of protection for the land. Options for landholders under the program include permanent legal protection for property under a conservation agreement; legal declaration of land as a wildlife refuge; and (non-legally binding) registration of property to be managed for conservation (NSW OEH 2016c).

Forestry industry structural adjustment packages in river red gum, cypress pine, and private native forests in New South Wales, which operated during the previous reporting period, concluded during the current reporting period. The River Red Gum Structural Adjustment Package (comprising funding of $51.5 million for industry restructuring and $45.5 million to the National Parks and Wildlife Service) was delivered in response to the New South Wales government decision to create 85,721 hectares of new national and regional parks. The Brigalow-Nandewar (South Western Cypress) Structural Adjustment Package (comprising funding of $48.8 million for industry restructuring and $67.5 million to the National Parks and Wildlife Service) was delivered in response to the New South Wales government decision to create 350,000 hectares of conservation reserves in the Brigalow–Nandewar region.

Case study 7.6: Private forest management in Tasmania

In Tasmania, Private Forests Tasmania (PFT) is a government-funded authority established in 1994 to promote, foster and assist the private forestry sector. It works to facilitate and expand the development of the private forest resource in Tasmania. This includes advising and assisting private landowners in the management of native forests and the establishment and management of plantations on private land (PFT 2017).

PFT also pursues business development opportunities related to the management and use of private forests throughout Tasmania. This includes working toward securing the role of private forests in the forest products market, researching and promoting new market opportunities for forest products, addressing impediments to integrating trees into agricultural landscapes, and developing innovative systems to attract investment to the private forest estate (PFT 2016). Initiatives reported by PFT during 2015–16 included supporting the development of a group forest certification option for Tasmania.

In 2014–15, PFT received funding from the Tasmanian government's Agrivision 2050 Plan for a Private Forest Development Program, with the main objective of increasing the extent of commercial tree plantings on Tasmanian farms. PFT has partnered with the University of Tasmania in collaboration with CSIRO to implement this project.

Indicator 7.1d

Capacity to measure and monitor changes in the conservation and sustainable management of forests

Rationale

This indicator examines the capacity of forest owners and agencies to measure and monitor changes in the forest and the impact of forest activities. A comprehensive measurement and monitoring programme provides the basis for forest planning to support sustainable management.

Key points

- The ability to measure, monitor and report on forests varies considerably by tenure. The most comprehensive information continues to be available for multiple-use public forests, with lesser information on nature conservation reserves. Significant gaps in data collection and monitoring remain for leasehold and private forests, and for other Crown land.
- Australia's states and territories undertake forest and environmental data collection, monitoring and reporting in various ways. Tasmania and Victoria publish five-yearly 'state of the forests' reports, based on a framework of criteria and indicators similar to the national *Australia's State of the Forests Report* series (the SOFR series). Other states use similar approaches only for multiple-use public forests.
- Use of a framework of criteria and indicators, developed under the Montreal Process[387], for Australia's five-yearly national state of the forests reporting provides a mechanism for presenting disparate data in a consistent and repeatable format, and for covering the range of forest values.
- The availability, coverage and currency of the data available for the SOFR series vary considerably between indicators, but have improved overall for SOFR 2018 compared to SOFR 2013.
  - For 23 of the 44 national reporting indicators, the data available for SOFR 2018 were assessed as comprehensive in each of coverage, currency and frequency. The data were assessed as comprehensive in two of these three aspects for a further 11 indicators.
  - The capacity to report trends over time was present for 18 of the 44 indicators.
  - Compared with SOFR 2013, the quality of data presented in SOFR 2018 was assessed as improved for 14 of the 44 national reporting indicators.
- Australia also reports on the state of its forests internationally.
  - This occurs through the Global Forest Resources Assessment and the State of the World's Forest Genetic Resources processes undertaken by the Food and Agriculture Organization of the United Nations
  - Australia also reports against the United Nations Sustainable Development Goals and the United Nations Global Forest Goals of the Strategic Plan for Forests.
- Australia's strategy for its National Reserve System stipulates that the effectiveness and performance of protected area management must be monitored and evaluated against conservation goals. Management plans are in place for 19 million hectares of forest in the National Reserve System (57% of the area of forest in the National Reserve System).

[387] The Montreal Process Working Group on Criteria and Indicators for the Conservation and Sustainable Management of Temperate and Boreal Forests – see www.montrealprocess.org

The extent to which relevant and up-to-date information about forests is available for reporting provides a measure of the capacity to demonstrate sustainable forest management. Reporting on the capacity to measure change over time offers an opportunity for forest managers to review and prioritise data collection to make future measurement and monitoring more timely and relevant to management. If a reporting system is to measure change in Australia's forests successfully, it must be underpinned by adequate and ongoing data collection.

Monitoring and reporting by tenure

State and territory agencies and some private forest owners and managers collect primary forest inventory data, but the frequency and scope of such data collection vary across jurisdictions and by tenure. The most comprehensive information is available for multiple-use public forests and nature conservation reserves for which governments require regulatory and other reporting. Reliable information is also available for commercial plantations on both public and private land.

In publicly managed native forests – especially those managed for multiple uses, including wood production – inventories and assessments are undertaken regularly for management purposes and to monitor performance, and data are available for reporting on a range of indicators. State forest management agencies are also committed to reporting regularly on forest management in multiple-use public forests in relation to environmental, economic and social values. Their reporting processes provide the level of detail required for their jurisdictions. The national state of the forests reporting process that leads to the SOFR series provides a whole-of-nation overview, and is the basis for meeting legislated national and international obligations.

In contrast to government data collection and regulatory and other reporting requirements, private landowners and managers (including leaseholders) are rarely required, and often have little incentive, to collect data on their forests or to make such data publicly available. As a result, the most significant gaps in information on Australia's forests are for private and leasehold forests. Other areas with large gaps in information across all tenures and jurisdictions are some non-wood forest values (see Indicators 2.1d, 4.1a–e, 6.1b and 6.1d, for example) and ecosystem services (Indicator 6.1c), as well as measures of growth stage (Indicator 1.1b).

State and territory forest measurement, monitoring and reporting

Australia's states and territories vary in the levels of forest and environmental reporting that they publish. Of the states and territories, Tasmania and Victoria publish state of the forests reports (SOFRs) that cover all forest types and tenures. These reports are based on the same framework of criteria and indicators for sustainable forest management as used in Australia's SOFR, are also published at five-yearly intervals, and provide a component of the input from those states into the national SOFR.

Tasmania's SOFR provides information on the state of Tasmania's public and private forests, as required under the *Forest Practices Act 1985* (Tasmania). The most recent report, *State of the forests Tasmania 2017*, was released in 2017 (FPA 2017a[388]) and is a major source of data and information about Tasmania for *Australia's State of the Forests Report 2018*.

Under the *Sustainable Forests (Timber) Act 2004* (Victoria), the Victorian Government is required to produce a SOFR every five years; the most recent is *Victoria's State of the Forests Report 2013* (DEPI 2014d)[389]. In addition, VicForests, the state-owned business that is responsible for the sustainable harvest, regeneration and commercial sale of timber from Victoria's native public forests, produces annual *Sustainability Reports*[390] (VicForests 2016b). These present information on the activities performed by VicForests to achieve environmental, social and economically sustainable outcomes, including long-term monitoring of threatened species, retained trees and water quality.

New South Wales prepares indicator-based reports on the sustainable management of multiple-use public forests each year. These reports describe progress on the implementation of the four Forest Agreements and Integrated Forestry Operations Approvals (IFOAs)[391] that apply in seven forest regions of New South Wales. The reports summarise the results of monitoring ecologically sustainable forest management criteria and indicators, wood supply, compliance with IFOAs for each IFOA region, and achievement of milestones defined in the four Forest Agreements and the IFOAs[392]. New South Wales also prepares state of the environment reports each three years, most recently in 2015.

Western Australia published state of the environment reports in 1992, 1998 and 2007, and reports specifically on key performance indicators for forests through a management plan process (see below).

In South Australia, ForestrySA publishes an annual report covering plantation forests on public land (there is no native forest harvesting in South Australia). In addition, the South Australian Environment Protection Authority is required to report each five years and has produced a state of the environment report for South Australia in 2003, 2008 and 2013.

388 www.fpa.tas.gov.au/FPA_publications/state_of_the_forests_tasmania_reports; www.fpa.tas.gov.au/__data/assets/pdf_file/0005/163418/State_of_the_Forests_Report_2017_-_erratum_Feb_2018.pdf

389 www.forestsandreserves.vic.gov.au/__data/assets/pdf_file/0019/52705/VIC_SFR2013_lowres.pdf

390 www.vicforests.com.au/about-vicforests/corporate-reporting-1/sustainability-report-2016

391 www.epa.nsw.gov.au/your-environment/native-forestry/integrated-forestry-operations-approvals/annual-reports

392 Annual reporting against the three western New South Wales IFOAs covers compliance, timber harvesting and achievement of milestones.

The four states with regional forest agreements (RFAs) – New South Wales, Tasmania, Victoria and Western Australia – are required to produce five-yearly independent reviews assessing the progress and performance of each RFA. The review process varies slightly for each RFA, but generally the reviews require an independent assessment of the results from monitoring Montreal Process sustainability criteria and indicators, of activities undertaken against the RFA milestones and obligations agreed by each state with the Australian Government, and against the recommendations of previous reviews. The status of the reviews is summarised in Table 7.11. Indicator 7.1a provides further information on RFAs.

Many other measurement and monitoring activities support state and territory reporting. Examples are provided below.

Australian Capital Territory

Annual or regular forest monitoring undertaken in the Australian Capital Territory includes monitoring of fire recovery in Namadgi National Park and Tidbinbilla Nature Reserve, monitoring of deer impacts in Namadgi National Park, and monitoring of biodiversity and health of box-gum woodland.

New South Wales

Examples of monitoring programs and projects undertaken by various departments and agencies in New South Wales include the following:

- the New South Wales *Report on Native Vegetation*. This report is updated yearly, with the most recent report covering 2013–14[393]. It provides a comprehensive picture of the status of the regulation, protection and extent of native vegetation in the state
- 'State of the Parks', a monitoring and reporting framework used by the National Parks and Wildlife Service of NSW. This is based on International Union for Conservation of Nature best-practice guidelines, and collects information on park attributes (e.g., gazetted area, bioregions, international agreements, and catchment management areas), contextual information (e.g., plans, values, threats, stakeholders, commercial activities and visitation), and the effectiveness of dealing with management issues such as pest plants and animals, weeds, visitors, fire, law enforcement, and natural and cultural heritage[394]. However, no 'State of the Parks' data have been publicly available since 2007.

Table 7.11: Status of five-yearly reviews of regional forest agreements (RFAs)

State RFA	Signing year	Five-yearly reviews[a] First period Due	 Status[b]	 Second period Due	 Status[b]	 Third period Due	 Status[b]
Tasmania[c]							
Tasmania	1997	2002	Completed	2007	Completed	2012	Completed
Victoria							
East Gippsland	1997	2002	Collectively combined with second-period review, and completed	2007	Collectively combined with first-period review, and completed	2012	Completed
Central Highlands	1998	2003		2008		2013	Completed
North East	1999	2004		2009		2014	Completed
Gippsland	2000	2005		2010		2015	Completed
Western Victoria	2000	2005		2010		2015	Completed
New South Wales[d]							
Eden	1999	2004	Collectively completed	2009	Combined with the third period review and commenced[f]	2014	Combined with the second period review and commenced[f]
North East[e]	2000	2005		2010		2015	
Southern	2001	2006		2011		2016	
Western Australia							
South West	1999	2004	Combined with the second period review, and completed	2009	Combined with the first review period, and completed	2014	Commenced[f]

[a] Review reports are available at www.agriculture.gov.au/forestry/policies/rfa.
[b] Status of reviews is at 31 August 2018.
[c] An assessment was completed for Tasmania in 2017, and the RFA was extended for a further 20 years.
[d] An assessment was completed for New South Wales in 2018, and the three RFAs were extended for a further 20 years.
[e] The North East RFA covers two regions, Upper North East and Lower North East.
[f] Completion scheduled for 2018.

393 www.environment.nsw.gov.au/resources/nativeveg/nsw-report-native-vegetation-2013-14.pdf
394 www.environment.nsw.gov.au/sop/

- a project to map threatened ecological communities in State forests, which developed a method to identify communities most likely to be affected by wood harvesting activities, and which was completed in 2016[395]
- a program, completed in 2016, that mapped koala habitat and occupancy in New South Wales native forests, to inform new identification and protection requirements in native forest areas on private and public land[396]
- mapping of the extent and severity of Bell-Miner-Associated Dieback across 1.25 million hectares in northern NSW, across all tenures, using aerial surveys, satellite imagery, and follow-up ground checking. This is a joint project undertaken by the Forestry Corporation of NSW[397], the Department of Primary Industries and the National Parks and Wildlife Service
- regular biodiversity monitoring, plantation health monitoring, and soil and water monitoring, undertaken by the Forestry Corporation of NSW, as reported in the Forestry Corporation *Annual Report Sustainability Supplement*, most recently covering 2015–16[398]
- collation of records of plants, mammals, birds, reptiles, amphibians, some fungi, some invertebrates (such as insects and snails listed under the former *Threatened Species Conservation Act 1995* (NSW)) and some fish into the Atlas of NSW Wildlife by the Office of Environment and Heritage. The Atlas also contains known and predicted distributions of vegetation communities, and of endangered populations and key threatening processes listed under the former *Threatened Species Conservation Act 1995* (NSW).

Northern Territory

The Northern Territory's 'Three Parks Program' managed by the Parks and Wildlife Commission of the Northern Territory combines remotely sensed imagery of fire history with on-ground data collected from a network of 220 permanent plots in Litchfield, Kakadu and Nitmiluk National Parks. Plot sampling involves annual recording of fire incidence and severity. Detailed flora and fauna sampling is undertaken every five years.

Queensland

The Queensland Government undertakes a range of activities for monitoring and reporting changes in the extent, state, condition and sustainable management of Queensland's state forests and nature conservation reserves. Examples of forest monitoring undertaken in Queensland include:

- broad-scale monitoring using long-term plots across a range of forest types in north Queensland through the Terrestrial Ecosystem Research Network
- fire-related monitoring including long-term burning plots in several regions
- long-term inventory plots on multiple-use public forest and private native forests
- a statewide vegetation mapping program to map regional ecosystems (defined as vegetation communities in a bioregion that are consistently associated with a particular combination of geology, landform and soil)
- the Statewide Landcover and Trees Study, which uses satellite imagery to monitor forests and woodlands to assess vegetation extent and clearing activities
- monitoring of significant species, including mahogany glider (*Petaurus gracillis*), northern bettong (*Bettongia tropica*), koala (*Phascolarctos cinereus*), Kroombit tinker frog (*Taudactylus pleione*) and Hastings River mouse (*Pseudomys oralis*)
- monitoring of acacia-dominated communities in central Queensland
- identifying and monitoring the conservation of biodiversity including preparing recovery plans that are required under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*.

There are also approximately 150 permanent tree growth monitoring plots across 18 sites in southern Queensland, some measured by the Department of Agriculture and Fisheries[399] and others measured by the Private Forestry Service Queensland, generally on a 3–5 year cycle. These monitoring plots vary in size and shape, and have been subject to a range of different silvicultural treatments. They are mostly located in dry eucalypt forest.

South Australia

Fire management plans guide fire management activities in regions of high fire risk across South Australia. Each regional plan includes a monitoring section with specific recommendations for that region. For example, the Southern Flinders Ranges Fire Management Plan specifies an examination of the suitability of the proposed Ecological Fire Management Guidelines for species of declining woodland birds.

Tasmania

Monitoring is a requirement of the *Forest Practices Act 1985* (Tasmania), and is implemented by Tasmania's Forest Practices Authority (FPA). The FPA employs scientists who undertake monitoring and research projects in areas related to cultural heritage, botany, geomorphology, soil science, visual landscape and zoology. These projects contribute to the scientific knowledge underpinning the Forest Practices Code provisions for natural and cultural values and associated planning tools.

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395 www.epa.nsw.gov.au/native-forestry/tec-mapping-project.htm

396 www.epa.nsw.gov.au/native-forestry/koala-mapping-program.htm

397 Until January 2013, Forests NSW.

398 www.forestrycorporation.com.au/__data/assets/pdf_file/0017/692000/SustainabilitySnapshot2015-16.pdf

399 Until February 2015, the Department of Agriculture, Fisheries and Forestry.

Two types of monitoring are undertaken by the FPA. Compliance monitoring determines whether prescribed management is actually conducted. Effectiveness monitoring determines whether the management specified has achieved its objective, and whether the outcome was actually a consequence of that management. The effectiveness of the biodiversity provisions of the Forest Practices Code was reviewed in 2012 (Koch et al. 2012), which identified gaps and was used to determine monitoring priorities (FPA 2012).

The FPA reports annually on the findings of biodiversity-related projects (FPA 2014, 2015a, 2016b). Most projects are done in collaboration with other research providers, including the University of Tasmania, Forestry Tasmania[400], the Department of Primary Industries, Parks, Water and Environment, and private forest management companies.

In addition to broad-scale monitoring in Tasmania, site-specific surveys are undertaken to ensure that non-wood values are assessed before forest disturbance activities commence, as required by the Forest Practices Code and the Tasmanian Reserve Management Code of Practice. These surveys aim to identify and protect Indigenous and non-Indigenous heritage sites, geomorphic features, and threatened species and communities. Information from these surveys is contributed to state-wide databases for conservation and forest-practices planning.

Victoria

The Victorian Department of Environment, Land, Water and Planning (DELWP)[401] undertakes a range of activities for monitoring and reporting changes in the extent, state, condition and sustainable management of Victoria's State forests and nature conservation reserves. These activities are known collectively as the Victorian Forest Monitoring Program (VFMP)[402]. The VFMP was initiated in 2010 with the aim of providing a continuously updated description of forests, using a combination of permanent plots measured every five years (see Figure 7.4, SOFR 2013), and aerial photography and satellite imagery. Up to June 2017, 662 permanent plots had been installed and measured. Re-measurement commenced in October 2015.

Examples of other forest monitoring projects underway in Victoria include:

- periodic re-measurement by VicForests of permanent plots in the Permanent Growth Plot Program, to monitor tree growth in multiple-use public forest
- biodiversity surveys undertaken by VicForests in 1939 regrowth mountain ash (*Eucalyptus regnans*) forest in the Central Highlands Forest Management Area. Plots have been marked permanently to enable re-measurement
- surveys undertaken in the Central Highlands Forest Management Area as part of the Leadbeaters Possum Recovery Project, to detect colonies of this species
- Grampians, Glenelg, Southern (East Gippsland) and Central Highlands Ark projects undertaken by DELWP that involve regional monitoring of mammals using hair tubes, traps and cameras on various land tenures, to assess the effectiveness of fox and wild dog control programs
- monitoring of forest fuel loads by Forest Fire Management Victoria in the Victorian Bushfire Monitoring Program, for development of fire protection strategies
- biodiversity surveys in 1939 regrowth mountain ash forest in the Central Highlands Forest Management Area undertaken by VicForests. The plots measured have been marked permanently to enable re-measurement.

Western Australia

Forests on public land in south-west Western Australia are managed by the Department of Biodiversity, Conservation and Attractions (DBCA)[403] in accordance with the *Forest Management Plan 2014–2023* produced by the Conservation Commission of Western Australia[404] (CCWA 2013)[405]. The plan specifies a number of monitoring and auditing actions based on key performance indicators. The current plan covers the period 2014–2023 and replaces the previous plan that covered the period 2004–2013.

The Conservation and Parks Commission undertakes mid-term and end-of-term audits of plan implementation, including the extent to which key performance indicator targets have been achieved. The plan uses the Montreal Process criteria and indicators structure, so monitoring and auditing provides data and information that is consistent with the needs of national State of the Forests reporting.

Monitoring of forest and vegetation condition within the plan area is undertaken through various activities including biological surveys and Forestcheck, *Phytophthora cinnamomi* mapping, evaluation of prescribed burns, inventory, operational monitoring, and assessments undertaken related to performance indicators. Forestcheck, the key forest biodiversity monitoring program of DBCA, has been monitoring biodiversity in jarrah (*E. marginata*) forests since 2001. *The Forest Management Plan 2014–2023* uses results from Forestcheck for monitoring a number of indicators, and aims to maintain and extend this system (see Case study 7.7).

400 From July 2017, Sustainable Timber Tasmania.

401 Until January 2015, the Department of Environment and Primary Industries (DEPI).

402 www.forestsandreserves.vic.gov.au/forest-management/victorian-forest-monitoring-program

403 Until July 2017, the Department of Parks and Wildlife (DPaW)

404 From October 2015, the Conservation and Parks Commission of Western Australia

405 www.dpaw.wa.gov.au/images/documents/conservation-management/forests/FMP/20130282_WEB_FOREST_MGT_PLAN_WEB.pdf

Case study 7.7: The FORESTCHECK project: integrated biodiversity monitoring in jarrah forest

FORESTCHECK is an integrated monitoring system designed to support forest management in the south-west of Western Australia. It provides information about changes and trends in key elements of forest biodiversity in jarrah (*Eucalyptus marginata*) forest associated with management activities, including wood harvesting and silvicultural treatments.

The initial set of 48 monitoring grids established throughout the range of the jarrah forest has been increased to 67 grids, in order to expand the coverage of forest ecosystems and the range of silvicultural treatment and fire history sampled. Grids established since 2013 cover silvicultural practices implemented during the period of the *Forest Management Plan 2004–2013* in the Jarrah South and Jarrah Sandy Basins forest ecosystems. Additional grids have also been established in examples of long-unburnt forest.

Sets of grids are assessed on a five-yearly basis for attributes including forest structure, soil condition, and levels of litter and coarse woody debris. Elements of biodiversity are also assessed, including vascular flora, vertebrate fauna (birds, mammals and reptiles), cryptogams (lichens, liverworts and mosses), macrofungi and invertebrate fauna.

To date, most grids have been monitored twice each – once between 2001 and 2006, and once between 2007 and 2012, but some grids have been monitored up to four times. More than 3,700 species have been recorded in the FORESTCHECK system, with invertebrates being the richest group of organisms. Overall species richness and composition are influenced more strongly by forest ecosystem type and by the season in which the monitoring is undertaken, than by silvicultural treatment or by time since fire. Macrofungi, cryptogams and bird species assemblages are sensitive to the season of monitoring, probably reflecting climatic conditions and changes in the structure of the vegetation between sampling events.

Biodiversity is monitored in a way that allows detection of changes caused by wood harvesting or other silvicultural disturbance. Data from the first round of monitoring show that species return to a site after wood harvesting, as the forest structure and habitats re-establish. This process can take from a few years to several decades, depending on the habitat requirements of individual species. Habitat features such as tree hollows and large woody debris take many years to form, and maintenance of site biodiversity therefore requires that they are retained when wood is harvested (CCWA 2013). For all species groups studied (vascular flora, macrofungi, lichens, bryophytes, mosses, insects and other invertebrates, birds and animals), the effect of wood harvesting was negligible after 40 years: few significant impacts were evident and most species groups were resilient to the disturbance imposed (Abbott and Williams 2011). Data from the second round of monitoring are currently being prepared for publication.

Figure 7.7: Monitoring post-fire responses at FORESTCHECK grids following the January–February 2015 Lower Hotham bushfire

A Mature jarrah (*Eucalyptus marginata*) tree collapsed following ignition of dead wood in an old injury at the base of the stem

B Ashbed resulting from complete burning of a fallen marri (*Corymbia calophylla*) tree

Seven grids were burnt during a large bushfire in January–February 2015 (Figure 7.7). This has provided a valuable opportunity to monitor post-fire responses of selected biota, as well as changes in the amount and condition of fine and coarse woody debris on the forest floor, and impacts on stand structure.

Source: Western Australian Department of Biodiversity, Conservation and Attractions (Lachlan McCaw).

National forest monitoring and reporting

The National Forest Inventory (NFI) held in the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES), Australian Government Department of Agriculture and Water Resources, is a compilation of data and information supplied by states and territories, supplemented with national data, and with these data integrated into national classification schemes and databases. Tabular data on commercial plantations are collected yearly, and spatial data on all forests are collected every five years. Maintenance of the NFI is mandated in Australia's *National Forest Policy Statement* (Commonwealth of Australia 1992).

ABARES has primary responsibility for national forest reporting in Australia, including coordinating the preparation of the five-yearly *Australia's State of the Forests* series (the SOFR series). The process and mandate for preparing the SOFR series is summarised in the Introduction.

Australia's national state of the forests reporting through the five-yearly SOFR series is based on a framework of 7 criteria and 44 indicators of sustainable forest management that are closely aligned with the international Montreal Process[406]. This framework provides a mechanism for presenting Australia's disparate forest data in a consistent and repeatable format, in spite of varying state, territory and national data collection processes, classification systems and standards. Reporting against Montreal Process criteria and indicators deliberately does not score, rank or aggregate individual indicators, allowing users of the report (researchers, policy makers, forest owners or managers) to make their own interpretation of the meaning and causes of changes in forest parameters, and the overall condition of any particular forest area.

Coverage and currency of data, frequency of data collection, and capacity to report on trends also vary among indicators, and only certain indicators are readily measured quantitatively.

Table 7.12 summarises Australia's capacity to report against these 44 indicators for SOFR 2018, based on the coverage, currency, and update frequency of data available for each indicator, and the capacity to report trends. Table 7.12 also presents changes over the period 2011–2016 (that is, since SOFR 2013) in the quality of the data that contribute to the SOFR series reporting. This analysis was performed separately for three components of Indicator 1.1a (forest area, type and tenure), for two components of Indicator 6.1d (wood products, and non-wood products) and for two components of Indicator 6.4a (area of Indigenous forest, and Indigenous heritage). The lowest-scoring component of an indicator was incorporated into the summary statistics.

Overall, the data available for SOFR 2018 were assessed as comprehensive in three aspects (coverage, currency and update frequency) for 23 of the indicators (up from 17 for SOFR 2013), and comprehensive in any two of these aspects for a further 11 indicators. Trends over time could be reported for 18 of the 44 indicators for SOFR 2018 (up from 16 for SOFR 2013), and there has been an overall improvement in the quality of data for 14 of the indicators. The capacity to report for one indicator (Indicator 1.1b, forest growth stage) was particularly deficient, and this and Indicator 6.1c (value of forest-based services) were the only indicators with an overall decline in data quality since SOFR 2013.

New and improved datasets reported in SOFR 2018

A number of new and improved social, economic and biophysical datasets have been compiled for the National Forest Inventory, and analysed and presented in SOFR 2018. These include:

- a national forest cover dataset that has been further improved using the Multiple Lines of Evidence approach (Indicator 1.1a)
- a new national forest tenure dataset (Indicator 1.1a)
- an improved dataset on areas of forest managed for protection, including data on covenanted private forests and on Ramsar wetlands (Indicator 1.1c)
- a new national forest fragmentation dataset (Indicator 1.1d)
- a corrected and updated spatial dataset of forest commerciality (Indicator 2.1a)
- new tables of key pests and weeds by jurisdiction (Indicator 3.1a)
- consistent fire area data, and new fire area metrics, based on a national compilation of data from states and territories (Indicator 3.1b)
- data on forest carbon stocks by pool (above-ground, below-ground) and by jurisdiction (Indicator 5.1a)
- a corrected and improved dataset of forest on Indigenous land, by Indigenous land management category (Indicator 6.4a)
- a new Indigenous heritage dataset (Indicator 6.4a).

Gaps in SOFR 2018 data

There are remaining or ongoing gaps in the data compiled for SOFR 2018:

- native forest growth-stage data are not collected routinely by many state and territory jurisdictions (Indicator 1.1b)
- there are gaps in species lists for forest-dwelling invertebrate fauna, fungi, lichens and algae (Indicator 1.2a)
- information on the production, consumption and trade of non-wood forest products, and the value of forest-based services, is difficult to obtain (Indicators 2.1d, 6.1b and 6.1d)
- nationally meaningful data on soil and water parameters are deficient (Indicators 4.1b–e)
- data on the use of forests for tourism and recreation are incomplete (Indicator 6.3a-b).

[406] www.montrealprocess.org; see also Appendix 1.

Table 7.12: Data coverage, currency, update frequency, capacity to report trends, and overall change in data quality since SOFR 2013

Criterion and Indicator		Data coverage	Data currency	Data update frequency	Capacity to report trends	Change in data quality since SOFR 2013
Criterion 1: Conservation of biological diversity						
1.1a[a]	Area of forest by forest type and tenure – *forest area*					↗
	Area of forest by forest type and tenure – *forest type*					↗
	Area of forest by forest type and tenure – *tenure*					↗
1.1b	Area of forest by growth stage[b]	[c]				↙
1.1c	Area of forest in protected area categories					↗[d]
1.1d	Fragmentation of forest cover					↗
1.2a	Forest dwelling species with ecological information			[e]		↗
1.2b	Status of forest dwelling species at risk					—
1.2c	Representative species monitored					↗[f]
1.3a	Species at risk of loss of genetic variation					↗[g]
1.3b	Genetic resource conservation mechanisms in place					↗[h]
Criterion 2: Maintenance of productive capacity of forest ecosystems						
2.1a	Native forest available for wood production					↗[i]
2.1b	Age class and growing stock of plantations					—
2.1c	Annual removal of wood products compared with sustainable volume					↗[i]
2.1d	Annual removal of non-wood forest products compared with sustainable level					—
2.1e	Effective forest regeneration and plantation re-establishment					↗[i]
Criterion 3: Maintenance of ecosystem health and vitality						
3.1a	Scale and impact on forest health and vitality					—
3.1b	Forest burnt by planned and unplanned fire					↗
Criterion 4: Conservation and maintenance of soil and water resources						
4.1a	Forest managed primarily for protective functions					—
4.1b	Management of the risk of soil erosion					—
4.1c	Management of the risks to soil physical properties					—
4.1d	Management of the risks to water quantity					—
4.1e	Management of the risks to water quality					—
Criterion 5: Maintenance of forest contribution to global carbon cycles						
5.1a	Contribution to global greenhouse gas balance					—
Criterion 6: Maintenance and enhancement of long-term multiple socio-economic benefits to meet the needs of societies						
6.1a	Value and volume of wood and wood products					—
6.1b	Values, quantities and use of non-wood forest products					—
6.1c	Value of forest-based services					↙
6.1d[j]	Wood and non-wood product production and consumption – *wood products*					—
	Wood and non-wood product production and consumption – *non-wood products*		[k]	[k]		—
6.1e	Recycling of forest products					↗
6.2a	Investment and expenditure in forest management					—
6.2b	Investment in research, development and extension, and new technologies					↗
6.3a	Area of forest available for public recreation/tourism					—
6.3b	Recreation/tourism activities available					—
6.4a[l]	Area to which Indigenous people have use and rights – *forest area*					↗
	Area to which Indigenous people have use and rights – *heritage*					—

Continued

Continues

Criterion and Indicator		Data coverage	Data currency	Data update frequency	Capacity to report trends	Change in data quality since SOFR 2013
6.4b	Registered places of non-Indigenous cultural value					—
6.4c	Protection of Indigenous values					—
6.4d	Importance of forests to people				[m]	—
6.5a	Direct and indirect employment					—
6.5b	Wage rates and injury rates					—
6.5c	Resilience of forest dependent communities					—
6.5d	Resilience of forest dependent Indigenous communities					—
Criterion 7: Legal, institutional and economic framework for forest conservation and sustainable management						
7.1a	Legal framework					—
7.1b	Institutional framework					—
7.1c	Economic framework					—
7.1d	Capacity to measure and monitor					—
7.1e	Capacity to conduct and apply research and development					—

Key	Data coverage	Data currency	Data update frequency	Capacity to report trend	Change in data quality since SOFR 2013
	Whole country assessed	Current data (data since 2011)	Annual to five-yearly	High	↗ Overall data quality has improved since SOFR 2013
	Incomplete national data	Mixed current and historical data	Less frequently than five-yearly	Partial	— Overall data quality is unchanged since SOFR 2013
	No data; case studies only	Historical data (pre-2011 data only)	Occasional or once only	None	↙ Overall data quality has declined since SOFR 2013

[a] Indicator 1.1a has been divided in order to report separately data quality for forest type, forest area, and forest tenure.
[b] Sufficient, consistent and coordinated data have not been collected at the state and territory level since 2008 to enable satisfactory data-based reporting against this indicator (see Table 1.13). Available data is therefore increasingly out of date.
[c] Data are only available for the old-growth stage. National data on other growth stages are not available.
[d] Reflects improvements in data on tenure of private forest reserves.
[e] There are gaps with regard to species lists for vascular plants, invertebrate fauna, fungi, lichens, algae or micro-organisms in forests.
[f] Variable across states and territories. Very good in Tasmania and Western Australia.
[g] Data remain patchy across species and jurisdictions, but are improving over time for targeted threatened species.
[h] Data on genetic conservation have improved.
[i] Capacity to report on private native forest available for wood production remains limited. Information on plantations has improved, however it has decreased for some jurisdictions for public native forests.
[j] Indicator 6.1d has been divided in order to report separately data quality for wood and non-wood forest products.
[k] For bee products only. Data were not available for other non-wood products.
[l] Indicator 6.4a has been divided in order to report separately data quality for forest on Indigenous land, and forest on Indigenous heritage sites.
[m] Good capacity to report trend on national attitudinal surveys.

This table, together with other data for Indicator 7.1d, is available in Microsoft Excel via www.doi.org/10.25814/5bda99c8d76da

Other national reporting relevant to forests

In addition to Australia's five-yearly SOFR series, regular national reports that provide updated information on Australia's forested environments include the five-yearly State of the Environment report series[407] (Jackson et al. 2017).

Emissions and sequestration of greenhouse gases across industry sectors, including carbon stocks in forests, emissions from forests and sequestration into forests, are recorded in Australia's National Greenhouse Gas Inventory maintained by the Department of the Environment and Energy. These parameters are reported in National Forest Inventory reports[408] (DoEE 2018b). Indicator 5.1a gives more information about the National Greenhouse Gas Inventory and the carbon cycle in Australia's forests.

International forest reporting and monitoring

Australia is a member country of the Montreal Process, which reports on forests using an internationally agreed framework of criteria and indicators (the 'C&I process') for monitoring sustainable forest management in temperate and boreal forests. The national SOFR series is Australia's reporting mechanism to the Montreal Process.

A Global Forest Resources Assessment (GFRA) is produced by the Food and Agriculture Organization of the United Nations (FAO) every five years, as a consistent description of the world's forests and how they are changing over time. The FAO also prepares State of the World's Forests reports on the status of forests and key issues concerning the forest sector, and prepares a State of the World's Forest Genetic Resources report. Australia's national SOFR series is the primary source of data for Australia's Country Report to the GFRA process, the State of the World's Forests reports, and the State of the World's Forest Genetic Resources reports.

Australia has committed to reporting against the United Nation's Sustainable Development Goals (SDGs). The GFRA provides the direct input for global forest reporting against the forest indicators in SDG 15 Life on Land. The GFRA is also a source for reporting against the Global Forest Goals of the United Nations Strategic Plan for Forests 2017–2030. Data compiled for Australia's national SOFR series are thus used for Australia's contribution to the GFRA, the UN SDGs and the UN Global Forest Goals.

SOFR data are also used to report to the UN Convention on Biological Diversity and other international agencies. Data in Australia's NFI are also one input to the reporting of forest-related emissions data to the UN Framework Convention on Climate Change, including for its Kyoto Protocol.

Effectiveness of monitoring the national forest reserve system

Australia's National Reserve System (NRS) represents the collective efforts of Australian governments and non-government organisations to achieve an Australian system of protected areas, as a major contribution to the conservation of Australia's native biodiversity (NRMMC 2004). The area of forest in the NRS is reported in Indicator 1.1c.

Australia's Strategy for the National Reserve System 2009–2030[409] (NRMMC 2009) has national targets for a comprehensive, adequate and representative (CAR) reserve system that meets regional, national and international goals. The strategy also stipulates that the effectiveness and performance of protected area management must be monitored and evaluated to provide a measure of the achievement of conservation goals in a manner that is open to public scrutiny. Assessment includes evaluating the coverage of protected area systems and the extent to which biodiversity is represented, evaluating the adequacy and appropriateness of management systems and processes, and assessing the condition of protected areas and trends in specific conservation values. The Australian Government collects information from state and territory governments and other protected area managers about the location and management of protected areas, and collates and stores this information as the Collaborative Australian Protected Area Database (CAPAD).

The NRS helps Australia to meet international obligations and goals under the UN Convention on Biological Diversity, including for implemented management plans and management effectiveness assessments. These data are being incorporated into a global database maintained by the World Conservation Monitoring Centre[410] as part of the UN Environment Programme[411].

Management plans provide guidance for sustainable forest management practices, and for the monitoring and evaluation of management performance. Nationally, 19.1 million hectares of forest in the NRS has management plans in place, which is 57% of the area of forest in the NRS; a further 27% is covered by transitional management arrangements, while the remaining 16% has no management planning documentation (Table 7.13).

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407 www.environment.gov.au/science/soe

408 www.environment.gov.au/climate-change/climate-science-data/greenhouse-gas-measurement/publications#national

409 www.environment.gov.au/land/nrs/publications/strategy-national-reserve-system

410 See www.unep-wcmc.org. The World Conservation Monitoring Centre Protected Areas Programme manages the World Database on Protected Areas (www.protectedplanet.net), develops and supports the scientific basis for the valuation of protected areas, assesses the management and ecological effectiveness of these areas, and monitors this performance at a global level.

411 See Parties to the Convention on Biological Diversity COP 10 Decision X/31, www.cbd.int/decision/cop/default.shtml?id=12297

Monitoring and measurement.

As at 2016, more than 75% of the area of forest in the NRS in the Australian Capital Territory, New South Wales, the Northern Territory and Victoria was managed under an existing management plan identified in CAPAD. The majority of forest area in the NRS in Queensland and South Australia is not covered by existing management plans identified in CAPAD. However, many areas of forest in the NRS in Queensland are managed under pre-existing management plans rated as transitional. In addition, while South Australian state legislation requires NRS areas to have management plans, processes may not have commenced or have been completed to allow all of these to be described as existing under CAPAD requirements (Table 7.13).

Table 7.13: Status of management plans covering forests in the National Reserve System, 2016

	Proportion of area of forest in the National Reserve System with management plans of given status (%)								
Status	**ACT**	**NSW**	**NT**	**Qld**	**SA**	**Tas.**	**Vic.**	**WA**	**Australia**
Exists[a]	99	84	78	16	48	60	85	58	57
Transitional[b]	0	13	11	51	25	26	0	35	27
None[c]	1	3	10	33	27	14	15	7	16

[a] Exists: planning documentation identified in CAPAD is in statutes or plans formally adopted after consultation, with strategies and implementation actions.
[b] Transitional: planning documentation identified in CAPAD is in preparation or in draft, or intent is documented, or old plans exist that require updating.
[c] None: no form of management documentation identified in the CAPAD.
Forest areas in the National Reserve System are given in Table 1.17.
Source: Australian Government Department of the Environment and Energy (CAPAD 2016), including data updated for Qld and the ACT; forest area data from the National Forest Inventory.

This table, together with other data for Indicator 7.1d, is available in Microsoft Excel via www.doi.org/10.25814/5bda99c8d76da

Indicator 7.1e

Capacity to conduct and apply research and development aimed at improving forest management and delivery of forest goods and services

Rationale

This indicator reports on the scientific understanding of Australian forest ecosystem characteristics and functions needed to underpin sustainable forest management. Research, inventory and the development of assessment methodologies provide the basis for sustainable forest management.

Key points

- This indicator reviews the provision of forestry and forest products research and development (R&D) by national agencies, state and territory agencies, and universities.
- An estimated 276 researchers and technicians were involved in forestry and forest products R&D in Australia in 2013. This is a reduction from 455 estimated for 2011, and 733 estimated for 2008. The decline has occurred across the public and private sectors, including government agencies and universities.
- Ongoing changes in funding and delivery models by state and territory governments have generally reduced forest R&D capacity in their forest management agencies. The total number of forestry and forest products researchers employed by state and territory agencies was reported as 89.5 full-time-equivalent (FTE) staff in 2015–16, approximately half the 171.8 FTE reported for 2011–12.
- Ongoing changes in funding and delivery models by the Australian Government reduced forest R&D capacity across a number of national organisations, including some for which government funding or support ceased during the SOFR 2018 reporting period. However, a number of new, university-based forestry and/or forest products research centres were established during the SOFR 2018 reporting period.

A scientific understanding of the characteristics and functions of Australian forest ecosystems is needed to underpin their management. Research and development (R&D) provides the basis for biological surveys and forest inventories, forest management, the silvicultural regime for harvesting forests, forest health surveillance, and the development of methods for assessing sustainable forest management. This indicator examines the institutional capacity for forest-related R&D; Indicator 6.2b quantifies investments in R&D by three industry subsectors.

Australia has gained a good level of scientific understanding of the characteristics and functions of its unique forest ecosystems, based on more than 100 years of research in a broad range of forest areas. This knowledge is required to underpin sustainable forest management. However, since 2007, Australia's capacity to conduct and apply R&D to improve the scientific understanding of forests and delivery of forest products has progressively decreased. Significant changes in R&D capacity have occurred at the national, state and territory levels of government, and within the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and academic institutions. Many of these changes reflect either general changes in overall government priorities or specific changes in government priorities for science-based R&D.

'Forestry' R&D covers research in relation to commercial management and protection of forests, including environmental and ecological considerations. It does not cover research on areas managed specifically for conservation (e.g. forest areas in nature conservation reserves), or programs monitoring growth, health, nutrition and biodiversity. 'Forest products' R&D covers research on value-adding to wood in its broadest sense, but not work on final product development (e.g. furniture production), production runs in mills, environmental monitoring or quality control assessment. These categories have been stable across a number of industry surveys and SOFR reporting periods.

National-level forest research and development capacity

Over the SOFR 2018 reporting period 2011–16, Australia's capacity to conduct and apply forest R&D at the national level has been coordinated and delivered through a number of organisations, including:

- the Australian Bureau of Agricultural and Resource Economics and Sciences
- the Australian Centre for International Agricultural Research
- the Commonwealth Scientific and Industrial Research Organisation
- Forest and Wood Products Australia
- the Cooperative Research Centre for Forestry
- the Bushfire and Natural Hazards Cooperative Research Centre
- the Plant Biosecurity Cooperative Research Centre
- the Terrestrial Ecosystem Research Network.

As an indication of the extent to which these organisations enhanced Australia's capacity to conduct and apply forest R&D, their activities are briefly described below.

Australian Bureau of Agricultural and Resource Economics and Sciences

The Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES), within the Australian Government Department of Agriculture and Water Resources, provides integrated economic, social and scientific research for strategic policy development across the agriculture, fisheries and forestry sectors.

ABARES also contributes to R&D aimed at improving sustainable forest management, and the sustainable and profitable delivery of forest goods and services. For example, ABARES coordinates the preparation of the *Australia's State of the Forests Report* series, publishes the *Australian Forests and Wood Products Statistics* series, and undertakes or coordinates other nationally relevant research on Australia's forests.

Australian Centre for International Agricultural Research

The Australian Centre for International Agricultural Research (ACIAR) commissions collaborative agriculture, fisheries and forestry research projects in developing countries, and over a 30-year period has invested over AU$100 million to fund 150 forestry projects and activities in 29 countries, with most of these projects implemented in Indonesia, Vietnam and Papua New Guinea.

While ACIAR forestry research projects are not conducted in Australia, there are direct and indirect benefits for Australian forest research. ACIAR funding contributes directly to building and sustaining forest research capabilities in Australian research institutions, including universities and CSIRO. ACIAR projects have resulted in improved knowledge of the performance of various Australian trees under different environmental conditions, including many commercially important eucalypts and acacias. Reliable techniques for growing sandalwood plantations have also been developed. The enhanced networks that exist with collaborating partner country scientists facilitate ongoing exchange of scientific information, and in the case of forest biosecurity can assist Australia to monitor the spread of new threats to Australian forests and forestry, particularly in neighbouring countries in the Pacific region (Bartlett 2016).

Commonwealth Scientific and Industrial Research Organisation

The Commonwealth Scientific and Industrial Research Organisation (CSIRO) is Australia's national science research agency. Approximately 25 staff work in forestry disciplines (2017), down from 235 staff (including 85 scientists) that worked in CSIRO Forestry and Forest Products in 2000 (Kile et al. 2014).

Between 2007 and 2014, forest research programs at CSIRO were mostly delivered under the Sustainable Agriculture Flagship and the Climate Adaptation Flagship. Following another major restructure in 2014, remaining forest research has been delivered by the Forest and Landscape Processes and Risks Program within CSIRO Land and Water, with a focus on sustainable forest production, carbon and water balance in forests, growing and managing forests in developing countries for poverty alleviation, and predicting risk from bushfires and bushfire management. The program aims to develop strategies for keeping Australia's forests productive and healthy into the future, so that they continue to provide a range of products and services like wood, habitat and clean water. This research also contributes to carbon sequestration and forest sustainability[412].

CSIRO research is mostly performed in collaboration with other national, state and territory research agencies, universities and research institutions, as well as international research agencies.

Forest and Wood Products Australia

Forest and Wood Products Australia (FWPA) is a not-for-profit company jointly funded by the forest and wood products sector (through levies) and the Australian Government. It invests in R&D projects relevant to the Australian forest and wood products sector, and undertakes promotional and marketing activities for the sector. Current investments are delivered through five programs (FWPA 2017):

1. Promoting the advantages of wood products
2. Aligning products to market needs
3. Assisting value chain optimisation
4. Increasing resource availability and reducing risk
5. Impacting decision making and industry capability.

[412] Commonwealth Scientific and Industrial Research Organisation: More about CSIRO Land and Water. www.csiro.au/en/Research/LWF

Research completed during the SOFR 2018 reporting period was aimed at improving forest industry productivity and competitiveness, informing industry's climate change response, increasing investment, increasing forest usage, and ensuring that the sustainability of forests, wood products and services was effectively communicated.

Research in wood product manufacturing has led to the identification of new products and methods for manufacturing processed forest products (excluding pulp, paper and cardboard) – for example, new applications for timber in construction, new timber treatments and new export markets.

Bushfire Cooperative Research Centre, and Bushfire and Natural Hazards Cooperative Research Centre

In Australia, bushfires often affect forests and the communities associated with them. Following the Black Saturday bushfires of February 2009 in Victoria, the Australian Government granted the Bushfire Cooperative Research Centre (CRC) an extension of funding to examine national issues arising from the tragedy. This led to a new three-year research program for the Bushfire CRC, from 2010 to 2013. The research built on outputs from the CRC's first seven years of research, to give communities and fire managers a solid basis to better prepare for, manage and respond to severe bushfires. The research focused on understanding the risks associated with bushfires, how to better communicate these risks to the public, and how to better manage the direct threat of bushfires when they occur.

The Bushfire and Natural Hazards CRC (BNH CRC), launched in 2013, builds on the prior work of the Bushfire CRC, and is conducting coordinated and interdisciplinary research. This includes working with communities to improve disaster resilience and reduce the human, social, economic and environmental costs from bushfires and other natural hazards. Research undertaken by the BNH CRC supports the development of cohesive, evidence-based policies, strategies, programs and tools to build a more disaster-resilient Australia[413]. The BNH CRC provides long-term research that directly supports emergency services and other government and non-government agencies as they work to prevent, prepare for, respond to and recover from natural disasters.

The BNH CRC, like the Bushfire CRC before it, is 'end-user driven'. This means that the various emergency service agencies, departments and non-government organisations around the country that are CRC partners have a significant say in the development and use of the research program.

Plant Biosecurity Cooperative Research Centre

The Plant Biosecurity Cooperative Research Centre (PBCRC) was established in 2012 in recognition of the need to strengthen Australia's plant biosecurity scientific capacity.

The PBCRC aims to develop and deploy scientific knowledge, tools, resources and capacity to safeguard Australia, its plant industries and regional communities from the economic, environmental and social consequences of damaging invasive plant pests and diseases (PBCRC 2012).

Research conducted by the PBCRC has relevance to native and commercial forests, and includes strategies for the eradication of the fungal pathogen *Phytophthora cinnamomi*, a significant cause of dieback in native forests, as well as strategies for the detection and management of pests and diseases damaging to commercial forestry. In collaboration with NSW Department of Primary Industries and Queensland Department of Agriculture and Fisheries[414], PBCRC scientists are investigating how to manage the impact of myrtle rust (*Austropuccinia psidii*), a disease that has the potential to cause widespread change in native plant species and impacts on the ecological communities they support (see Case study 3.1). Myrtle rust also has the potential to have severe economic impacts on plant nurseries, native and plantation forestry and new growing industries such as lemon myrtle production.

The PBCRC continues the work of the Cooperative Research Centre for National Plant Biosecurity, which began operating in November 2005. PBCRC has an extensive collaborative network of researchers and educators from 27 participating organisations from both Australia and overseas, representing industry, universities, and state and federal government.

Involvement of end-users of the research as participants ensures maximum benefit and impact in the delivery of project outputs, development of new products and services, and capture of intellectual property.

Cooperative Research Centre for Forestry

The Cooperative Research Centre (CRC) for Forestry was an Australia-wide joint venture supported by the forest industry, research organisations, state agencies and the Australian Government, which was wound up in June 2013. Some of the CRC for Forestry's research programs and research personnel were taken over by the Forest Industries Research Centre at the University of the Sunshine Coast, or by the National Centre for Future Forest Industries at the University of Tasmania (see below).

The research at the CRC for Forestry was organised around four programs: managing and monitoring for growth and health, high-value wood resources, harvesting and operations, and trees in the landscape. By 2012, the CRC for Forestry had developed into a broadly-based research organisation with 31 partners across Australia. It performed research along the whole value chain of production forestry, including social, environmental and regional economic considerations, and focused on research outcomes for adoption by industry end-users.

Some of the work of the CRC for Forestry was picked up by the National Centre for Future Forest Industries (2012–15), with research covering utilisation of plantation hardwood, plantation productivity and risk mitigation. Participants included the University of Tasmania, Queensland Department of Agriculture and Fisheries, CSIRO and the University of the Sunshine Coast.

413 Bushfire and Natural Hazards Cooperative Research Centre: About us. www.bnhcrc.com.au/About

414 Until February 2015, the Department of Agriculture, Fisheries and Forestry.

Terrestrial Ecosystem Research Network

The Terrestrial Ecosystem Research Network (TERN) provides infrastructure and networks that enables Australia's ecosystem science community to collect and integrate ecosystem data across broad spatial and temporal scales. It is designed to examine Australian ecosystems and ecosystem processes at different scales from targeted monitoring at the local level, through to surveillance monitoring at regional scales, through to continental-scale observation and modelling. TERN has built on significant past research on understanding Australian ecosystems, including forests, by collating, calibrating, validating and standardising existing datasets[415].

TERN is designed to connect ecosystem scientists, enabling them to collect, contribute, store, share and integrate data across relevant disciplines. Examples relevant to Australia's forests include:

- OzFlux, a network of towers around Australia that continuously measure the exchanges of carbon dioxide, water vapour and energy between the terrestrial ecosystem and atmosphere. Twenty-six active OzFlux sites cover forest types ranging from open woodland and savanna to tall, wet eucalypt forest and rainforest
- AusPlots, a plot-based surveillance monitoring program undertaking baseline assessments of ecosystems across the country. AusPlots Forests monitoring plots are distributed through tall eucalypt forest ecosystems around Australia
- The Australian SuperSite Network (ASN) is a national network of multidisciplinary ecosystem observatories, including ten SuperSites that each represent a significant Australian biome. The network includes a range of forest types from mulga (*Acacia aneura*) woodlands to tall eucalypt forest and tropical rainforest.

Long-term ecological research in Australia's forests

Long-Term Ecological Research (LTER) sites are dedicated to multidisciplinary, long-term, site-based ecological research; some LTER sites are dedicated to forest research. Long-term research is critical to the understanding of ecosystem processes and to formulating policy to establish and maintain sustainable forest management. Networks of LTER sites existed in Australia and around the world during the SOFR 2018 reporting period, including Tasmania's Warra LTER site (see Case study 7.8), and Queensland's Karawatha LTER plots.

In 2012, several of Australia's forested LTER sites were also brought together under TERN's Long-Term Ecological Research Network (LTERN) to establish a new coordinated and collaborative approach across forest types (including tropical rainforests, tall eucalypt forests and mallee woodlands), land tenures and land uses (including plantation forestry, conservation, restoration, tourism and

Case study 7.8: Warra Long-Term Ecological Research site

The Warra LTER site was established in 1995 to facilitate understanding of the ecological processes in Tasmania's wet eucalypt forests. The site contains forests managed under different regimes, and provides for ecological and silvicultural research experiments. Research areas include forest biodiversity, hydrology, fire, climate change, fauna, harvesting practices and social impacts, and Warra is the Tasmanian focal area for research into wet eucalypt forests and their management. Research at Warra is supported by nine site partner agencies.

New research infrastructure investment at Warra provided through TERN includes the Warra Flux Tower (part of the OzFlux Network), the Warra Supersite (part of the Australian Supersites Network), a 5 x 5 km AusCover plot, and three 1-ha AusPlots Forests plots. Fully documented datasets from ongoing measurements made at Warra are lodged on TERN data portals[416].

Warra continues to host substantial research activity. Over 220 research projects have been conducted at Warra since its commencement, many of which are ongoing.

This research has generated 320 reports and publications as at June 2017, over 100 of which are in international peer-reviewed journals. In addition to the TERN-funded infrastructure, long-term 'flagship' projects at Warra include the Silvicultural Systems Trial, Log Decay Study, Mt Weld Altitudinal Monitoring Plots, Warra Weirs Hydrological monitoring, Wildfire Chronosequence Plots, and the Southern Forests Experimental Forest Landscape.

Science findings from these studies have been used throughout the life of Warra to inform operational management. Examples include the development of Variable Retention silviculture for harvesting mature wet eucalypt forests; a Landscape Context Planning System for long-term retention of sufficient forest in the landscape surrounding harvested areas to sustain forest-dependent species; and guidelines for managing the coarse woody debris habitat for species dependent on this habitat.

[415] Terrestrial Ecosystems Research Network website: What is TERN? www.tern.org.au/What-is-TERN-pg22570.html

[416] TERN SuperSites website: Warra Tall Eucalypt SuperSite. supersites.tern.org.au/supersites/wrra

agriculture). The LTERN facility integrates some established plot networks and long-term ecological monitoring programs across Australia. These span a number of ecosystems including tropical rainforests and savannas, tall eucalypt forests, mallee woodlands and shrublands, alpine regions, and deserts. LTERN is designed to monitor biodiversity and better understand disturbance regimes associated with fire, wood harvesting, livestock grazing, climate change and invasive species. The data collected across each plot network can vary, but the range includes vegetation, soils, invertebrates, birds, reptiles, arboreal marsupials, genetics and phenology[417].

State and territory forest research and development capacity

The capacity of Australia's states and territories to conduct and apply forest R&D is led by the government agencies that are responsible for forest policy, management or conservation in each jurisdiction. Much of this state and territory forest research effort is conducted in collaboration with other organisations, including national organisations such as CSIRO and various CRCs as well as universities, and can involve state and territory government research units hosted by these institutions. Changes in the capacity of state and territory agencies to conduct and apply forest R&D have occurred during the SOFR 2018 reporting period, largely as a result of changes in government priorities and provision of funding.

Only partial information is available on forest research capacity in individual states and territories. Table 7.14 reports the number of government-employed researchers and technicians for 2011–12 and 2015–16 for each jurisdiction, separated into plantations and native forest R&D effort. The numerical data and associated changes in capacity are discussed by jurisdiction in subsequent sections. Table 7.15 reports the number of government-employed researchers and technicians for 2011–12 and 2015–16 in each of the various R&D activity areas (discipline areas), separated again into plantations and native forest R&D effort.

The national data for research capacity reported by state and territory agencies shows a significant decline from 2011–12 to 2015–16, with total forest-related R&D capacity in 2015–16 reduced to nearly one-third of that in 2011–12. While the overall numbers differ to those reported by Turner and Lambert (2016, see below), probably owing to differences in timing of data collection and classification of personnel and roles, the relative changes year-on-year are consistent across the two datasets. The reduction in research capacity focussing on plantations is more marked than that for native forest, but both are substantial. The overall reduction in research capacity presents a risk for industry, especially when capacity in key areas is greatly diminished. From 2011–12 to 2015–16, capacity declined in almost all discipline areas. Notable among these is the loss of silvicultural research and tree breeding expertise in the plantation sector, and the reductions in flora and fauna ecology expertise across both native forest and plantations.

Table 7.14: Full-time-equivalent state and territory government employees engaged in forest-related research and development

	Full-time-equivalent government R&D employees					
	2011–12			2015–16		
Jurisdiction	**Plantations**	**Native forest**	**Total**	**Plantations**	**Native forest**	**Total**
ACT	0.0	7.0	7.0	0.0	7.0	7.0
NSW	12.5	12.5	25.0	8.0	8.0	16.0
NT	3.2	0.0	3.2	0.9	0.2	1.1
Qld	31.6	0.9	32.5	20.5	1.2	21.7
SA	15.8	0.8	16.6	1.0	0.0	1.0
Tas.	21.8	21.8	43.6	3.1	6.3	9.3
Vic.	0.0	21.9	21.9	0.0	17.8	17.8
WA	0.0	22.0	22.0	0.0	15.6	15.6
Australia	**84.9**	**86.9**	**171.8**	**33.5**	**56.0**	**89.5**

Notes: For South Australia and Tasmania the 2011–12 values are 2010–11 data from SOFR 2013. Numbers of private sector, Commonwealth-funded, university-funded, and CSIRO personnel are reported in other tables. New South Wales total staff numbers have been split equally between plantations and native forest. Total for Tasmania in 2011–12 has been split equally between plantations and native forest. The 2.0 FTE from the Forest Practices Authority of Tasmania have been split equally between plantations and native forest for 2015–16. Totals may not tally due to rounding.

Source: Data reported by states and territories.

This table, together with other data for Indicator 7.1e, is available in Microsoft Excel via www.doi.org/10.25814/5bda99c8d76da

[417] Long Term Ecological Research Network website: What is LTERN? www.ltern.org.au/about/what-is-ltern

Table 7.15: Full-time-equivalent research effort by government employees by type of activity, as reported by jurisdictions

Research and development activity	Government R&D employees (full-time equivalent)			
	Plantations		Native forest	
	2011–12	2015–16	2011–12	2015–16
Silvicultural research	16	0.8	1.5	1.0
Tree breeding (not horticultural)	3.8	2.2	1	1.0
Forest hydrology	1.2	0.2	1.7	1.4
Timber use	3.1	1.5	0	0.2
Fire behaviour	0.2	0.5	0.7	1.8
Forest pathology	2.6	2.0	3	0.5
Agroforestry	1.5	0	1.5	0
Fauna ecology including aquatic biota	4	1.5	21.6	17.3
Fire ecology	0.2	0.1	16.6	15.1
Forest health and biosecurity	11.1	5.1	3	3.3
Flora ecology	0.5	0	3	2.3
Non-timber forest products	0.5	0	0.5	0.1
Climate change	1.7	0	1.5	0.4
Statistical analysis	0.7	0.8	0.5	0.9
Forest industries	15	9.6	0	0
Sustainable forest management	0.8	3.5	7.9	4.9
Spatial analysis, modelling and remote sensing	0	1.5	0	1.5
Forest carbon	0	1.5	0	1.5
Resource analysis	0	0.5	0	0.5
Other (not elsewhere classified)	21.9	2.1	22.8	2.1
Total	**85.0**	**33.5**	**86.9**	**56.0**

Notes: For South Australia and Tasmania the 2011–12 values are 2010–11 data from SOFR 2013. New South Wales total staff numbers have been split equally between plantations and native forest. Tasmania's 43.6 FTE for 2011–12 has been split equally between plantations and native forest in the 'Other' activity. The 2.0 FTE from the Forest Practices Authority of Tasmania have been split equally between plantations and native forest for 2015–16, in the 'Other' activity. Totals may not tally due to rounding.

Source: Data reported by states and territories.

This table, together with other data for Indicator 7.1e, is available in Microsoft Excel via www.doi.org/10.25814/5bda99c8d76da

Australian Capital Territory

The Environment, Planning and Sustainable Development Directorate of the Australian Capital Territory Government supports forest management and facilitates research on forested areas, focussing on native forest. It undertakes research on local flora and fauna, prepares scientific advice on the environment and natural resource management, conducts ecological surveys, monitors biodiversity, and prepares and guides implementation of threatened species action plans. Numbers of personnel and focus of research activities have remained stable during the SOFR 2018 reporting period.

New South Wales

Forest R&D in New South Wales is undertaken by the NSW Department of Primary Industries (DPI) Forest Science group, under a memorandum of understanding with the Forestry Corporation of NSW, and through collaborative research arrangements. The DPI Forest Science group has scientific and technical expertise in forest ecology and sustainability, forest health and resource assessment, carbon in forests, wood products and bioenergy, and biometric services.

The number of full-time-equivalent (FTE) positions in forest-related R&D at the DPI Forest Science group decreased from 25 in 2011–12 to 16 in 2015–16. Decreases in capacity occurred across a number of research areas, including agroforestry, flora and fauna ecology, and climate change. Research previously reported under forest pathology and forest entomology in 2011–12 was more accurately reclassified as forest health and biosecurity for 2015–16.

The information on government agency research and development activities for 2015–16 relates to the DPI Forest Science group only. The majority of forest researchers work opportunistically in both native forests and plantations, so it is not possible to split their time accurately between native forest and plantation work. Other New South Wales agencies did not report forest-related R&D employees.

Queensland

The Queensland Government through its Department of Agriculture and Fisheries[418] retains a substantial forestry R&D portfolio. The primary focus of research effort by Queensland Government personnel is on plantations, with a specific focus on forest value, health and forest product

[418] Until February 2015, the Department of Agriculture, Fisheries and Forestry.

innovation. Queensland reported a decline in total numbers of forest research personnel from 32.6 FTE in 2011–12 to 21.7 FTE in 2015–16 (a 33% reduction), offset by an increase in numbers of collaborating research personnel at academic institutions from 1.2 FTE in 2011–12 to 24.6 FTE in 2015, the latter split evenly between plantations (12.6 FTE) and native forests (12.0 FTE). Collaborating academic institutions include the University of the Sunshine Coast, University of Queensland, Griffith University and Queensland University of Technology. The research staff employed by the University of the Sunshine Coast include adjunct staff members and higher degree research candidates at the university's Forest Industries Research Centre, and the university's Tropical Forests and People Research Centre established in 2014.

South Australia

The focus of state government forestry research in South Australia over the period 2011–12 to 2015–16 was on plantations. During 2015, the majority of Forestry SA staff transferred to the private sector and were employed by OneFortyOne plantations. South Australia reported 1.0 FTE forestry-related research personnel for 2015–16.

Tasmania

For 2015–16, Tasmania reported a total of 9.3 FTE forest researchers in government agencies, comprising 4.8 FTE at Forestry Tasmania[419], 2.5 FTE at the Department of Primary Industries, Parks, Water and Environment (DPIPWE), and 2.0 at the Tasmanian Forest Practices Authority (FPA). This is a substantial reduction from the 43.6 FTE forest researchers in government agencies reported for 2010–11. In previous reporting periods, much of the Tasmanian forest-related research effort occurred through the CRC for Forestry (see above), which operated from July 2005 to June 2013.

Over the SOFR 2018 reporting period, Forestry Tasmania undertook and collaborated in research into native forest silviculture, plantation silviculture, forest remote sensing, and biology and conservation (including forest health surveillance) and, together with the Tasmanian Parks and Wildlife Service, managed the Warra Long-term Ecological Research site (see Case study 7.8) in southern Tasmania. At least one-third of Forestry Tasmania's research expenditure was devoted to development and extension work for the strategic or operational uptake of research.

The majority of Forestry Tasmania researchers were in flora and fauna ecology, silviculture, tree breeding, hydrology, diseases and pests. Research effort in silviculture was maintained over the period 2011 to 2016. There is an increasing research effort undertaken at the landscape level, in the emerging disciplines of conservation biology, landscape ecology, landscape genetics and dynamic forest management, due to the increasing recognition of the need to manage forests at this scale.

Forest research in earth sciences and cultural heritage undertaken by the FPA during 2011–16 concentrated on landscape-scale erosion history and erosion risks, determining the influence of Aboriginal-lit fires on vegetation and landscape character, stream monitoring, determining the principles of carbon sequestration in Tasmanian native forests, and developing procedures for systematic recording and protection of cultural heritage. The FPA also undertook research in natural values, biodiversity and conservation management, and updated and improved the Mature Habitat Availability Map used for strategic management of mature forest features such as tree hollows. FPA staff collaborated with staff of Forestry Tasmania and the Australian National University to explore the use of LiDAR for creating a similar map with greater spatial resolution.

FPA research is done in collaboration with researchers, students and staff in government departments, institutions, and companies such as University of Tasmania, Murdoch University, University of Queensland, Australian National University, University of the Fraser Valley in British Columbia, Canada, DPIPWE, Forestry Tasmania, Private Forests Tasmania, Timberlands Pacific, Gunns, Forico, Timberlands Pacific and Norske-Skog. FPA researchers also provided assistance to researchers working in similar fields overseas, specifically in Papua New Guinea and the USA.

In addition to state-funded R&D personnel, Tasmania reported 4.5 FTE forest researchers employed by private companies for 2015–16. These companies were Norske Skog, Timberlands Pacific and Forico. Research by academic institutions is reported separately below.

Victoria

The number of forest researchers employed by the state of Victoria has remained relatively stable, declining from 21.9 to 17.8 FTE between 2011–12 and 2015–16 (a 19% reduction). All research personnel have focussed on native forest, with a significant proportion working on fire ecology (6.8 FTE), fauna ecology (5.8 FTE) and sustainable forest management (1.5 FTE) during 2015–16. The data on FTE forest researchers in government agencies shown in Tables 7.14 and 7.15 include employees of the Department of Environment, Land, Water and Planning (DELWP)[420], VicForests and the Arthur Rylah Institute (ARI), DELWP.

In addition, Victoria reported 26.3 academic FTEs working in forest R&D. This figure includes those funded by DELWP through the Integrated Forest and Ecosystem Research (IFER) program at the University of Melbourne (see below) and the BNH CRC (Bushfire and Natural Hazards Co-operative Research Centre, see above). These personnel were all focussed on native forests, and for 2015–16 included 5.2 FTE working on forest hydrology, 12.9 FTE on fire behaviour, 4.5 FTE on fire ecology, 0.9 FTE on sustainable forest management and 2.8 FTE on forest health.

[419] From July 2017, Sustainable Timber Tasmania.

[420] Until January 2015, the Department of Environment and Primary Industries.

Western Australia

The number of forest researchers employed by the state of Western Australia declined from 22.0 FTE to 15.6 FTE between 2011–12 and 2015–16 (a 29% decline). All research personnel focussed on native forests, with a significant proportion working on fire ecology (4.5 FTE), fauna ecology (3.5 FTE) and sustainable forest management (3.3 FTE) during 2015–16. These data on R&D capacity are based on an audit of staff and projects undertaken by the Science and Conservation Division of the Department of Parks and Wildlife[421], as at the end of 2015–16. In 2013–14, research activity was reported for the area covered by the Western Australian Regional Forest Agreement and the Forest Management Plan, with the addition of 3.0 FTE research staff working on fire ecology and operating in the North Kimberley and Great Western Woodlands (Goldfields Region).

National research capacity surveys

A series of surveys conducted by Turner and Lambert on expenditure on R&D for forestry and forest products has also collected data on R&D capacity, using a consistent methodology, at intervals in the period 1981–82 to 2012–13 (Turner and Lambert 2016). The definitions of 'Forestry R&D' and 'Forest Products' R&D used by Turner and Lambert, and survey results on R&D expenditure, are detailed in Indicator 6.2a. Table 7.16 summarises the data on forestry and forest product research capacity for the various categories of R&D organisation, as compiled in the Turner and Lambert surveys from 1985 to 2013. Changes in researcher numbers as a measure of research capacity do not take into account concurrent changes in facilities and infrastructure.

Turner and Lambert estimated that there were 276 researchers and technicians involved in forestry and forest products R&D in 2012–13, together with additional support staff and external contractors. This represented a steady decline in research staff in the Commonwealth and state sectors since about 1990, not fully compensated by increases in research staff in the university and private sectors. The increases in university and private sector research capacity to 2008 were due to more organisations reporting research, rather than an increase in actual numbers of any particular research group.

The expertise of each researcher was not recorded for these surveys, but discussions with employing organisations indicated that there has been a greater decline in some areas of research, such as forest health, silviculture and forest hydrology, compared to others.

Table 7.16: Research capacity for forestry and forest products in Australia, from Turner and Lambert (2016)

		R&D staff numbers			
Organisation	**Staff type**	**1985**	**2008**	**2011**	**2013**
CSIRO	Scientists	145	75	38	32
	Technical staff	132	81	39	16
	Support	48	17	4	0
	Subtotal	**325**	**173**	**81**	**48**
State agencies	Scientists	180	117	77	56
	Technical staff	206	109	71	37
	Support	46	21	9	0
	Subtotal	**432**	**247**	**157**	**93**
Private companies	Scientists	6	59	30	21
	Technical staff	3	57	30	15
	Support	1	14	7	1
	Subtotal	**10**	**130**	**67**	**37**
Universities	Scientists	11	90	72	54
	Technical staff	10	47	39	21
	Support	6	46	39	23
	Subtotal	**27**	**183**	**150**	**98**
Total		**794**	**733**	**455**	**276**

Source: Turner and Lambert (2016)

This table, together with other data for Indicator 7.1e, is available in Microsoft Excel via www.doi.org/10.25814/5bda99c8d76da

[421] From July 2017, the Department of Biodiversity, Conservation and Attractions.

University-based forest research capacity

Much of our scientific understanding of Australia's forests is developed in universities, with the capacity for forest research present at a number of Australia's universities. Research is carried out both by university research staff and by students enrolled in Honours, Masters or Doctoral degrees. Universities produce high-quality, peer-reviewed research that adds to the development of assessment methodologies and the scientific understanding of Australia's forests, and which is needed to underpin sustainable forest management.

Many academic institutions contribute to the range of forest research programs established under research agencies funded by the Australian Government, as well as research agencies funded by state and territory governments. In addition, research centres and facilities at universities provide focal points for research training and collaboration, including with other universities, government agencies and the private sector.

The Australian Research Council (ARC) is responsible for administering Excellence in Research for Australia (ERA), Australia's national research evaluation framework. Eight Australian universities reported activities in the field of forestry sciences in the most recent (2015) ERA survey: the Australian National University, Murdoch University, Southern Cross University, the University of Melbourne, the University of Queensland, the University of Tasmania, the University of the Sunshine Coast, and the University of Western Sydney. Research in forest products also occurs at Monash University (through the Australian Pulp and Paper Institute) and Queensland University of Technology (through the Biorefineries for Profit project).

In Tasmania, the ARC Centre for Forest Value situated on the University of Tasmania's Hobart campus was established in early 2016. The research effort of the centre covers forest ecology and restoration, timber in service, and supply chain information management, and the Centre also trains forest scientists to work within the forest industry. The Centre has eight industry partners: Greening Australia, Forestry Tasmania (now Sustainable Timber Tasmania), SFM Environmental Solutions, Forico, Neville-Smith Forest Products, Next 50 Architects, FWPA, and the Island Workshop Prefab Lab. The Centre succeeded the National Centre for Future Forest Industries (2012–2015).

In Queensland, the Forest Industries Research Centre (FIRC), located at the University of the Sunshine Coast, is focused on issues relating to complex forestry value chains, and thus the economic and environmental sustainability of forest industries. This approach covers research disciplines including genetics and genomics, silviculture and stand management, forest health and pest management, ecology and biodiversity management, timber and biomass harvest and haulage, fibre quality and value, timber processing and biorefinery, renewable energy and biofuels, and timber construction materials. FIRC takes a multidisciplinary approach to understand and identify value in the interactions between these research disciplines.

Also in Queensland, the Centre for Future Timber Structures, University of Queensland, is a Centre of Excellence for the education of future timber industry professionals and innovation in the use of timber in the built environment. Areas of research include fibre-reinforced timber composites, fire safety of timber structures, and timber use in advanced manufacturing. Partners include the Queensland Department of Agriculture and Fisheries, the University of Queensland, and industry.

In New South Wales, the Western Sydney University Hawkesbury Institute for the Environment operates the world's only 'free air carbon dioxide enrichment' (FACE) experiment in native forest (EucFACE), as well as a series of Whole-Tree Chambers in the Hawkesbury Forest. EucFACE is designed to predict the effects of rising atmospheric carbon dioxide (CO_2) levels on Australia's native forests, including trees, animals, soil and grasses. The Whole-Tree Chambers provide enclosed, controlled environments for trees up to nine metres tall, in which researchers manipulate air temperature, soil moisture, irrigation, CO_2 levels and humidity to determine the integrated effects of altered climates on tree physiology.

Also in New South Wales, researchers in Southern Cross University's Forest Research Centre investigate the ecology of native forests both in Australia and overseas, as well as studying how native forests and plantations can sustainably produce wood products, environmental services and carbon. Particular areas of focus include tropical and subtropical forestry and agroforestry, computer modelling for forest management and decision-support systems, forest ecology and management, forest genetics, new products from trees, mixed-species plantations, and community engagement in land-use planning.

In the Australian Capital Territory, the Fenner School of Environment and Society at the Australian National University takes a multi-disciplinary approach to research, research training and policy in environment and sustainability, including issues relating to the management, conservation and sustainability of forest ecosystems. The School includes economists, hydrologists, historians, ecologists, foresters, geographers and climatologists, working both nationally and internationally.

Harvested pine logs awaiting transportation from a plantation, Queensland.

In Western Australia, the State Centre of Excellence on Climate Change, Woodland and Forest Health at Murdoch University focuses on tree, woodland and forest decline under climate change, with the aim of restoring biodiversity values, and developing policies and action for the restoration of woodlands and forests.

In Victoria, the Integrated Forest Ecosystem Research (IFER) program is a research initiative between the School of Ecosystem and Forest Sciences at the University of Melbourne and DELWP. It aims to enhance the evidence base for managing the impacts of fire, climate and management regimes on multiple forest values in Victoria's forest ecosystems. The IFER program investigates forest ecosystems in Victoria under six main landscape-level themes: fire behaviour, carbon, biodiversity, water, vulnerability, and social and economic values.

On 04 June 2016, the Australian Government announced the establishment of a National Institute for Forest Products Innovation to be jointly based at the University of Tasmania in Launceston, and at the University of South Australia campus in Mt Gambier. The Institute will focus on innovation in the forest products industry and will provide additional research and development across Australia in forest management, timber processing, wood fibre recovery, advanced manufacturing and the bio-economy.

Appendix A

Comparison of international Montreal Process indicators for sustainable forest management with Australia's national indicators for sustainable forest management

In reporting on the state of its forests, Australia uses the seven criteria developed in 1995 by the international-level Montreal Process Working Group on Criteria and Indicators for the Conservation and Sustainable Management of Temperate and Boreal Forests (Montreal Process Working Group 2009a, 2009b). Indicators are nested under each of these criteria.

In 1998, the national-level Montreal Process Implementation Group for Australia (MIG), which comprises representatives of the Australian Government and state and territory governments, adapted the Montreal Process set of indicators to better suit reporting on Australia's unique forests. However, some of Australia's original set of indicators proved difficult to measure, and some overlapped. In 2006, MIG reviewed the indicators and reduced the list used in Australia to 44 (Commonwealth of Australia 2008). This set of 44 national indicators underpinned SOFR 2008 and SOFR 2013, and again underpins SOFR 2018.

Table A1 shows the alignment of Australia's 44 national indicators with the 54 international indicators of the Montreal Process.

Table A1: Alignment of the international Montreal Process indicators with Australia's national indicators used in SOFR 2018

International Montreal Process criteria and indicators		Australian indicator(s) with which each Montreal Process indicator aligns		Australia's criteria and indicators		Montreal Process indicator(s) with which each Australian indicator aligns	
Indicator number	Indicator name	Strong alignment	Partial alignment	Indicator number	Indicator name	Strong alignment	Partial alignment
Criterion 1 Conservation of biological diversity							
1.1	**Ecosystem diversity**			**1.1**	**Ecosystem diversity**		
1.1.a	Area and percent of forest by forest ecosystem type, successional stage, age class, and forest ownership or tenure	1.1a	1.1b	**1.1a**	Area of forest by forest type and tenure	1.1.a	–
1.1.b	Area and percent of forest in protected areas by forest ecosystem type, and by age class or successional stage	1.1c	1.1b	**1.1b**	Area of forest by growth stage	–	1.1.a 1.1.b
1.1.c	Fragmentation of forests	1.1d	–	**1.1c**	Area of forest in protected area categories	1.1.b	–
				1.1d	Fragmentation of forest cover	1.1.c	–
1.2	**Species diversity**			**1.2**	**Species diversity**		
1.2.a	Number of native forest associated species	–	1.2a	**1.2a**	Forest dwelling species for which ecological information is available	–	1.2.a
1.2.b	Number and status of native forest associated species at risk, as determined by legislation or scientific assessment	1.2b	–	**1.2b**	The status of forest dwelling species at risk of not maintaining viable breeding populations, as determined by legislation or scientific assessment	1.2.b	–
1.2.c	Status of on site and off site efforts focused on conservation of species diversity	–	–	**1.2c**	Representative species from a range of habitats monitored at scales relevant to regional forest management	–	1.3.b
1.3	**Genetic diversity**			**1.3**	**Genetic diversity**		
1.3.a	Number and geographic distribution of forest associated species at risk of losing genetic variation and locally adapted genotypes	1.3a	–	**1.3a**	Forest associated species at risk from isolation and the loss of genetic variation, and conservation efforts for those species	1.3.a	1.3.c
1.3.b	Population levels of selected representative forest associated species to describe genetic diversity	–	1.2c	**1.3b**	Native forest and plantations of indigenous timber species which have genetic resource conservation mechanisms in place	–	1.3.c
1.3c	Status of on site and off site efforts focused on conservation of genetic diversity	–	1.3a 1.3b				

Continued

Continues

International Montreal Process criteria and indicators

Indicator number	Indicator name	Australian indicator(s) with which each Montreal Process indicator aligns: Strong alignment	Partial alignment
Criterion 2 Maintenance of productive capacity of forest ecosystems			
2.a	Area and percent of forest land and net areas of forest land available for wood production	2.1a	–
2.b	Total growing stock and annual increment of both merchantable and non-merchantable tree species in forests available for wood production	2.1a	–
2.c	Area, percent, and growing stock of plantations of native and exotic species	2.1b	–
2.d	Annual harvest of wood products by volume and as a percentage of net growth or sustained yield	2.1c	–
2.e	Annual harvest of non-wood forest products	2.1d	–
Criterion 3 Maintenance of ecosystem health and vitality			
3.a	Area and percent of forest affected by biotic processes and agents (e.g. disease, insects, invasive species) beyond reference conditions	3.1a	–
3.b	Area and percent of forest affected by abiotic agents (e.g. fire, storm, land clearance) beyond reference conditions	3.1a 3.1b	–
Criterion 4 Conservation and maintenance of soil and water resources			
4.1	**Protective function**		
4.1.a	Area and percent of forest whose designation or land management focus is the protection of soil or water resources	4.1a	–
4.2	**Soil**		
4.2.a	Proportion of forest management activities that meet best management practices or other relevant legislation to protect soil resources	4.1b 4.1c	–
4.2.b	Area and percent of forest land with significant soil degradation	–	–
4.3	**Water**		
4.3.a	Proportion of forest management activities that meet best management practices, or other relevant legislation, to protect water related resources	4.1d 4.1e	–
4.3.b	Area and percent of water bodies, or stream length, in forest areas with significant change in physical, chemical or biological properties from reference conditions	–	–
Criterion 5 Maintenance of forest contribution to global carbon cycles			
5.a	Total forest ecosystem carbon pools and fluxes	5.1a	–
5.b	Total forest product carbon pools and fluxes	5.1a	–
5.c	Avoided fossil fuel carbon emissions by using forest biomass for energy	–	5.1a

Australia's criteria and indicators

Indicator number	Indicator name	Montreal Process indicator(s) with which each Australian indicator aligns: Strong alignment	Partial alignment
Criterion 2 Maintenance of productive capacity of forest ecosystems			
2.1a	Native forest available for wood production, area harvested, and growing stock of merchantable and non-merchantable tree species	2.a 2.b	–
2.1b	Age class and growing stock of plantations	2.c	–
2.1c	Annual removal of wood products compared to the volume determined to be sustainable for native forests and future yields for plantations	2.d	–
2.1d	Annual removal of non-wood forest products compared to the level determined to be sustainable	2.e	–
2.1e	The area of native forest harvested and the proportion of that effectively regenerated, and the area of plantation harvested and the proportion of that effectively re-established	–	–
Criterion 3 Maintenance of ecosystem health and vitality			
3.1a	Scale and impact of agents and processes affecting forest health and vitality	3.a 3.b	–
3.1b	Area of forest burnt by planned and unplanned fire	3.b	–
Criterion 4 Conservation and maintenance of soil and water resources			
4.1a	Area of forest land managed primarily for protective functions	4.1.a	–
4.1b	Management of the risk of soil erosion in forests	4.2.a	–
4.1c	Management of the risks to soil physical properties in forests	4.2.a	–
4.1d	Management of the risks to water quantity from forests	4.3.a	–
4.1e	Management of the risks to water quality in forests	4.3.a	–
Criterion 5 Maintenance of forest contribution to global carbon cycles			
5.1a	Contribution of forest ecosystems and forest industries to the global greenhouse gas balance	5.a 5.b	5.c

Continued

Continues

International Montreal Process criteria and indicators		Australian indicator(s) with which each Montreal Process indicator aligns		Australia's criteria and indicators		Montreal Process indicator(s) with which each Australian indicator aligns	
Indicator number	Indicator name	Strong alignment	Partial alignment	Indicator number	Indicator name	Strong alignment	Partial alignment
Criterion 6 Maintenance and enhancement of long-term multiple socio-economic benefits to meet the needs of societies							
6.1	**Production and consumption**			**6.1**	**Production and consumption**		
6.1.a	Value and volume of wood and wood products production, including primary and secondary processing	6.1a	–	**6.1a**	Value and volume of wood and wood products	6.1.a	–
6.1.b	Value of non-wood forest products produced or collected	6.1b	–	**6.1b**	Values, quantities and use of non-wood forest products	6.1.b	–
6.1.c	Revenue from forest based environmental services	6.1c	–	**6.1c**	Value of forest based services	6.1.c	–
6.1.d	Total and per capita consumption of wood and wood products in round wood equivalents	6.1d	–	**6.1d**	Production and consumption and import/export of wood, wood products and non-wood products	6.1.d 6.1.e 6.1.f 6.1.g	6.1.h
6.1.e	Total and per capita consumption of non-wood products	6.1d	–	**6.1e**	Degree of recycling of forest products	6.1.i	–
6.1.f	Value and volume in round wood equivalents of exports and imports of wood products	6.1d	–				
6.1.g	Value of exports and imports of non-wood products	6.1d	–				
6.1.h	Exports as a share of wood and wood products production and imports as a share of wood and wood products consumption	–	6.1d				
6.1.i	Recovery or recycling of forest products as a percent of total forest products consumption	6.1e	–				
6.2	**Investment in the forest sector**			**6.2**	**Investment in the forest sector**		
6.2.a	Value of capital investment and annual expenditure in forest management, wood and non-wood product industries, forest-based environmental services, recreation and tourism	6.2a	–	**6.2a**	Investment and expenditure in forest management	6.2.a	–
6.2.b	Annual investment and expenditure in forest-related research, extension and development, and education	6.2b	–	**6.2b**	Investment in research, development, extension and use of new and improved technologies	6.2.b	–
6.3	**Employment and community needs**			**6.5**	**Employment and community needs**		
6.3.a	Employment in the forest sector	6.5a	–	**6.5a**	Direct and indirect employment in the forest sector	6.3.a	–
6.3.b	Average wage rates, annual average income and annual injury rates in major forest employment categories	6.5b	–	**6.5b**	Wage rates and injury rates within the forest sector	6.3.b	–
6.3.c	Resilience of forest-dependent communities	6.5c	–	**6.5c**	Resilience of forest dependent communities to changing social and economic conditions	6.3.c	–
6.3.d	Area and percent of forests used for subsistence purposes	–	6.5d	**6.5d**	Resilience of forest dependent Indigenous communities to changing social and economic conditions	–	6.3.d
6.3.e	Distribution of revenues derived from forest management	–	–				
6.4	**Recreation and tourism**			**6.3**	**Recreation and tourism**		
6.4.a	Area and percent of forests available and/or managed for public recreation and tourism	6.3a	–	**6.3a**	Area of forest available for public recreation/tourism	6.4.a	–
6.4.b	Number, type, and geographic distribution of visits attributed to recreation and tourism and related to facilities available	6.3b	–	**6.3b**	Range and use of recreation/ tourism activities available	6.4.b	–

Continued

Continues

Criterion 6 Maintenance and enhancement of long-term multiple socio-economic benefits to meet the needs of societies *(Continued)*

International Montreal Process criteria and indicators — Australian indicator(s) with which each Montreal Process indicator aligns

Indicator number	Indicator name	Strong alignment	Partial alignment
6.5	**Cultural, social and spiritual needs and values**		
6.5.a	Area and percent of forests managed primarily to protect the range of cultural, social and spiritual needs and values	6.4a 6.4b 6.4c	–
6.5.b	The importance of forests to people	6.4d	–

Australia's criteria and indicators — Montreal Process indicator(s) with which each Australian indicator aligns

Indicator number	Indicator name	Strong alignment	Partial alignment
6.4	**Cultural, social and spiritual needs and values**		
6.4a	Area of forest to which Indigenous people have use and rights that protect their special values and are recognised through formal and informal management regimes	6.5.a	–
6.4b	Registered places of non-Indigenous cultural value in forests that are formally managed to protect those values	6.5.a	–
6.4c	The extent to which Indigenous values are protected, maintained and enhanced through Indigenous participation in forest management	6.5.a	–
6.4d	The importance of forests to people	6.5.b	–

Criterion 7 Legal, institutional and economic framework for forest conservation and sustainable management

International Montreal Process criteria and indicators — Australian indicator(s) with which each Montreal Process indicator aligns

Indicator number	Indicator name	Strong alignment	Partial alignment
7.1.a	Legislation and policies supporting the sustainable management of forests	7.1a	7.1b
7.1.b	Cross-sectoral policy and programme coordination	–	7.1a 7.1b
7.2.a	Taxation and other economic strategies that affect the sustainable management of forests	7.1c	–
7.3.a	Clarity and security of land and resource tenure and property rights	–	7.1a
7.3b	Enforcement of laws related to forests	–	7.1a
7.4.a	Programmes, services and other resources supporting the sustainable management of forests	–	7.1b
7.4.b	Development and application of research and technologies for the sustainable management of forests	7.1e	–
7.5.a	Partnerships to support the sustainable management of forests	–	–
7.5.b	Public participation and conflict resolution in forest-related decision making	–	7.1b
7.5.c	Monitoring, assessment and reporting on progress towards sustainable management of forests	7.1d	–

Australia's criteria and indicators — Montreal Process indicator(s) with which each Australian indicator aligns

Indicator number	Indicator name	Strong alignment	Partial alignment
7.1a	Extent to which the legal framework supports the conservation and sustainable management of forests	7.1.a	7.3.a 7.3.b
7.1b	Extent to which the institutional framework supports the conservation and sustainable management of forests	–	7.1.a 7.4.a 7.5.b
7.1c	Extent to which the economic framework supports the conservation and sustainable management of forests	7.2.a	–
7.1d	Capacity to measure and monitor changes in the conservation and sustainable management of forests	7.5.c	–
7.1e	Capacity to conduct and apply research and development aimed at improving forest management and delivery of forest goods and services	7.4.b	–

–, no such alignment

Glossary

Numbers separate alternative definitions or uses.

Term	Definition and use
Abiotic	The non-biological components of the environment (e.g. climate, soil and water).
Above-ground biomass	All living biomass above the soil, including stump, stem, bark, branches and foliage, and attached material such as dead branches. See *Below-ground biomass, Biomass.*
Acacia	As a national forest type, forest dominated by trees of the genus *Acacia*.
Acidification	Increasing levels of acidity – for example, in soil – that can damage soil and vegetation.
Adaptive capacity (human)	Ability, or potential, of a community or individual to modify or change characteristics or behaviour to cope better with change or stresses. See *Community.*
Afforestation	Establishment of forest on land not previously forested. The Kyoto Protocol and initiatives such as the Carbon Farming Initiative use specific definitions of afforestation. See *Deforestation, Forest, Reforestation.*
Age class	Group of trees of a similar age. For example, a cohort of native forest trees regenerating after a disturbance event, or a set of plantations established in a given time-period.
Aggregated retention	A native forest silvicultural system in which clumps or clusters of trees are retained in forest stands harvested for wood. A form of variable retention. See *Silvicultural practices / systems, Variable retention.*
Agroforestry	See *Farm forestry*.
Apical dominance	Growth habit of a shoot whereby growth and development of lateral buds are suppressed.
Allowable cut	The average quantity of wood, usually prescribed in a legislative instrument or an approved management plan, permitted to be harvested from a forest management planning unit or region, annually or periodically, under management for sustained yield. See *Sustainable yield, Sustained yield*
Arboretum	A collection of living trees established at a single site at least partly for observation and scientific study. Plural: arboreta.
Arisings	Logs produced (arising) as a result of the harvest of logs of other species or of other grades, but that do not meet the size or quality specifications for those other species or grades.
Below-ground biomass	All biomass of live roots in the soil. (Fine roots are often excluded from measurement because it is difficult to separate these from soil organic matter.) See *Above-ground biomass, Biomass.*
Biodiversity; Biological diversity	The variety of all life forms, plants, animals and microorganisms, their genes and the ecosystems they inhabit. See *Ecosystem diversity, Genetic diversity, Species diversity.*
Bioenergy	A form of energy derived from biomass, when biomass is used to generate electricity or heat or to produce fuels. See *Biofuel, Biomass.*
Biofuel	An energy source made from organisms and their products such as wood and plant matter, algae, or animal fats. See *Bioenergy.*
Biogeographic	Relating to the study of the distribution of living things.
Biological diversity	See *Biodiversity.*
Biomass	1. Material of biological origin (plant and other). 2. Living and dead organic material located above-ground and below-ground, for example, trees, grasses, litter, roots and soil organic matter (for purposes of carbon accounting).
Biome	A large, regional ecological unit, usually defined by some dominant vegetative pattern.
Bioregion	A large, geographically distinct area that has a common climate, geology, landform, and vegetation and animal communities. See *IBRA.*
Biotic	Used in reference to the biological components of the environment (e.g. plants, animals and other organisms).
Bole log	Log taken from the tree trunk between the ground and the crown break (the height of the first major branch).
Bole volume	Volume of a bole log.
Broadscale clearing	Clearing of large tracts of native vegetation. See *Forest clearing, Land clearing.*

Term	Definition and use
Bushfire	Fire started naturally (such as by lightning), accidentally or deliberately (such as by arson), but not in accordance with planned fire management prescriptions. See *Unplanned fire, Wildfire.*
Bushland	A general term in Australia for natural vegetation, covering any kind of habitat from open, shrubby country with scattered trees, to tall, closed forests.
Callitris	As a national forest type, forest dominated by trees of the genus *Callitris*.
Canopy	Uppermost layer of a forest comprising tree crowns, branches and leaves.
CAR reserve system	A forest reserve system that includes the full range of vegetation communities ('comprehensive'), with a level of reservation sufficiently large to maintain species diversity as well as community interaction and evolution ('adequate'), and conserving the diversity (including genetic diversity) within each vegetation community ('representative'). The CAR reserve system comprises dedicated reserves, informal reserves, and areas where forest values are protected by management prescriptions, as well as areas protected on private land. Dedicated, or formal, reserves are set aside for conservation through areas such as national parks. Informal forest reserves are areas set aside for conservation in forests that are otherwise production forests, such as special protection zones in state forests. In further areas, such as production forests, protection of values may be prescribed through management prescriptions in codes of practice or management plans; examples include components of the CAR reserve system that are not mappable in advance of their detection, and/or where inclusion in dedicated or informal reserves is impractical, such as riparian vegetation, or rare, dispersed or fragmented values. See *National Reserve System, Protected area, Vegetation community.*
Carbon accounting	Estimation of the amount of carbon stored in an ecosystem and changes in this amount.
Carbon credit	A tradable certificate, permit or legal instrument, deriving from a verified reduction of one unit (one tonne) of carbon dioxide emissions (or equivalent), and tradable to offset one unit (one tonne) of carbon dioxide emissions (or equivalent).
Carbon sequestration	Removal of carbon from the atmosphere and its storage in vegetation, soils or elsewhere.
Carbon sink	A carbon reservoir or pool that has the capacity to accumulate carbon.
Carbon source	A carbon reservoir or pool that has the capacity to release carbon.
Carbon stock	Quantity of carbon in a carbon reservoir or pool; the quantity of carbon stored in forests and wood products.
Carbon store	A carbon reservoir or pool. Forests and wood products are examples of carbon stores.
Casuarina	As a national forest type, *Casuarina* forest is forest dominated by any of four genera in the family Casuarinaceae; typically, forest dominated by trees of the genera *Allocasuarina* or *Casuarina*.
Certification	See *Forest certification.*
Certified forest	A forest that has been certified by an accredited, independent third party to comply with the requirements of a credible and recognised forest management standard. See *Forest certification.*
Chain of custody	A process of verifying the origin and supply of wood or timber product through the supply chain to a point of market. Generally, this applies to products from forests with forest certification or where products are legally harvested. See *Forest certification.*
Chlorosis	Yellowing or whitening of leaf tissue due to a lack of chlorophyll, typically caused by disease, changed drainage, plant nutrient deficiencies, damage to roots, or compaction of soil.
Clearfelling	A native forest silvicultural system in which all (or nearly all) the trees in an area are harvested in one operation, such that more than half of the harvested area is greater than one tree height from a retained forest edge. Clearfelling is generally used in native forest types dominated by shade-intolerant tree species. In the harvest of plantations, clearfelling is harvesting all the trees on a site. See *Silvicultural practices / systems.*
Clone	Genetically identical copies of a plant produced by tissue culture or vegetative reproduction.
Closed forest	Forest in which the tree crown cover ranges from over 80% to 100%. See *Open forest, Woodland forest, Crown cover.*
CO_2-equivalent (CO_2-e)	Measurement unit for the effect in the atmosphere of greenhouse gases relative to the effect of a unit of carbon dioxide (CO_2).
Code of forest practice	A set of principles, procedures, guidelines and standards that defines and prescribes minimum acceptable practices in wood harvesting and associated forestry operations.
Commercial plantation	1. A National Forest Inventory forest category that comprises hardwood or softwood plantations managed commercially to supply logs to wood-processing industries for the manufacture of wood products. Previously known as Industrial plantation. 'Commercial plantation' does not include forest reported in the other two national forest categories, 'Native forest' and 'Other forest'. 2. A plantation reported through the National Plantation Inventory. See *Native forest, Other forest, Plantation.*
Commerciality	The expected volume yield of commercial sawlog or veneer log (or high-value equivalent) that is available over the long term, based on good silvicultural practices; derived from the combination of merchantability and productivity.
Community	1. Biological: a naturally occurring group of species inhabiting a particular area and interacting with each other, especially through biological relationships, relatively independently of other communities. 2. Human: a group of people associated with a particular place or geographic area.

Term	Definition and use
Community adaptive capacity (human)	See *Adaptive capacity.*
Community resilience (human)	The capacity of an individual, community or human system to absorb and respond to shocks while sustaining an acceptable level of function, structure, and identity.
Compaction	See *Soil compaction.*
Compliance audit	An audit of conformance to an environmental or forest management standard, silvicultural practice, or set of code of practice prescriptions. See *Code of forest practice, Forest certification.*
Conifer	Any taxon of the order Pinales (formerly Coniferales), a group of gymnosperms with characteristic reproductive structures called cones; includes Araucariaceae (araucaria family), Cupressaceae (cypress family), Pinaceae (pine family) and Podocarpaceae (podocarp family). See *Pine, Softwood.*
Connectivity	The degree of vegetation structural links between forest patches in a landscape, which facilitate species movement across habitat within the landscape context.
Conservation covenant	A voluntary, permanent, legally binding agreement made between a landholder and a covenant scheme provider to protect and enhance the natural, cultural and/or scientific values of a specified area of land. Conservation covenants are typically entered into for privately managed forest on private freehold or leasehold tenures; the provider can include not-for-profit organisations, government agencies or local councils. See *Conservation reserve.*
Conservation reserve	Area of land set aside to protect inherent environmental values. Development in, and use of, conservation reserves is usually restricted to activities that are compatible with conservation of the environmental values for which the reserve was declared. Conservation reserves include national parks, conservation parks and nature reserves, and informal reserves on public land, and are complemented by areas protected by conservation covenants on private land. See *Conservation covenant, Nature conservation reserve (Public).*
Cording	The practice of placing large (5–30 centimetre diameter) woody material on extraction tracks before harvesting, to minimise soil erosion. See *Matting.*
Coverage	Digital representation of spatial data for a geographic unit or region, typically with attributes that describe a theme associated with the geographic unit. Usually created and used in geographic information systems.
Criterion	As used in Australia's State of the Forests reports, a category of conditions or processes by which sustainable forest management may be assessed. A criterion is characterised by a set of related indicators that are monitored periodically to assess change in conditions or monitor trends over time. See *Indicator, Montreal Process.*
Critically endangered species / ecological community	A native species / ecological community facing an extremely high risk of extinction in the wild in the immediate future. One of the categories of threatened species / ecological communities defined in the Commonwealth *Environment Protection and Biological Conservation Act 1999*. See *Ecological community, Endangered species / ecological community, Extinct, Extinct in the wild, Threatened ecological community, Threatened species, Vulnerable species / ecological community.*
Crown cover	The area of ground covered by tree canopies, ignoring overlaps and gaps within individual canopies.
Crown density	A property of tree crowns, measured as the proportion of light from the sky that is blocked from reaching the ground by living or dead plant material.
Crown land	Land belonging to the Crown, being a national, state or territory government, including Crown land under private leasehold title. See *Leasehold title, Other Crown land, Public land.*
Defined forest area	Area of forest under management control of an agency. In relation to the Australian Standard for Sustainable Forest Management (AS 4708), the area of forest (including land and water) to which the requirements of the standard are applied, and over which a forest manager can demonstrate management control, which allows them to achieve the requirements of that standard.
Deforestation	A type of land clearing involving the permanent removal of tree cover. The Kyoto Protocol and initiatives such as the Carbon Farming Initiative use specific definitions of deforestation. See *Afforestation, Forest, Reforestation.*
Degradation	1. Loss of specific aspects of a forest ecosystem, such as tree cover, structural features or species, or of habitat characteristics that support the requirements of species or communities, short of being defined as deforestation. 2. Reduction in the capacity of a forest to provide a range of goods and services.
Dieback	A symptom of disease agents or environmental factors in which foliage dies progressively from the extremities and trees exhibit loss of vigour; used in reference to native forests affected by cinnamon fungus (*Phytophthora cinnamomi*), salinity, drought or pest load, or by changed nutrient, water or fire regimes, or trees on land subjected to overgrazing.
Direct employment	The number of jobs in public and private agencies and firms relating to the process of producing goods or providing a service. Any secondary economic activity resulting from the primary activity is included in indirect employment. See *Indirect employment.*
Dry forest / dry sclerophyll forest	Typically, eucalypt-dominated sclerophyll forest associated with water-limited or nutrient-limited conditions, and with an understorey (if present) of sclerophyll trees or shrubs. Ground cover can be bare, litter, grassy or heathy. See *Eucalypt, Sclerophyll, Wet forest / wet sclerophyll forest.*

Term	Definition and use
Ecological community	A group of plants, animals and other organisms that are interacting in a habitat. See *Community.*
Ecological and/or ecosystem resilience	See *Resilience.*
Ecologically mature	Displaying a range of structural, functional and compositional attributes and ecological processes characteristic of forests in their mature or senescent growth stages. See *Mature, Old-growth.*
Ecologically sustainable forest management	The integration of commercial and non-commercial values of forests so that the welfare of society (both material and non-material) is improved, while ensuring that the values of forests, both as a resource for commercial use and for conservation, are not lost or degraded for current and future generations. Some jurisdictions have legislated principles of ecologically sustainable forest management that have to be considered in managing public forests. See *Sustainable forest management.*
Ecologically sustainable use	Use of natural resources within their capacity to sustain natural processes, while maintaining the life-support systems of nature and ensuring that the benefit of use by the present generation does not diminish the potential to meet the needs and aspirations of future generations.
Ecosystem	A dynamic complex of plant, animal and microorganism communities and their non-living environment, interacting as a functional unit.
Ecosystem diversity	The diversity of different ecological communities formed by living organisms and the relations among them. See *Biodiversity, Genetic diversity, Species diversity.*
Ecosystem services	The benefits (goods and services) provided by ecosystems, and the contributions that ecosystems make to human well-being, arising from both biotic and abiotic processes as well as their interaction.
Ecotourism	Tourism that features places of ecological interest, such as forests, and experience of the environment.
Edge effect	The effect or influence of a area of vegetation on an adjacent area of vegetation. This can include the effect of adjacent non-forest land on a forest stand, the effect of a forest stand on adjacent non-forest land, the effect of a mature forest stand on adjacent regenerating forest, or the effect of regenerating forest on an adjacent mature forest stand.
Endangered species / ecological community	A native species/ecological community facing a very high risk of extinction in the wild in the near future. One of the categories of threatened species / ecological communities defined in the Commonwealth *Environment Protection and Biological Conservation Act 1999*. See *Critically endangered species / ecological community, Ecological community, Extinct, Extinct in the wild, Threatened ecological community, Threatened species, Vulnerable species / ecological community.*
Endemic	Species of plant or animal that occurs naturally only in a specified region or country. See *Exotic, Indigenous (of species), Introduced species.*
Environmental compliance	Conforming to specified requirements in environmental laws, regulations, environmental management systems, management plans, planning specifications, codes of practice, standards and prescription guidelines. See *Code of forest practice, Environmental management system.*
Environmental management system	A framework for the systematic management of an organisation's environmental obligations and objectives.
Environmental planting	In a forest context, trees established for environmental benefit (rather than for commercial use) by direct seeding or planting that have the potential to attain a crown cover of 20% or more and a height of at least 2 metres. See *Commercial plantation, Other forest, Plantation.*
Environmental services	See *Ecosystem services.*
Eucalypt	1. Any member of the genera *Angophora*, *Corymbia* and *Eucalyptus*, being trees or large shrubs in the family Myrtaceae, mostly native to Australia.
	2. As a national forest type, forest dominated by any of the three genera *Angophora*, *Corymbia* and *Eucalyptus*.
Even-aged forest	Native forest in which all trees are about the same age or of the same age class, even though they may vary in size because of their different rates of growth or location within the stand. See *Uneven-aged forest.*
Exclusion zone	Forest excluded from wood harvest or management operations as a result of the application of a prescription in a code of practice (such as for fire, forest or reserve management).
Exotic	Species of plant or animal that does not occur naturally in a region or country. See *Indigenous (of species), Introduced species.*
Ex situ conservation	The conservation of species and genetic components of biological diversity outside their natural habitats. See *In situ conservation.*
Extinct	A species for which there is no reasonable doubt that the last individual has died, or for which exhaustive surveys in known or expected habitats throughout its historical range have failed to record an individual over a time frame appropriate to its lifecycle and form. One of the categories of threatened species defined in the Commonwealth *Environment Protection and Biological Conservation Act 1999*.
Extinct in the wild	A species known to survive only in cultivation, in captivity or as a naturalised population well outside its past range, and that has not been recorded in its known and/or expected habitat, at appropriate seasons, anywhere in its past range, despite exhaustive surveys over a time frame appropriate to its life cycle and form. One of the categories of threatened species defined in the Commonwealth *Environment Protection and Biological Conservation Act 1999*.

Term	Definition and use
Farm forestry	Establishment and/or management of trees or forests on agricultural landscapes for commercial, aesthetic and/or environmental reasons. Also known as agroforestry.
Fecundity	The capacity of an individual or a species to reproduce or multiply. Can be measured as the rate of production of viable, fertile offspring that survive to reproductive age. See *Fertility.*
Fertility	The ability of an individual, population or species to sexually reproduce successfully. See *Fecundity.*
Fibreboard	A category of reconstituted wood panel products made from pulpwood and/or wood-processing residues such as woodchips, sawmill shavings and sawdust plus a resin or binder, pressed into panels. Types of fibreboard (in order of increasing density) include particleboard, medium-density fibreboard (MDF), high-density fibreboard and hardboard.
Fire regime	The frequency, intensity, seasonality and scale of burning of an area or vegetation type over a period of time. The history or forecast of fire events in a particular area or vegetation type.
Firewood	Wood used for residential heating. See *Fuelwood.*
Floriculture	Cultivation of flowering and ornamental plants.
Floristics	Study of the distribution and relationships of plants over a geographic area.
Forest	An area, incorporating all living and non-living components, that is dominated by trees having usually a single stem and a mature or potentially mature stand height exceeding 2 metres and with existing or potential crown cover of overstorey strata about equal to or greater than 20%. This includes Australia's diverse native forests and plantations, regardless of age. It is also sufficiently broad to encompass areas of trees that are sometimes described as woodlands.
Forest certification	A process whereby the quality of sustainable forest management is assessed and certified by an accredited, independent third party, against the criteria and requirements of a credible and recognised forest management standard. See *Certified forest.*
Forest clearing	Conversion of forested land to agricultural, urban or other non-forest land uses. See *Broadscale clearing, Land clearing.*
Forest-dependent community (human)	A community having an identified dependence on the forestry and wood products industries. See *Community.*
Forest-dependent species	A species that requires a forest habitat for at least part of its lifecycle, and that could not survive or reproduce in the absence of this habitat.
Forest-dwelling species	A species that may use a forest habitat for at least part of its lifecycle.
Forest health	The effects of the sum of the ecosystem processes (energy, nutrient, hydrological and biological processes) that together maintain the vitality of a forest ecosystem.
Forest land	Land carrying forest. Also called the forest estate. See *Forest.*
Forest management	A system of practices and activity for conservation, stewardship and productive use of forest land, aimed at fulfilling desired environmental, economic and social functions and objectives for the forest.
Forest management plan	A documented, long-term plan for a forest area that defines management goals, objectives and outcomes that are monitored and periodically reviewed, and that expressly includes the management of forest. Management plans can take many forms, including forest management plans; natural resource, environment and water catchment management plans that cover and include a focus on forests; and strategic management planning systems required for forest certification.
Forestry	The establishment and/or management of forests to meet desired goals, needs, and values, for human and environmental benefits.
Forestry operations	1. Work undertaken in the course of forest establishment and/or management for purposes including forest protection, public recreation, research, catchment protection and wood production. 2. Operational forest management activities related to wood production.
Formal reserve	See *CAR reserve system.*
Fragmentation	1. The degree to which forest exists in separate areas that are not spatially connected. 2. The process of loss of spatial connectivity between forest areas. See *Connectivity.*
Free-on-board value	The value of goods to the seller at the point of loading goods onto transport to overseas markets, excluding transport and insurance costs.
Fuel load	The total amount of combustible material in a defined area.
Fuelwood	Wood or wood products used as industrial fuel or for bioenergy production. See *Bioenergy, Firewood.*
Genetic diversity	The diversity of genetic information within and between individual species. See *Biodiversity, Ecosystem diversity, Species diversity.*
Genetic resources	Material of plant, animal, microbial or other origin that contains functional units of heredity and that has actual or potential value for humanity.
Genotype	The genetic constitution or make-up of an organism.
Geographic information system	A system for capturing, storing, analysing and managing data and associated attributes that are spatially referenced to the surface of the Earth. Commonly abbreviated to GIS system.

Term	Definition and use
Geospatial	Relating to the relative position of features on the surface of the Earth.
Girder	A specialised, large-dimensioned, durable timber product, usually in squared-end form, that is used in building bridges, wharves and the framework of large buildings.
Global carbon cycle	The movement of carbon between different parts of the Earth, biosphere and atmosphere, including the storage of carbon in those parts.
Grafting	A method of plant propagation, whereby a bud, shoot or tissue of one plant is joined with another plant.
Greenhouse gas	Gas that affects the temperature of the Earth's surface and climate, including water vapour, ozone, chlorofluorocarbons, carbon dioxide, methane and nitrous oxide. National inventories report anthropogenic emissions and removals of greenhouse gases not controlled by the Montreal Protocol on Substances that Deplete the Ozone Layer.
Green Triangle	1. A region straddling the state border between south-west Victoria and south-east South Australia where there are significant areas of plantations, as well as wood-processing facilities. 2. The National Plantation Inventory region of this name.
Green wood	1. Wood freshly harvested or milled that has not been dried. 2. Wood from live sandalwood trees that meets a specified quality standard and size.
Gross calorific value	The amount of heat released by a fuel during combustion under standard conditions.
Gross domestic product	The total market value of goods and services produced in a country in a given period, after deducting the cost of intermediate goods and services used in production (but not deducting allowances for the consumption of fixed capital, or depreciation). The sum of the value added by each industry across the economy. See *Industry value added.*
Gross value of production	Value placed on production at the wholesale prices realised in the marketplace (where the marketplace refers to local consumption, export, or a point before value-adding by a secondary industry). Gross value of production provides a value for products that do not have a final market price.
Group selection	A native forest silvicultural system in which groups (small patches or stands) of trees are harvested, allowing for subsequent regeneration and leading to a forest comprising patches of differently aged trees. See *Selection logging, Silvicultural practices / systems.*
Growing stock	The living tree component of the standing volume in a forest at a given time. See S*tanding volume.*
Gymnosperm	A plant, such as a cycad or conifer, the seeds of which are not enclosed within an ovary. See *Conifer.*
Habitat	The environment where a plant, animal or ecological community normally lives or occurs. See *Ecological community.*
Habitat tree	1. A tree (alive or dead) containing hollows or crevices, where animals can live, breed or shelter, retained in a harvested area to provide habitat. 2. A tree with artificially created hollows to provide suitable nesting or shelter sites for endangered fauna.
Hardwood	Wood or wood products from flowering trees (broad-leaved tree species), such as eucalypts, irrespective of the physical hardness of the wood; also used to refer to the trees that have such wood, and plantations of such trees.
Harvested wood products	Wood products originating from harvested trees and removed from harvest areas for use as-is or after further processing.
Harvesting	1. As part of forest management, cutting (felling) of trees to produce wood products. 2. Collection (gathering) of non-wood forest products.
Heathland	A shrubland habitat found mainly on low-quality acidic soils and characterised by open low-growing woody vegetation. It forms extensive and highly diverse communities across Australia in humid and sub-humid areas. Heathland above 2 metres tall can also be classified as 'Other woody vegetation'. See *Other woody vegetation, Shrubland.*
Hybridisation	The process of crossing different breeds or cultivars of a single plant species, or crossing plants of different taxa (subspecies, species or genera). Hybridisation can occur naturally between closely related species.
IBRA (Interim Biogeographic Regionalisation for Australia)	A set of 85 bioregions within the Australian landmass, used as the basis for the National Reserve System's planning framework and some state-based reporting. See *National Reserve System.*
Indicator	1. As used in Australia's State of the Forests reports, an aspect of a criterion by which sustainable forest management may be assessed. 2. A quantitative or qualitative variable that can be measured or described and that, when observed periodically, demonstrates trends in forest condition or use. See *Criterion, Montreal Process.*
Indigenous (of people)	Of Aboriginal or Torres Strait Islander descent.
Indigenous (of species)	Species of plant or animal that occurs naturally in a specified region or country. See *Endemic, Exotic.*
Indigenous co-managed (of lands)	Lands that are owned and managed by non-Indigenous parties, and for which formal, legally binding agreements are in place to include Indigenous peoples and communities in the process of developing and implementing management plans. See *Indigenous managed (of lands), Indigenous owned and managed (of lands), Other special rights (of lands).*

Term	Definition and use
Indigenous estate (land or forest)	Land or forest over which Indigenous peoples and communities have ownership, management or rights of use for customary purposes. See *Indigenous co-managed (of lands), Indigenous managed (of lands), Indigenous owned and managed (of lands), Other special rights (of lands).*
Indigenous Land Use Agreement	A voluntary agreement between Native Title parties and other people. Native title is the recognition in Australian law that Indigenous people have rights and interests to land that come from their traditional laws and customs.
Indigenous managed (of lands)	Lands that are managed but not owned by Indigenous peoples and communities (e.g. Crown reserves and leases), and lands that are owned by Indigenous peoples and communities for which there are formal shared management agreements with Australian or state and territory government agencies. See *Indigenous co-managed (of lands), Indigenous owned and managed (of lands), Other special rights (of lands).*
Indigenous owned and managed (of lands)	Freehold lands that are owned and managed by Indigenous peoples and communities. See *Indigenous co-managed (of lands), Indigenous managed (of lands), Other special rights (of lands).*
Indigenous Protected Area	An area of Indigenous-owned land or sea for which traditional owners have entered into an agreement with the Australian Government to promote biodiversity and cultural resource conservation. See *Protected area.*
Indirect employment	The number of jobs in secondary economic activity resulting directly from a primary economic activity, in provision of materials, supplies, goods and services to support the primary activity, and generated or supported in retail and service sectors by the spending of salaries and wages of individuals and families included in direct employment. See *Direct employment.*
Industrial plantation	See *Commercial plantation.*
Industry value added	The value added by an industry to the inputs used by that industry; the contribution of that industry to Gross domestic product. In the Australia's State of the Forests Report series, 'Industry value added' excludes some downstream parts of the forestry, wood and paper products industries, particularly wholesaling, retailing and further value-adding (including the manufacturing of some commodities). See *Gross domestic product.*
Informal reserve	Reserve on public land protected through an administrative instrument by a public land management agency. See *CAR reserve system.*
In situ conservation	The conservation of species and genetic components of biological diversity in their natural habitats. See *Ex situ conservation.*
Integrated pest management	A pest control strategy that uses an array of complementary methods, such as natural predators and parasites, pest-resistant varieties, cultural practices, biological controls, various physical techniques and chemicals.
Introduced species	A species of plant or animal occurring outside its natural range (past or present) and dispersal potential—that is, outside the range it occupies naturally or could occupy without direct or indirect introduction or care by humans. See *Exotic, Indigenous (of species).*
Jurisdictions	The Commonwealth, states and territories of Australia, in each of which its own system of laws has authority.
Key threatening process	A threatening process listed under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*. See *Threatening process.*
Land clearing	Removal of vegetation to convert land to another land use. See *Broadscale clearing, Forest clearing.*
Land tenure	Formal title, ownership or occupancy of land. See *Crown land, Leasehold forest, Multiple-use public forest, Nature conservation reserve, Other Crown land, Private forest, Unresolved tenure.*
Leasehold forest	Crown land held under leasehold title and generally privately managed. One of six tenure classes used to classify land in the National Forest Inventory. See *Crown land, Leasehold title.*
Leasehold title	Land title held under a contract by which one party conveys the land to another party for a specified time and purpose, usually in return for a periodic payment.
Legally binding instrument	An instrument, law, regulation, act or process that has associated legal rights, duties and/or requirements. See *Non-legally binding instrument.*
LiDAR (Light Detection and Ranging)	A technology that uses laser (light) pulses from (most commonly) an aircraft to collect information on terrain and vegetation features (such as tree height), based on the return time of pulses back to the sensor.
Litter	The uppermost layer of the forest floor consisting chiefly of fallen leaves, wooden debris and other decaying organic matter.
Log landing	A cleared area where harvested logs are laid or piled in stacks after being gathered from the site or sites of felling and before transport to a wood-processing facility.
Macroinvertebrate	Organism without a backbone, and of sufficient size to be seen without the aid of a microscope; examples are insects, shellfish and crustaceans.

Term	Definition and use
Mallee	1. A woody plant, usually a eucalypt, that is multi-stemmed from ground level. 2. A forest dominated by mallee species.
Managed investment scheme (MIS)	A pooled investment scheme that satisfies the definition of 'managed investment scheme' in Section 9 of the Commonwealth *Corporations Act 2001* and fulfils associated regulatory requirements; describes a wide range of investments in financial products, real estate, agriculture and plantation forestry.
Managed losses	Losses of carbon directly from forests to the atmosphere that are associated with the management of forests, for example prescribed burns or post-harvest burns.
Management effectiveness	A measure of how well a protected area, or system of protected areas, is being managed in terms of protecting values and achieving goals and objectives, based on an audit process or evaluation.
Mangrove	1. A tree or shrub that normally grows above mean sea level in the intertidal zone of coastal environments and estuarine margins. 2. The tidal habitat comprising mangrove trees and shrubs. 3. A national forest type dominated by mangrove trees.
Matting	The practice of placing small (less than 5 centimetre diameter) woody material on extraction tracks before wood harvesting to protect soil against heavy vehicle traffic and to minimise soil erosion. See *Cording.*
Mature	1. A native forest growth stage in which trees are at maximum height with crowns at full lateral development. 2. A native forest growth stage, generally taken as 80 or more years since disturbance. One of four growth stages used at the national level to describe the age of trees and stands of trees. See *Apical dominance, Ecologically mature, Regeneration, Regrowth, Senescent.*
Medium-density fibreboard (MDF)	See *Fibreboard.*
Melaleuca	As a national forest type, forest dominated by trees of the genus *Melaleuca*.
Merchantability	With respect to a tree or tree species, suitability for commercial wood products. An emphasis is placed on commercial production of sawlogs or high-value equivalents.
Merchantable tree species	A tree species with known commercial uses for wood products, based on standards, technology or market conditions. See *Non-merchantable tree species.*
MODIS (Moderate-resolution Imaging Spectroradiometer)	A remote-sensing technology carried on two Earth Observing System satellites, capturing data covering the visual and infrared spectrum and imaging the entire Earth every 1–2 days.
Monitoring	The periodic and systematic measurement and assessment of a value, attribute or indicator.
Montane	Ecosystems associated with mountain landscapes, alpine environments or higher elevations.
Montreal Process	1. The Montreal Process Working Group on Criteria and Indicators for the Conservation and Sustainable Management of Temperate and Boreal Forests (commonly, the Montreal Process Working Group). Currently comprises 12 countries. Australia is a member of the Montreal Process Working Group. 2. An initiative by the Montreal Process Working Group, comprising development and implementation of a comprehensive set of criteria and indicators for the conservation and sustainable management of temperate and boreal forests. See *Criterion, Indicator.*
Mosaic (of vegetation)	Vegetation composed of patches of different types, arising from differences in soil or landform or periodic disturbance (such as fire or wood harvesting).
Multi-leaders (of trees)	A condition in trees where the apical dominance of the shoot at the top of the plant is lost, allowing lateral buds to grow into two or more stems or leaders. See *Apical dominance.*
Multiple Lines of Evidence approach	With respect to mapping forests, compilation of data from a range of different sources, followed by assessment and validation to arrive at a best-possible dataset for the attribute being mapped.
Multiple-use public forest	Publicly owned state forest, timber reserves and other land on which a range of forest values – including provision of wood for harvest, water supply, conservation of biodiversity, recreation and environmental protection – are managed by state and territory government agencies in accordance with relevant Acts and regulations. One of six tenure classes used to classify land in the National Forest Inventory.
National Carbon Accounting System	See *National Greenhouse Gas Inventory*
National Forest Inventory	Australia's system of integrated national forest data, compiled from state, territory and Australian government agencies and independent, remotely sensed data using national standards and protocols for collation and reporting. Used to meet national and international forest-related reporting requirements. Includes native forests, commercial plantations and other forests. See *National Plantation Inventory.*
National forest type	Any one of eight broad forest types (Acacia, Callitris, Casuarina, Eucalypt, Mangrove, Melaleuca, Rainforest, and Other native forest) into which Australia's native forests are classified in the National Forest Inventory. See *National Forest Inventory.*
National Greenhouse Gas Inventory	Australia's system for measuring and monitoring changes in greenhouse gas emission and sequestration; includes modelling of carbon stocks and stock changes. Previously referred to as the National Carbon Accounting System.
National Plantation Inventory	Australia's national inventory of commercial forest plantations; a program of the National Forest Inventory. See *National Forest Inventory.*

Term	Definition and use
National Reserve System	Australia's network of protected areas, conserving examples of natural landscapes and native plants and animals. The National Reserve System comprises Commonwealth, state and territory reserves, and protected areas on private land, Indigenous land, and land managed by conservation organisations.
National Vegetation Information System (NVIS)	A system developed by the Commonwealth, state and territory governments that provides information on the extent and distribution of vegetation types.
Native (of species)	A species located within its natural range. See *Non-native (of species).*
Native forest	A National Forest Inventory forest category that comprises national forest types dominated by the suite of native tree species naturally associated with forest in that location and located within their natural range. 'Native forest' does not include forest reported in the other two national forest categories, 'Commercial plantation' and 'Other forest'. See *National Forest Inventory, National forest type, Commercial plantation, Other forest.*
Nature conservation reserve	Crown land that is formally reserved for environmental, conservation and recreational purposes, including national parks, nature reserves, state and territory recreation and conservation areas, and some formal reserves in state forests as defined by jurisdictions. It does not include informal reserves and those pending gazettal. The commercial harvesting of wood and non-wood forest products is generally not permitted in nature conservation reserves. One of six tenure classes used to classify land in the National Forest Inventory. See *Conservation reserve, Crown land.*
Non-bole log	Log taken from the main trunk or branches of a tree above the crown break (the height of the first major branch). The non-bole material in mature trees is additional to the sustained yield.
Non-forest	Vegetation communities and habitats that are not forest, including marine environments, alpine meadows, other woody vegetation (including open woodland, heathland and shrubland), grassland, non-forest waterways and wetlands, rock outcrops, mudflats and farmland. See *Forest, Habitat, Other woody vegetation, Vegetation community.*
Non-forest land	Land that does not carry forest. See *Forest land.*
Non-legally binding instrument	A policy, recommendation or guideline, or a system of policies, recommendations and/or guidelines, with a defined intention that they be abided by to achieve a desired outcome, but without legal penalties for non-compliance. See *Legally binding instrument.*
Non-merchantable tree species	A tree species with no currently known commercial uses for wood products, based on standards, technology or market conditions. See *Merchantable tree species.*
Non-native (of species)	A species located outside its natural range. See *Native (of species).*
Non-production native forest	Native forest that is not managed for commercial wood production.
Non-vascular plant	A plant without a water-conducting system, including algae, liverworts and mosses.
Non-wood forest product	A product of biological origin, other than wood, derived from forests, including game animals, seeds, berries, chemical products, mushrooms, oils, foliage, medicinal plants, flowers, fodder, and wood and non-wood Indigenous artefacts.
Old-growth forest	Ecologically mature forest where the effects of disturbances are now negligible. See *Ecologically mature, Mature.*
Open forest	Forest in which tree crown cover ranges from over 50% to 80%. See *Closed forest, Woodland forest, Crown cover.*
Other Crown land	Crown land reserved for a variety of purposes, including utilities, scientific research, education, stock routes, mining, water-supply catchments, and use by Indigenous communities. Excludes leasehold forest, nature conservation reserve, and multiple-use public forest. One of six tenure classes used to classify land in the National Forest Inventory. See *Crown land.*
Other forest	A National Forest Inventory forest category that includes non-commercial plantations and planted forests that are not reported through the National Plantation Inventory but that satisfy the definition of forest. It includes farm forestry and agroforestry plantations, sandalwood plantations, environmental plantings, plantations within the reserve system, and plantations regarded as not commercially viable. Non-planted forests dominated by introduced species are also included in this category. 'Other forest' does not include forest reported in the other two national forest categories, 'Commercial plantation' and 'Native forest'. See *Forest, Commercial plantation, Native forest, Plantation.*
Other log products	Low-quality sawlogs, girders, poles, piles, other logs that are not sawlogs (including sliced veneer sawlogs) or pulplogs, wood used in mines, split and round posts, bush sawn/hewn timber and sleepers, and fuelwood logs and firewood. This category can also include other log types not included elsewhere, such as peeled veneer logs. Differs from the category 'Other wood products' in including fuelwood logs and firewood. See *Other wood products.*
Other native forest	A National Forest Inventory native forest type comprising forest types of minor extent such as Agonis, Atalaya, Banksia, Hakea, Grevillea, Heterodendron, Leptospermum, Lophostemon and Syncarpia (named after their dominant genera), as well as native forests where the type is unknown. See *National Forest Inventory, Native forest, Commercial plantation.*

Term	Definition and use
Other special rights (of lands)	Lands subject to Native Title determinations and active Indigenous Land Use Agreements. These are independent of tenure and, in most cases, do not grant ownership or management rights of land to Indigenous peoples and communities, but can provide for the right to access areas of cultural significance or a legal requirement for consultation with local Indigenous peoples and communities before major development activities take place. See *Indigenous co-managed (of lands), Indigenous managed (of lands), Indigenous owned and managed (of lands)*.
Other wood products	Low-quality sawlogs, girders, poles, piles, other logs that are not sawlogs (including sliced veneer sawlogs) or pulplogs, wood used in mines, split and round posts, bush sawn/hewn timber and sleepers; but not fuelwood logs or firewood. This category can also include other log types not included elsewhere, such as peeled veneer logs. Differs from the category 'Other log products' in excluding fuelwood logs and firewood. See *Other log products.*
Other woody vegetation	A non-forest vegetation type: open woodland, heathland or shrubland generally containing a tree component with actual or potential tree height greater than 2 metres, but either actual or potential tree canopy crown cover of 5–20% or combined cover of shrubs and trees greater than 10% but cover of trees less than 5%. See *Crown cover, Heathland, Shrubland.*
Overstorey	1. The uppermost layer of foliage in a forest. 2. Trees occupying the uppermost layer in a forest of more than one layer (storey).
Parasitoid	An organism that spends a significant proportion of its life attached to or within a single host organism, and that ultimately kills (and often consumes) the host.
Particleboard	A panel product made by compressing wood particles (usually from softwood) and resin under heat and pressure, commonly used in flooring and joinery. See *Fibreboard.*
Patch (of vegetation)	Basic unit of a landscape vegetation mosaic.
Pattern (of vegetation)	The spatial arrangement or configuration of vegetation, including forest, across the landscape.
Peeler log	A log suitable for rotary peeling to produce veneer. See *Veneer log.*
Photosynthesis	A process in plants in which energy from sunlight and carbon dioxide from the air are used to produce plant matter, releasing oxygen.
Pile (wood product)	A round-wood product that meets specified marine durability requirements and is used principally for wharves and to support the framework of buildings in a marine environment.
Pine	1. A tree of the genus *Pinus* in the family Pinaceae. 2. Can also refer to a tree of other conifer families, e.g. Araucariaceae, Cupressaceae and Podocarpaceae. See *Conifer, Softwood.*
Planned fire	Fire started in accordance with a fire management plan or planned burning program, such as fuel-reduction burning. See *Prescribed burn, Prescribed burning, Unplanned fire.*
Plantation	Intensively managed stand of trees of either native or exotic species, created by the regular placement of seedlings or seeds. See *Environmental planting, Commercial plantation, Other forest.*
Plant community	See *Community (definition 1), Vegetation community.*
Planted forest	Forest comprising planted trees. For international reporting purposes, the 'Commercial plantation' and 'Other forest' National Forest Inventory categories (excluding forests of naturalised exotic species) comprise Australian 'planted forest'.
Plywood	A panel product made by gluing together veneers of wood under heat and pressure, commonly used in construction and joinery. See *Veneer.*
Pole	A round-wood product generally treated with preservatives that is used to support transmission lines or as a structural member in pole-frame building construction.
Post	A wood-product from durable hardwood or treated softwood species that is used in an upright support role and meeting specifications for a range of functions.
Prescribed burn	Fire started in accordance with a fire management plan or planned burning program, such as fuel-reduction burning. See *Planned fire, Prescribed burning.*
Prescribed burning	The controlled application of fire under specified environmental conditions to a predetermined area and at a time, intensity and rate of spread required to attain planned resource management objectives; also referred to as the use of planned fire. See *Planned fire, Prescribed burn.*
Private forest	Land held under freehold title and typically under private ownership. It excludes leased Crown land, and includes land held under freehold title with special conditions attached for designated Indigenous communities. One of six tenure classes used to classify land in the National Forest Inventory.
Privately managed forest	Forest that is managed under private ownership (including private land that is owned and managed by the Crown), as well as privately managed leasehold forest.

Term	Definition and use
Productivity	1. Capacity of an ecosystem to grow, produce or yield products. 2. Amount of growth or product yield per unit area per unit time. 3. Potential annual volume growth of trees per unit area at peak mean annual increment in fully stocked forest stands.
Protected area	1. General definition: a geographically defined area that is designated or regulated and managed to achieve specific conservation objectives (Article 2, Convention on Biological Diversity). 2. Specific definitions for reserve systems: an area of land and/or sea especially dedicated to the protection and maintenance of biological diversity, and of natural and associated cultural resources, and managed through legal or other effective means (IUCN definition); a clearly defined geographical space, recognised, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values (revised IUCN definition). See *Indigenous Protected Area.*
Protected by prescription	Areas where protection of values is prescribed through management prescriptions in codes of practice or management plans or harvesting plans. Includes components of the CAR reserve system that are not always mappable in advance of their detection, and/or where inclusion in dedicated or informal reserves is impractical, such as riparian vegetation, or rare, dispersed or fragmented values. See *CAR reserve system.*
Provenance	1. The place of origin of a plant or animal. 2. A set of individuals of a plant or animal species that originate from a particular location.
Public forest	See *Publicly managed forest.*
Public land	Land belonging to the Crown, i.e. a government, but excluding leasehold Crown land. See *Crown land, Leasehold title.*
Publicly managed forest	1. Forest on public land for which management responsibility has generally been delegated to government agencies, including multiple-use public forests, nature conservation reserves and other Crown land, but excluding leasehold forest. 2. Any forest on Crown land for which management responsibility has been delegated to government agencies, local governments or other instrumentalities. See *Crown land, Public land.*
Pulplog	A log harvested from a plantation or native forest stand that does not meet sawlog quality specifications and is designated to produce pulpwood. See *Pulpwood.*
Pulpwood	Wood used to manufacture pulp or paper products.
Rainforest	A national forest type that is dominated by rainforest species, typically in moist to wet or sheltered environments, and with broad-leaved species. Can include areas with up to 30% cover of non-rainforest species, typically as emergents, but where rainforest species dominate the character of the site.
Reconstituted wood products	Products manufactured from reconstituted wood fibres or flakes, originating from sources such as woodchips, sawdust, wood shavings or sawmill off-cuts. Includes fibreboard (particleboard, medium-density fibreboard, high-density fibreboard and hardboard) and laminated products (but not laminated veneer).
Recycling	The collection, separation and processing of previously used and recovered wood fibre and wood and paper products for manufacture into raw materials or new products.
Reforestation	Establishment of forest on land that historically contained forest but was converted to some other use, such as agriculture. The Kyoto Protocol and initiatives such as the Carbon Farming Initiative use specific definitions of reforestation. See *Afforestation, Deforestation, Forest.*
Regeneration	1. A native forest growth stage that includes juvenile and sapling stages, where trees are very small and crowns exhibit apical dominance. 2. A native forest growth stage generally taken as less than 20 years since disturbance. One of four growth stages used at the national level to describe the age of trees and stands of trees. 3. New trees arising naturally or with human assistance after harvesting, fire or other causes have removed all or some of the overstorey. 4. The process of managing a forest after disturbance to produce a regenerating forest stand. See *Apical dominance, Mature, Regrowth, Senescent.*
Regional Forest Agreement	An agreement between the Australian Government and one of four state governments about the long-term management and use of forests in a region that meets the requirements listed in the Commonwealth *Regional Forest Agreements Act 2002*.
Regrowth	1. A native forest growth stage in which trees generally have well-developed stems with crowns of small branches, and are actively growing in height and diameter but are below mature stand height. Apical dominance is apparent in vigorous trees. 2. A native forest growth stage generally taken as 20–80 years since disturbance. One of four growth stages used at the national level to describe the age of trees and stands of trees. See *Apical dominance, Mature, Regeneration, Senescent.*
Remote sensing	Practice of acquiring and using data from satellites or aircraft to infer or measure land cover, land use and vegetation attributes. May be used in combination with ground surveys to check the accuracy of interpretation.
Re-sawing	Cutting timber along the grain to reduce larger boards into smaller sections.
Research and development	Investigative work conducted to acquire knowledge, apply knowledge, develop or implement new products or procedures, or make significant improvements to existing products or procedures.

Term	Definition and use
Resilience (ecological and ecosystem)	The capacity of an ecological system to absorb and respond to shocks while retaining essentially the same function, structure and feedbacks, and therefore identity.
Resilience (human-community)	See *Community resilience (human)*.
Resolution (image)	Measurement of the output quality or detail of an image, usually given as pixel size (the size of the square areas recorded) or ground sample distance (the distance between adjacent pixel centres measured on the ground). Higher resolution means more image detail and smaller pixels; for example, an image with 1 m x 1 m pixels is of higher resolution than an image with 1,000 m x 1,000 m pixels.
Riparian zone	The interface between land and a flowing water body such as a stream or river. Plant communities along perennial watercourses are called riparian vegetation. See *Community (definition 1), Vegetation community.*
River regulation	The control or modification of the natural flow of a river or stream, most commonly by the use of dams.
Rotation	The planned number of years between regeneration or establishment of a stand of trees, and final harvesting. Rotation length is used in forest management planning to determine sustainable yield. See *Harvesting, Regeneration.*
Roundwood	Wood in round form, e.g. sawlogs, pulplogs, poles, piles, girders and posts.
Rural dieback	See *Dieback.*
Rut	A depression or groove worn into a snig track, path or road by machinery or erosion by water. Typically, rutting is reported in terms of rut depth. See *Snig Track.*
Salinity / salinisation	The amount of salt in water or soil. Salinisation is the process of increasing salinity levels, such as occurs in soils and streams when saline groundwater rises towards the surface following clearing of forests for farmland.
Salvage harvesting	The harvest of trees that are dead or dying as a result of insect attack, disease, drought, fire or other factors.
Sandalwood	A native tree (e.g. *Santalum spicatum*, *S. lanceolatum*) or exotic tree (e.g. *S. album*) in the family Santalaceae, which yields fragrant timber and oil.
Savanna	A tropical or subtropical, woodland/grassland ecosystem with trees sufficiently widely spaced that adjacent tree canopies are not in contact. Areas of savanna where the canopy cover reaches or exceeds 20% are classified as woodland forest. Typically, rainfall is seasonal, and dry-season fires are frequent.
Sawlog	Log used to manufacture sawn timber. High-quality sawlogs are sawlogs meeting specified size and grade specifications (including amount of permissible defect). Low-quality sawlogs are sawlogs not meeting high-quality sawlog specifications.
Sawmill	A wood-processing facility in which logs are sawn by specialised machinery into timber such as boards.
Sawn timber	Timber produced by sawing logs into particular sizes; also called sawn wood.
Sawn wood	See *Sawn timber.*
Sclerophyll	A description of plants or vegetation that have tough leaves, such as eucalypts and acacias, adapted to dry or nutrient-poor conditions.
Seed orchard	A stand of trees planted and managed specifically for the production of genetically superior seeds.
Seed tree	A tree left standing in a harvested area for the purpose of providing seed for natural regeneration.
Seed-tree silviculture	A native forest silvicultural system in which trees are retained in a harvested area to provide seed for natural regeneration. See *Silvicultural practices / systems.*
Selection harvesting	A silvicultural system in which trees, typically above a certain specified size or growth stage, are removed singly or in groups, while other trees, such as regrowth, pole stems or habitat trees, are retained to maintain an uneven-aged forest. See *Group selection, Silvicultural practices / systems, Single-tree / small group selection.*
Senescent	1. A native forest growth stage older than mature, when irregular crowns form (sometimes referred to as 'over-mature'). 2. A native forest growth stage at various ages after 80 years since disturbance. One of four growth stages used at the national level to describe the age of trees and stands of trees. See *Apical dominance, Mature, Regeneration, Regrowth.*
Sensu lato (s.l.)	In the broad sense (of a taxon). See *Taxon.*
Shelterwood	A native forest silvicultural system of securing natural tree regeneration under a partially harvested overstorey, which is subsequently removed by successive harvest(s) to allow seedlings and young regeneration to occupy the site. See *Silvicultural practices / systems.*
Shrubland	A non-forest vegetation type dominated by woody plants that are multi-stemmed or single-stemmed. Shrubland above 2 metres tall can also be classified as 'Other woody vegetation'. See *Heathland, Other woody vegetation.*
Siltation	Deposition of silt (fine soil and mineral matter), usually related to the degradation of watercourses due to soil erosion.
Silvicultural practices / systems	Methods used in managing forest establishment, composition, growth, harvesting and regeneration. See *Aggregated retention, Clearfelling, Group selection, Seed-tree silviculture, Selection logging, Shelterwood, Silviculture, Single tree / small group selection, Variable retention.*
Silviculture	The art, science and technology of managing forests to achieve specified forest management objectives.

Term	Definition and use
Single tree / small group selection	A native forest silvicultural system in which single trees or small groups of trees of various ages are harvested; a method suitable for promoting regeneration of shade-tolerant species, or growth of preferred species or individual trees. See *Selection logging, Silvicultural practices / systems.*
Skeletal soils	Shallow soils, usually on ridges or steep slopes.
Slash	Tree debris left on site following harvesting events.
Snig track	A track along which logs are pulled (snigged) or conveyed from the place where the tree is felled to a nearby log landing or point of loading; also known as an extraction track.
Softwood	Wood or wood products from conifers, irrespective of the physical softness of the timber; also used to refer to the trees that have such wood, and plantations of such trees. See *Conifer.*
Soil compaction	A reduction in soil volume without loss of soil, leading to poor soil aeration, reduced drainage, and impeded root development.
Soil degradation	Any phenomenon that lowers the current and/or future capacity of the soil to support existing forest vegetation and ecosystems.
Soil erosion hazard	The susceptibility of soil to erosion, combining soil properties, site and climate factors, and management practices. Site factors can include slope, aspect, vegetation and drainage.
Soil moisture regime	The spatial distribution and annual variation in water availability in a soil profile.
Species diversity	The variety of species in an ecosystem. See *Biodiversity, Ecosystem diversity, Genetic diversity.*
Stand	A contiguous area within a forest that contains a cohort of trees that have a common set of characteristics. Normally a stand will be described or managed as a single unit.
Standing volume	The volume (excluding branches) above stump height of living or dead standing trees.
Statistical local area (SLA)	Base spatial unit at which the Australian Bureau of Statistics collects statistics across Australia.
Stocking	The density of a unit area of a forest stand measured as the number of trees, tree basal area, wood volume, or proportion of crown closure. Can apply to stocking of retained trees after harvest, or to the adequacy of seedling regeneration or planted stock. See *Stand.*
Subspecies	A taxonomically recognised subdivision of a species.
Sustainable development	Development that meets current needs without compromising the ability of future generations to meet their own needs.
Sustainable forest management	1. A set of objectives, activities and outcomes consistent with maintaining or improving a forest's ecological integrity and contributing to people's wellbeing now and in the future. 2. The practice of stewardship and use of forests and forest lands in such a way, and at a rate, that maintains their biodiversity, productivity, regeneration capacity and vitality, and their potential to fulfil, now and in the future, relevant ecological, economic and social functions at local, national and global levels, and that does not cause damage to other ecosystems. See *Ecologically sustainable forest management.*
Sustainable yield	The yield of products (e.g. wood, water) from an area of forest that ensures that the functioning of the forest ecosystem as a whole is maintained and the flow of products can continue indefinitely under a given management strategy and suite of sustainable-use objectives.
Sustained yield	In regards to wood, the yield that a forest area can produce continuously at a given intensity of management without impairment of the productivity of the land for a given period of time.
Taxon	A taxonomic unit in the classification of plants and animals (e.g. a subspecies, species or genus). Plural: taxa.
Tenure	Title to land as controlled by legislation. See *Land tenure.*
Threat	A natural, human-induced or human-exacerbated factor or process that increases the risk to a species of population reduction or extinction, or that creates a significant risk to the persistence or integrity of an ecological community. See *Ecological community, Threatening process.*
Threatened ecological community	An ecological community listed in any one of the following categories defined in the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*: critically endangered, endangered or vulnerable. See *Critically endangered species / ecological community, Ecological community, Endangered species / ecological community, Vulnerable species / ecological community.*
Threatened species	A species of native flora or fauna that is listed in any one of the following categories defined in the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*: extinct, extinct in the wild, critically endangered, endangered or vulnerable. See *Critically endangered species / ecological community, Endangered species / ecological community, Extinct, Extinct in the wild, Vulnerable species / ecological community.*

Term	Definition and use
Threatening process	1. A process that threatens, or may threaten, the survival, abundance or evolutionary development of a native species or ecological community, as defined in the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*. 2. A natural, human-induced or human-exacerbated process that increases the risk to a species of population reduction or extinction, or is a significant risk to the persistence or integrity of an ecological community. 3. A process identified as a historical, current or future threat in listing or conservation advice of a threatened ecological community or species. See *Ecological community, Key threatening process, Threat.*
Timber	Products usually square or rectangular in cross-section milled from logs and that conform to industry grades, standards or specifications.
Traditional Owners	An Aboriginal and Torres Strait Islander group, people or community with traditional ownership of an area of country that has clear boundaries from the country of other groups. Traditional Owners have common social, cultural and spiritual affiliation and responsibility for their land, and usually have rights to forage on and guide management of that land.
Turbidity	The degree to which the clarity of water is reduced by suspended solids, silt, sediments or organic matter.
Turnover	Sales and service income for a business: the total value of sales of all goods and services, whether or not manufactured by the business (exclusive of goods and services tax, and not deducting the costs of inputs or intermediate goods and services).
Understorey	Layer or layers of vegetation beneath the main canopy or overstorey of a forest.
Uneven-aged forest	Forest with trees of more than one age or age class present on the same site. See *Even-aged forest.*
Unplanned fire	Fire started naturally (such as by lightning), accidentally or deliberately (such as by arson), but not in accordance with planned fire management prescriptions. See *Bushfire, Planned fire, Wildfire.*
Unresolved tenure	Land where data are insufficient to determine land ownership status. One of six tenure classes used to classify land in the National Forest Inventory.
Value-adding	The process of converting timber or forest products into one or more higher-valued products.
Variable retention	A native forest silvicultural system designed to meet both harvest objectives and ecological objectives through the retention of trees within an area planned for harvest, with the amount and configuration of retention dependent upon the silvicultural objectives for the stand; an alternative to clearfelling. See *Aggregated retention, Clearfelling, Silvicultural practices / systems.*
Vascular plant	A plant with conducting tissue that transports water, mineral salts and sugars; includes clubmosses, horsetails, ferns, gymnosperms (including conifers) and angiosperms (flowering plants).
Vegetation community	A naturally occurring group of plant species inhabiting a particular area and interacting with each other, especially through biotic relationships, relatively independently of other plant communities. See *Community (definition 1).*
Veneer	Thin sheets of wood, usually thinner than 3 millimetres, which can be glued and pressed to make plywood, or glued and pressed onto core panels (typically wood, particleboard or medium-density fibreboard) to produce panels. Can be produced by slicing or peeling logs.
Veneer log	A log suitable for producing sliced veneer sheets. Excludes peeler logs used to produce rotary-peeled veneer. See *Peeler log.*
Vulnerable species / ecological community	A native species / ecological community facing a high risk of extinction in the wild in the medium-term future. One of the categories of threatened species / ecological communities defined in the Commonwealth *Environment Protection and Biological Conservation Act 1999.* See *Critically endangered species / ecological community, Ecological community, Endangered species / ecological community, Extinct, Extinct in the wild, Threatened ecological community, Threatened species.*
Water yield	The amount of water that flows out of a catchment (drainage basin).
Watershed	The dividing line between two catchments (drainage basins).
Watertable	The underground level at which the ground is saturated with water, where the water pressure is equal to atmospheric pressure.
Wet forest / wet sclerophyll forest	Typically, eucalypt-dominated forest (not dry forest or rainforest) associated with moist (mesic) conditions, and with an understorey (if present) dominated or co-dominated by rainforest species or non-sclerophyll shrubs. See *Dry forest / dry sclerophyll forest, Eucalypt, Rainforest, Sclerophyll.*
Wetland	Land consisting of swamps, marshes or mangroves. Forest wetlands are wetland ecosystems where forests are present. See *Mangroves.*
Wild harvest	Commodity harvested from the wild, including farming of wildlife and feral animals.
Wilderness	Land that, together with its plant and animal communities, has not been substantially modified by, and is remote from, the influences of European settlement, or is capable of being restored to such a state; is of sufficient size to make its maintenance in such a state feasible; and can provide opportunities for solitude and self-reliant recreation.
Wildfire	1. A large destructive forest fire that spreads rapidly. 2. Fire started naturally (such as by lightning), accidentally or deliberately (such as by arson), but not in accordance with planned fire management prescriptions. See *Bushfire, Unplanned fire.*

Term	Definition and use
Wildlife corridor	An area or strip of suitable habitat designed to connect wildlife populations that have been separated by human activities.
Wildling	A plant of a plantation tree species that has grown independently in forest or land adjoining the plantation.
Windthrow	Trees uprooted or broken as a result of severe wind associated with storms; the process of uprooting or breaking trees in this way.
Wood	The hard, fibrous, underbark component of the stem and/or branches of a tree, often suitable for conversion into products.
Woodchips	Small chips of wood produced from logs for use in fibre products or for conversion to pulp for paper manufacture.
Woodland forest	Forest in which the tree crown cover ranges from 20% to 50%. See *Closed forest, Open forest, Crown cover, Other woody vegetation.*

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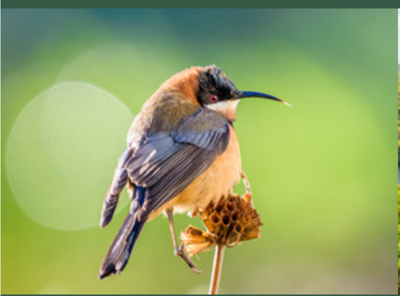
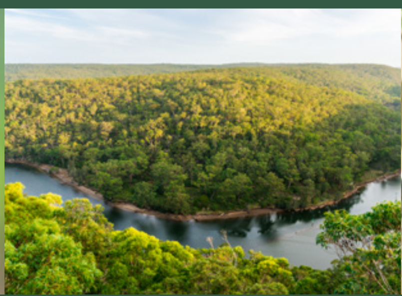
Forest in Tasmania. Photo: iStockphoto/Gudella

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