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Status of Australia's forest genetic resources

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Foreword

Forest genetic resources are genetic materials of actual or potential value. Australia's rich diversity of native forest and woody plant species is a valuable genetic resource. Native and introduced forest genetic resources underpin Australia's forestry and wood products industries, which directly employ about 67 000 people and generate an annual turnover of about $24 billion. Forest trees also provide many other environmental services, directly and indirectly, which have market and non-market values.

Commonwealth, state and territory governments, research organisations, seed banks, arboreta and the private forestry sector in Australia all contribute to the conservation and sustainable management of Australia's forest genetic resources. Australia also participates in a number of international forums on the conservation and sustainable use of forest resources.

Many countries already use Australian native species of *Acacia*, *Casuarina* or *Eucalyptus* on a large scale for social, economic and environmental benefits. Australian native species are adapted to dry environments, so can be planted in areas with low and variable rainfall.

Australia also imports a range of forest genetic resources for various purposes. *Pinus* species are the cornerstone of the softwood plantation industry in Australia and many introduced tree species are an integral part of Australian urban and peri-urban landscapes.

Australia continues to actively exchange forest genetic resources with many countries for research, improvement, commercial use and conservation, and Australian governments and private forestry institutions have well-developed systems for documenting and sharing information on forest and other woody plant species.

I trust that this report will be a useful resource for researchers, forest industries and policymakers in Australia and abroad, and will contribute to 'The state of the world's forest genetic resources' report to be published in 2013 by the Food and Agriculture Organization of the United Nations.

Paul Morris
Executive Director

Contents

Tables

Figures

Maps

Boxes

Summary

Forest genetic resources are the genetic diversity within and among tree species with actual or potential social, economic and environmental values.

Australia has 147.4 million hectares of native forest and 2.0 million hectares of plantation forests. Within Australia, the value of turnover in wood products industries was $24 billion in 2010–11, representing 6.2 per cent of manufacturing income. The forest industry employed over 67 000 people in 2011–12, exported $2.2 billion in wood products and imported $4.2 billion in wood products.

Around 2500 tree species are native to Australia. The main genera include *Acacia* (around 950 species), *Eucalyptus* and *Corymbia* (together around 800 species). Most Australian tree species are thought to have been formally described, with these descriptions compiled into the *Flora of Australia*. New tree species of major genetic interest have been described as recently as 1995 in the case of *Wollemia nobilis* (Wollemi pine). While varieties and subspecies have been described for some species, within-species genetic diversity is poorly understood for most.

Around 200 native Australian tree species are currently commercially significant in Australia and other countries and many introduced species are grown in Australia. Australia is thus a provider of forest genetic resources to the world, as well as a user of global forest genetic resources. Trees of several Australian genera (for example, *Acacia*, *Araucaria*, *Callitris*, *Casuarina*, *Eucalyptus*, *Grevillea*, *Macadamia*, *Melaleuca* and *Toona*) are grown extensively overseas for a variety of uses including commercial wood products, bioenergy, seeds and nuts, essential oils, farm forestry, soil conservation, aesthetic values and other environmental plantings.

Half of the plantation forests in Australia are native species, mainly *Eucalyptus*, and half are exotic species, mainly *Pinus*. Plantations in Australia are based on relatively few species, predominantly *Eucalyptus globulus*, *E. nitens*, *E. grandis*, *Pinus radiata* and other *Pinus* species and hybrids.

A substantial proportion of the genetic base of these plantation species has been brought into collections to support breeding programs, with a focus on species that are widely cultivated, including *Eucalyptus* and *Pinus*. Some collections of plantation genetic resources are held by forest industry members and some by industry cooperatives and research organisations.

Australia's forest genetic resources play an important role in maintaining and improving plantation forest productivity. These resources are used to select tree genotypes of higher growth rate, improved wood quality and site adaptation. Meeting the challenges associated with projected warmer and drier conditions under modelled climate change scenarios and the need for increased resistance or tolerance to potential pest and disease threats will require ongoing access to forest genetic resources to select and develop robust tree crops.

Australian tree improvement and propagation programs are applied to selected commercial forest tree species and are highly sophisticated, with some managed by individual industry members and some managed cooperatively. These tree improvement programs rely mostly on traditional methods of selection, breeding, improvement and propagation. Micro-propagation and clonal methods are used in deploying softwoods (*Pinus* species), teak (*Tectona grandis*) and in some hardwood applications (such as clonal seed orchards of *Eucalyptus* species). Molecular biology tools have been used to characterise and profile phylogenetic relationships among and

within some Australian tree taxa. Molecular markers are now also being developed and applied to accelerate selection of preferred varieties through association of traits of interest with molecular markers. There has been research on, but no commercial releases of, genetically modified trees in Australia defined as trees whose genetic material has been altered by the insertion of a modified gene or a gene from another organism using genetic engineering techniques. However, there is developing attention on the need to manage potential gene-flow from plantations of native species into nearby natural forests. While the genetics of some non-commercial forest tree species have been studied in some detail, there are many hundreds of species that have not been genetically characterised in detail.

Many forest genetic resources are effectively conserved in situ, for example through formal and informal conservation reserves that cover all the main Australian forest types. Within the main native forest timber production areas, regional forest agreements aim to reserve at least 15 per cent of the pre-1750 distribution of each forest type, 60 per cent of the existing distribution of each forest type if vulnerable, 60 per cent of existing old-growth forest, 90 per cent or more of high-quality wilderness forests, and all remaining rare and endangered forest ecosystems.

Ex situ conservation of forest genetic resources can occur through collections, whether developed for conservation or commercial reasons. The Australian Tree Seed Centre (ATSC) is the major publically funded tree seed bank in Australia and holds many collections of genotypes covering the genetic base of Australian forest trees. The ATSC has supplied more than 200 000 certified seed lots from over 1000 tree or shrub species to researchers in over 100 countries since the early 1960s. Numerous botanical gardens maintain collections of native Australian and exotic trees.

Australian forest genetic resources provide food and livelihoods in Australia and other countries. However, few Australians depend directly on forest food or other non-wood forest products for food or livelihoods.

Australia has prepared a national list of over 1340 threatened species under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). This list includes two extinct, two critically endangered, 56 endangered and 94 vulnerable forest tree or woody plant species. Australian states and territories have prepared threatened species lists for their jurisdictions, which may include locally threatened species not on the national list.

Potential threats to forest genetic resources in Australia (identified in EPBC Act assessments) include land-use change, urbanisation, fragmentation, exotic invasive plant species, pests and diseases, altered fire regimes and drought. Climate change may pose a threat to the genetic diversity of species with restricted natural ranges. There are limited studies linking these threats to extinctions of forest tree species, and many of the documented threats are historical. Phytophthora is fungus responsible for tree dieback (*Phytophthora cinnamomi*). Dieback occurring as a result of phytophthora has been listed as a 'key threatening process' under the EPBC Act because of the threat it poses to Australia's biodiversity, including forest and woody plant species. A recent (circa 2010) incursion of the exotic disease myrtle rust (*Puccinia psidii sensu lato*) is concerning because of its rapid spread along Australia's east coast and because of the broad range of susceptible native species within the family Myrtaceae, which includes eucalypts and many other important genera.

A large range of invasive weeds directly threaten forest genetic resources through competition, or indirectly by impeding access and increasing the risk of fires. Examples of invasive weeds of national significance are *Acacia nilotica* (prickly acacia), *Chrysanthemoides monilifera* subsp.

rotundata (bitou bush), *Cryptostegia grandiflora* (rubber vine), *Lantana* species (lantana) and *Rubus fruticosus* aggregate species (blackberry).

There is a growing interest in understanding the interaction between genetic variation, ecological diversity and climate change adaptation. However, the number of trained and experienced forest geneticists in Australia is decreasing as fewer people are attracted into forestry industry careers and as industry investment on research decreases.

This report was prepared as part of a global assessment of forest genetic resources by the Food and Agriculture Organization of the United Nations (FAO), to be published in 2013. It is a compendium of information on forest genetic resources to inform the global assessment by FAO and Australia's own forest policy requirements.

Eucalyptus regnans (mountain ash), Michael Ryan

1 Introduction to Australia and its forest sector

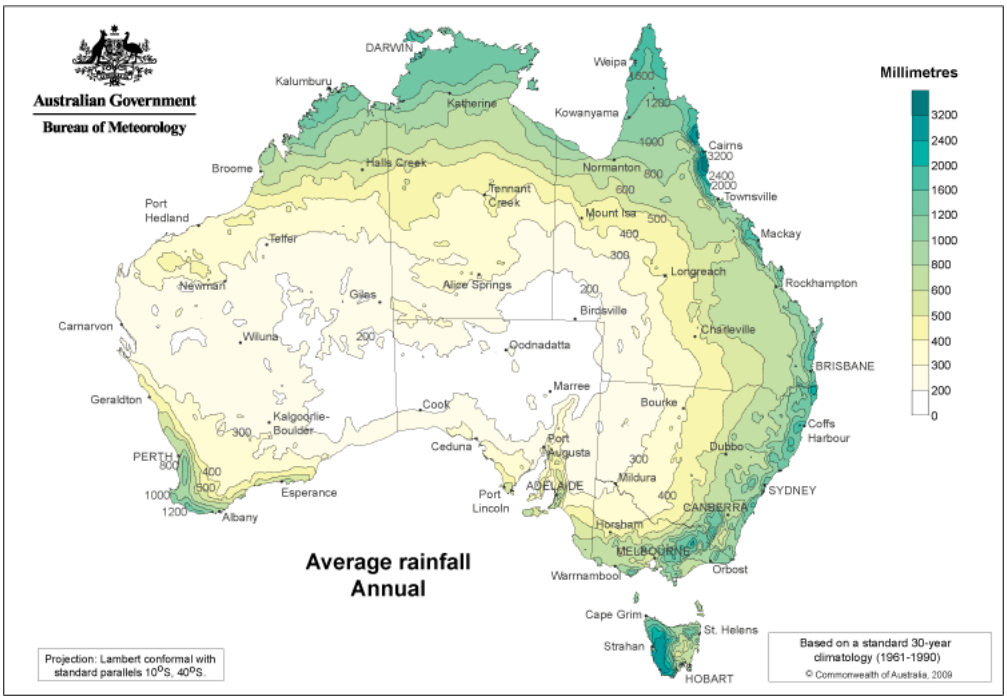
Location, size and physiographic features

Australia is located in the Southern Hemisphere between the Indian Ocean and the Pacific Ocean. It is the world's sixth largest country, with an area of about 769 million hectares. Australia is also the flattest continent in the world, with an average elevation of only 330 metres (Geosciences Australia 2012).

Climate

Australia is the world's driest inhabited continent; 70 per cent of it is arid or semi-arid land. Australia's arid land receives an average annual rainfall of less than 250 millimeters and its semi-arid land receives 250–350 millimeters. Drought is a recurring climatic feature over most of the country. Australia's climate ranges from tropical monsoon in the north to Mediterranean or temperate in the south, with a vast arid region in the interior. Australia generally experiences mild winters and hot summers. Mean annual rainfall is greatest in the north and along the east coast and is much lower in inland areas (Map 1).

Map 1 Australia's mean annual rainfall



Source: Bureau of Meteorology

Climate change modelling to 2030 and 2050 has projected that most areas of Australia where forests occur are likely to receive lower rainfall and experience increased temperatures compared with 2005 (CSIRO & BoM 2007; ABARES 2011b).

Human population trends

Australia's population has increased by about 16 per cent from about 19 million people in 2001 to over 22 million in 2012 and by about 900 per cent since 1800 (ABS 2012). The population increase has been much faster in the past decade than any other time in Australia's history. About 70 per cent of Australia's population lives in major cities. Indigenous Australians make up about 2 per cent of the country's population.

Main forest types and distribution of native forest and plantations

A forest is 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 equal to or greater than 20 per cent. This includes Australia's diverse native forests and plantations, regardless of age, and encompasses areas of trees that are sometimes described as woodlands (ABARES 2012a). In its forest extent, Australia includes areas of forest that are also used for agriculture, particularly for grazing.

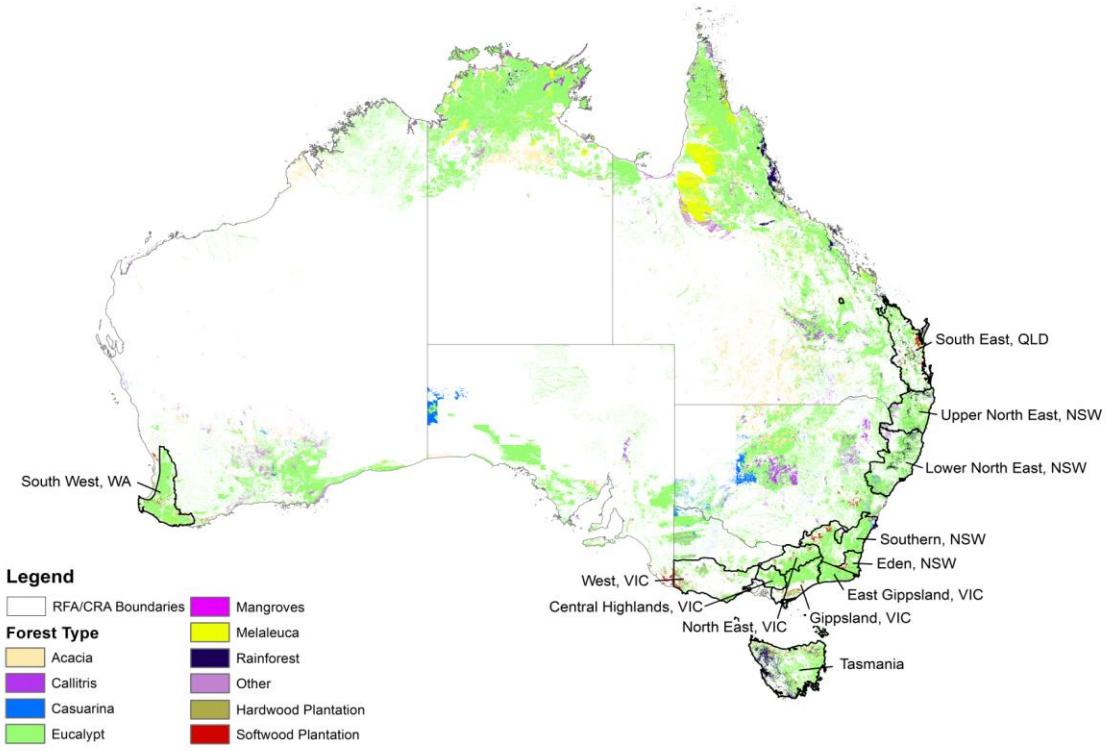
Australia has 147.4 million hectares of native forest and 2.0 million hectares of forestry plantations. Together, these cover about 19 per cent of the continent. Australia has about 4 per cent of the world's forests on 5 per cent of the world's land area (ABARES 2012a).

Map 2 depicts the distribution of dominant forest types across Australia. It also shows the regional forest agreement (RFA) and comprehensive regional assessment (CRA) areas (MPIGA 2008a). The diverse forest genetic resources of these forest types are subject to sustainable forest management and conservation in situ. Chapter 3 of this report and Indicator 1.1c in *Australia's State of the Forests Report* (MPIGA 2008a) give further information on areas of forests in various categories.

The distribution of forest types is determined mainly by climate and soil type, along with other factors such as frequency and incidence of fires. Eucalypts are by far the most dominant native forest species, followed by acacias. Australian endemic tree species are generally adapted to drought and fire (MPIGA 2008a). For instance, fire is essential for natural regeneration of *Eucalyptus* species.

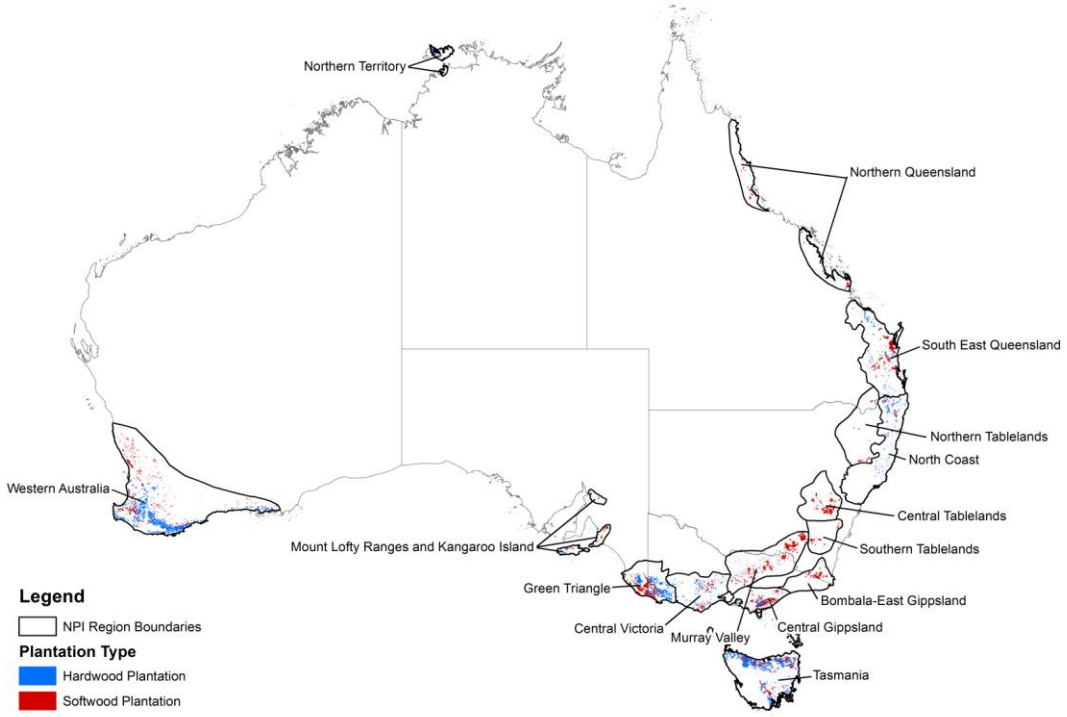
Map 3 shows the distribution of hardwood and softwood plantations in Australia—almost all commercial forestry plantations are established in the 14 regions reported on in the National Plantation Inventory (NPI). Hardwood plantations primarily comprise *Eucalyptus* species and softwood plantations are mainly *Pinus* species.

Map 2 Distribution of dominant forest types, regional forest agreement and comprehensive regional assessment areas



Source: ABARES

Map 3 Distribution of forest plantations and National Plantation Inventory regions



Source: ABARES

Table 1 shows the area in Australia under main forest categories as defined by FAO. These derived estimates, to be referred to as 'Australia's derived FAO forest extent', reflect the most recent native forest extent identified by states and territories in the 2008 *Australia's State of the Forests Report* (MPIGA 2008a), and plantation figures from the National Plantation Inventory (ABARES 2012a) as compiled in FAO's Global Forest Resource Assessment 2010. Primary or old-growth forests occur on about 5 million hectares, other native forests on 142 million hectares and plantations on 2 million hectares. Australia's ability to estimate its forest extent continues to improve with the increasing availability of high-resolution remotely sensed data and improvements in forest typing methods in Australia's woodland forests (20–50 per cent crown cover).

Table 1 Forest characteristics and areas

Main forest categories	Areas ('000 hectares)
Primary forest **a**	5 039
Other naturally regenerated forest	142 359
of which introduced species	0
Planted forest **b**	2 017
of which introduced species **c**	*980*
Total **d**	149 415

a Old-growth forest figures published in MPIGA (2008). **b** Forest planted for commercial harvest. Includes area covered by agroforestry of about 84 000 hectares. Australia's National Plantation Inventory does not compile information on areas planted for environmental purposes. An area of 45 000 hectares of *Araucaria cunninghamii* (hoop pine), a native softwood species, is included in the planted forest area (Gavran et al. 2012). **c** The planted forests of introduced species are dominated by exotic softwood species (*Pinus* spp.) (Gavran at al. 2012). **d** Figures may not tally due to rounding.

Note: Australia's forest extent figures were calculated to meet the requirements of FAO's Global Forest Resource Assessment 2010 for the purpose of providing regional and global forest information.

Source: Adapted from FAO (2010) and includes data from 2007 National Forest Inventory (MPIGA 2008a) and National Plantation Inventory (ABARES 2012a)

Forest tenure

The area of public, private and other forest ownership as defined by FAO is shown in Table 2. More than 108 million hectares of Australia's forests are publicly owned and more than 39 million hectares are privately owned.

Table 2 Forest ownership by area

Forest ownership	Areas ('000 hectares)
Public	108 255
Private	39 534
Other **a**	1 626
Total **b**	149 415

a Includes 'joint' ownership class along with 'unknown' or 'unresolved' ownership. **b** Figures may not tally due to rounding or changes in area of planted forest between 2007 and 2011 (Gavran & Parsons 2011, ABARES 2012a).

Note: Australia's forest extent figures were calculated to meet the requirements of FAO's Global Forest Resource Assessment 2010 for the purpose of providing regional and global forest information.

Source: Adapted from FAO (2010) and includes data from 2007 National Forest Inventory (MPIGA 2008a), National Plantation Inventory (ABARES 2012a)

Native forest

Figure 1 illustrates forest cover by tenure in six forest categories recognised in Australia. Of the 147 million hectares of Australia's native forests, about 70 per cent are privately managed,

including 26 per cent on land with freehold private title or managed by Indigenous communities, and 44 per cent on leasehold land where the predominant land use is grazing (ABARES 2011a).

Figure 1 Australia's native forest cover, by tenure

Note: Area figures in the legend are in thousand hectares.

Source: ABARES

Plantations

Australian state governments were the major plantation owners until the early 1990s, but since then most investment in new plantations has been by the private sector. From 1990 to 2010–11, private ownership of plantations increased from about 30 per cent to 74 per cent (ABARES 2012a). Most of this expansion in privately owned plantations was funded and managed by investment schemes, but this has been in sharp decline since 2009. Public ownership of plantations in 2010–11 was about 24 per cent, with the remainder owned by farm foresters and other private owners (8 per cent), managed investment schemes (24 per cent), superannuation funds (31 per cent) and timber industry companies (13 per cent).

Size and nature of native forests and plantations, and recent trends

Native forest

Of Australia's 147.4 million hectares of native forest, 9.4 million hectares are multiple-use public forest potentially available for timber harvesting (ABARES 2012a). Australian governments have collaboratively established 12 regional forest agreements (RFAs) for most of the main native forest timber production areas (Map 2). About 13.6 million hectares of forest was added to the nature conservation reserve network between 1990 and 2007; the area of public native forests remaining available for timber production was thereby reduced by about 4 million hectares (Davidson et al. 2008).

Eucalyptus saligna (Sydney blue gum), Mark Parsons

Plantations

Australia's total plantation area was about 2 million hectares in 2010—marginally less than 2009 but substantially more than five and 10 years ago (Gavran & Parsons 2011; ABARES 2012a). The area of softwood plantations increased slightly over the past 10 years and the area of hardwood plantations nearly doubled in the same period. The main plantation species used

for timber and fibre production are shown in Gavran and Parsons (2011, Figure 5, p. 5). Almost all of the softwood plantations are managed for sawlogs, while over three-quarters of the hardwood plantations are managed for pulpwood.

Forestry sector and recent trends

Australia's wood products industries have an annual turnover of about $24 billion, which reflects the value of sales and services across the industry sector. The forestry, timber and paper products sectors contribute about $7 billion to gross domestic product per year. This represents 6.2 per cent of Australia's total manufacturing sector and 0.6 per cent of national gross domestic production (ABARES 2012a, b).

Australia's exports of forest products increased in value from about $300 million (non-indexed) in 1984–85 to $2.2 billion in 2011–12. Imports of wood and paper products also rose from about $1.3 billion (non-indexed) in 1984–85 to $4.2 billion in 2011–12 (Davidson et al. 2008; ABARES 2012b).

The total native and plantation log volume harvested in Australia was over 26 million cubic metres in 2010–11, representing an increase of 8 per cent over the decade. The production of native forest logs declined by 40 per cent, while the hardwood plantation log supply increased by 425 per cent in the past decade (ABARES 2012a).

Australia's potential plantation log supply has been forecast by Gavran et al. (2012). The national plantation log harvest in 2009–10 was over 18.6 million cubic metres, which was about 4 per cent higher than that of 2005–06. The potential supply of logs from Australia's plantations is forecast to increase to an annual average of 26 million cubic metres in the period 2010–2014, then increase further to average over 29 million cubic metres a year in the period 2015–2019. Forecast supply in the period 2015–2019 comprises hardwood pulpwood (43 per cent, mainly eucalypt), softwood sawlogs (36 per cent, mainly pine), softwood pulpwood (19 per cent, mainly pine) and hardwood sawlogs (2 per cent, mainly eucalypt).

Forest genetic material supply and utilisation

Forest tree and woody plant species provide for many ecosystem or environmental services (Appendix 1) (FAO 2010). These include:

- solid wood products (use code U1)
- pulp and paper (U2)
- energy (fuel) (U3)
- non-wood forest products, including food, fodder, essential oils, nectar, resins, dyes, industrial gums (U4)
- agroforestry or farm forestry systems (U5)
- other uses including carbon sequestration plantings, landscape beauty, shade and windbreaks for other crops and livestock, flood control or mine site restoration (U6)
- soil and water conservation including watershed management (service code S1)
- soil fertility (S2)

- biodiversity conservation, including gene pools for future generations and habitat for wildlife (S3)
- cultural values (S4)
- aesthetic values (S5)
- religious values (S6)
- other services, including soil formation, soil protection/conservation (such as salinity mitigation), nutrient cycling and heritage (S7).

A broad suite of native and exotic tree species in Australia have been compiled into a listing (Table A1) developed from the FAO global system on forest genetic resources (REFORGEN) database, and annotated with the threatened status or the usage status of species.

Australia has a rich array of forest genetic resources consisting of a large range of native flora and exotic species (Table A1). The United Nations Environment Programme has identified Australia as one of the 12 'mega-diverse' countries and ranked it fifth in the world for diversity of native flora.

Of a total of about 2500 Australian tree species, some 200 are of current commercial significance in Australia or overseas, including eucalypts, acacias, casuarina, melaleuca and macadamia. About 5 to 10 per cent of Australian tree species have been thoroughly studied for their potential for commercial utilisation. These are among the species and subspecies in Appendix 1.

Australia's forest genetic resources play an important role in maintaining and improving forest productivity, being used to select forest tree genotypes better adapted to projected warmer and drier conditions and resistant or tolerant to potential increases in numbers and severity of pests, diseases and weeds associated with climate change. Australian forest species are adaptable to a wide range of environments, reflecting different climates and soil types.

Australian organisations, including herbaria and botanic gardens, contribute to collections of forest genetic materials throughout the world. CSIRO's Australian Tree Seed Centre (ATSC) has supplied more than 200 000 certified seed lots from over 1000 tree or shrub species to researchers in over 100 countries since early 1960s. Seed lots have also been exported for research purposes through various institutions, including state forest services, botanic gardens, universities and private seed collectors. Australia is a partner in the Millennium Seed Bank Partnership based at the Royal Botanic Gardens, United Kingdom, the largest ex situ conservation project in the world.

Australia has also imported forest genetic materials, including pine species from the United States, Central America and Europe. Imported *Pinus radiata* (radiata pine), *P. caribaea* and *P. elliottii* (southern pines) and *P. pinaster* (maritime pine) have become an important part of commercial plantations in Australia.

A number of Australian and overseas forestry companies draw from and depend on both the rich native forest diversity and ex situ conservation efforts, and invest in research on forest genetics and breeding in Australia.

Process used for preparing this Country Report

Australia's Country Report was prepared using the *Guidelines for the preparation of Country Reports for the State of the World's Forest Genetic Resources* (FAO 2010). It provides a representative coverage of native forest species, in particular those occurring in Australia's forest reserve systems and environmental plantings, and native and exotic commercial plantation species.

This report is focused on the conservation and sustainable use of forest genetic resources, consistent with the scope of the first 'The state of the world's forest genetic resources', a global report to be based on Country Reports and published in 2013 (FAO 2011).

Australia's Country Report was produced by the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES), which is part of the Department of Agriculture, Fisheries and Forestry (DAFF), in collaboration with CSIRO through the Australian Tree Seed Centre (ATSC).

In preparing this report many experts were consulted from forest industry, conservation, breeding and research institutions across Australia, including the Southern Tree Breeding Association (STBA), Greening Australia, the Australian National Botanical Gardens, universities, state and territory departments and small and large private enterprises. Consultees provided information on forest genetic resources and usage, conservation, education and management. ABARES also sourced information from states and territories for Indicator 1.3b, 'Native forest and plantations of indigenous timber species which have genetic resource conservation mechanisms in place' (MPIGA 2008a). Experts on Australia's legislation and international treaties from the Department of Sustainability, Environment, Water, Population and Communities, IP Australia and within DAFF were also consulted.

Information was also sourced from:

- a series of papers with the theme 'Achievements in forest tree genetic improvement in Australia and New Zealand' in *Australian Forestry* vols 70 (2007) and 71 (2008)
- a series of papers presented at the workshop 'Developing a Eucalypt Resource: learning from Australia and elsewhere', Wood Technology Research Centre, University of Canterbury, New Zealand, 2011
- a series of Australian papers presented to the meeting 'Joining silvicultural and genetic strategies to minimize *Eucalyptus* environmental stresses: from research to practice', Porto Seguro, Bahia State, Brazil, 14–18 November 2011
- presentations at the first and second Australasian Forest Genetics Conferences and pre and post conference tours, Hobart 2007 and Perth 2009
- presentations and discussions of Research Working Group 1 (Forest Genetics), Hobart 2007 and Fremantle 2009
- other specific references and sources of information listed in the bibliography of this report.

2 Current state of forest genetic resources

Australia's forest genetic resources are conserved in situ in native forests and other woody vegetation (Chapter 3) and various ex situ repositories (Chapter 4). Australia's native forests and other woody plant vegetation hold a rich diversity of genetic resources and are highly valued for their wide-ranging uses, as described in this report.

Areas of the major forest types and main forest species in Australia are given in Table 3. Eucalypts (78 per cent by area of total forest), acacias (7 per cent) and melaleucas (5 per cent) dominate the native forest (ABARES 2012a). About half of Australia's commercial plantations are eucalypts, mostly *Eucalyptus globulus* (blue gum), and half are exotic pines, mainly *Pinus radiata* (radiata or Monterey pine) (ABARES 2012a).

Priority forest tree and other woody plant species

The FAO global system on forest genetic resources (REFORGEN) database holds a long list of Australian native and exotic tree and other woody plant species (FAO 2012a). An update to this list was prepared for this report (Table A1). The updated list does not comprehensively cover all Australian tree species, but includes a good representation of:

- important plantation species for Australia and overseas
- threatened and endangered tree species, especially eucalypts and acacias
- exotic woody invasive species.

Table 4 provides a list of priority tree species drawn from the updated list of Australian species (Table A1), and includes commonly used species for large-scale plantings or high-profile endangered species (such as *Wollemia nobilis*).

Callitris forest, Michael Ryan

Table 3 Major forest types, areas and main endemic tree species

Forest type	Area ('000 ha)	Main species for each type
Acacia	10 365	*Acacia aneura* (mulga), *A. auriculiformis* (earpod wattle), *A. cambagei* (gidgee), *A. celsa* (salwood), *A. cochlocarpa* subsp. *velutinosa* (velvety spiral pod wattle), *A. colei* (Cole's wattle), *A. dealbata* (silver wattle), *A. harpophylla* (brigalow), *A. holosericea* (soapbush wattle), *A. mangium* (mangium), *A. mearnsii* (black wattle), *A. melanoxylon* (blackwood), *A. pendula* (myall), *A. pycnantha* (golden wattle), *A. saligna* (golden wreath wattle), *A. shirleyi* (lancewood), *A. unguiculata*
Callitris	2 597	*Callitris columellaris* (white cypress pine), *C. rhomboidea* (Port Jackson pine), *C. preissii* (Rottnest Island pine), *C. endlicheri* (black cypress pine), *C. verrucosa* (mallee pine), *C. oblonga* (pigmy cupress pine)
Casuarina	2 229	*Allocasuarina decaisneana*, *A. fraseriana* (Western Australian she-oak), *A. huegeliana*, *A. leuhmanii* (buloke), *A. littoralis* (black oak), *A. torulosa* (forest oak), *A. verticillata* (drooping she-oak), *Casuarina cristata* (belah), *C. cunninghamiana* (river she-oak), *C. equisetifolia* (coast she-oak), *C. glauca* (swamp oak), *C. pauper*, *Gymnostoma australianum* (Daintree pine)
Eucalypt	116 449	*Corymbia citriodora* (lemon-scented gum), *C. citriodora* subsp. *citriodora* (lemon-scented gum), *C. citriodora* subsp. *variegata* (spotted gum), *C. eximia* (yellow bloodwood), *C. ficifolia* (red-flowering gum), *C. gummifera* (red bloodwood), *C. maculata* (spotted gum), *C. papuana* (desert gum), *Eucalyptus alba* (white gum), *E. annulata* (open-fruited mallee), *E. blakelyi* (Blakely's red gum), *E. cinerea* (Argyle apple), *E. camaldulensis* (river red gum), *E. benthamii* (Camden white gum), *E. cladocalyx* (sugar gum), *E. cloeziana* (Gympie messmate), *E. crebra* (narrow-leaved ironbark), *E. delegatensis* (alpine ash), *E. diversicolor* (karri), *E. diversifolia* (soap mallee), *E. dumosa* (white mallee), *E. dunnii* (Dunn's white), *E. eremophila* (tall sand mallee), *E. erythronema* (red-flowered mallee), *E. globulus* (Tasmanian blue gum), *E. globulus* subsp. *maidenii* (Maiden's gum), *E. gomphocephala* (tuart), *E. grandis* (flooded gum), *E. horistes* (mallee), *E. incrassata* (ridge-fruited mallee), *E. largiflorens* (black box), *E. leptophylla* (narrow-leaved red mallee), *E. leucoxylon* (South Australian blue gum), *E. macrorhyncha* (red stringybark), *E. mannifera* (brittle gum), *E. melliodora* (yellow box), *E. marginata* (jarrah), *E. microcarpa* (grey box), *E. miniata* (woolybutt), *E. nitens* (shining gum), *E. obliqua* (messmate, stringybark), *E. ovata* (swamp gum), *E. pauciflora* (snow gum), *E. pellita* (red mahogany), *E. pilularis* (blackbutt), *E. polyanthemos* (red box), *E. polybractea* (blue-leaved mallee), *E. punctata* (grey gum), *E. pyriformis* (pear-fruited mallee), *E. regnans* (mountain ash), *E. rossii* (scribbly gum), *E. saligna* (Sydney blue gum), *E. salmonophloia* (salmon gum), *E. sideroxylon* (red ironbark), *E. sieberi* (silvertop ash), *E. smithii* (gully gum), *E. socialis* (red mallee), *E. tereticornis* (forest red gum), *E. tetrodonta* (stringybark), *E. tetrodonta* (Darwin stringybark), *E. torquata* (coral gum), *E. viminalis* (ribbon gum), *E. wandoo* (wandoo), *E. woodwardii* (lemon-flowered gum)
Mangrove	980	*Avicennia marina* (white mangrove*), Nypa fruticans* (mangrove palm)
Melaleuca	7 556	*Melaleuca argentea* (silver paperbark), *M. dealbata* (blue paperbark), *M. ericifolia* (swamp paperbark), *M. leucadendra* (long-leaved paperbark), *M. nervosa* (yellow-barked paperbark), *M. quinquenervia* (tea tree), *M. viridiflora* (broad-leaved paperbark)
Rainforest	3 280	*Agathis microstachya* (bull kauri pine), *Argyrodendron trifoliolatum* (white booyong), *Araucaria bidwillii* (bunya pine), *Alectryon coriaceus* (beach bird's-eye), *Atherosperma moschatum* (southern sassafras), *Bridelia exaltata* (brush ironbark), *Capparis arborea* (brush caper berry), *Castanospora alphandii* (brown tamarind), *Casuarina equisetifolia* (beach casuarina), *Claoxylon australe* (brittlewood), *Elaeocarpus grandis* (blue quandong), *Endiandra globosa* (black walnut), *Eupomatia laurina* (bolwarra), *Flindersia australis* (Australian teak), *Lagarostrobus franklinii* (Huon pine), *Lophostemon confertus* (brush box), *Neolitsea australiensis* (green bolly gum), *Nothofagus cunninghamii* (myrtle beech), *Nothofagus moorei* (Antarctic beech), *Phyllocladus aspleniifolius* (celery-top pine), *Pouteria australis* (black apple), *Randia fitzalanii* (brown gardenia),

Forest type	Area ('000 ha)	Main species for each type
		Tabernaemontana pandacaqui (banana bush), *Tasmannia insipida* (brush pepperbush), *Toechima tenax* (brush teak)
Other	3 942	*Banksia aemula* (Wallum banksia), *B. ericifolia* (heath banksia), *B. serrata* (saw banksia), *B. marginata* (silver banksia), *B. integrifolia* (coast banksia), *Grevillea robusta* (silky-oak), *Leptospermum amboinense*, *L. arachnoides*, *L. macrocarpum*, *L. rotundifolium*, *L. variabile*
Total native forest (2007)	147 397	
Hardwood plantation (2011)	992	*Corymbia maculata* (spotted gum), *Eucalyptus globulus* (Tasmanian blue gum), *E. grandis* (flooded gum), *E. nitens* (shining gum), *E. pilularis* (blackbutt), *E. regnans* (mountain ash), *E. cloeziana* (Gympie messmate), *E. dunnii* (Dunn's white gum)
Softwood plantation (2011)	1 025	*Araucaria cunninghamii* (hoop pine), *Pinus radiata* **a** (radiata pine), *P. pinaster* **a** (maritime pine), *P. caribaea* **a** (Caribbean pine), *P. elliottii* **a** (southern pine)
Mixed/unknown plantation (2010)	12	
Total plantation	2 009	
Total native forest + plantation **b**	149 415	
Per cent of Australia forested	19%	

a Exotic species. **b** Figures may not tally due to rounding.

Sources: ABARES; Areas of native forest types: MPIGA 2008a; Areas of plantations: National Plantation Inventory (ABARES 2012a)

Table 4 Priority species

Scientific name	Tree (T) or other (O)	Native (N) or exotic (E)	Reasons for priority
Acacia auriculiformis	T	N	Important species for tropical overseas planting
A. cochlocarpa subsp. *velutinosa*	T	N	Critically endangered species in Australia
A. colei	T	N	Important species for semi-arid overseas planting
A. dealbata	T	N	Important species for overseas planting
A. holosericea	T	N	Important species for overseas planting
A. mangium	T	N	Most widely planted *Acacia* in South-East Asia
A. mearnsii	T	N	Important species for overseas planting; also a notable invasive outside of Australia
A. melanoxylon	T	N	Widely planted overseas and important native timber in Australia; also a notable invasive outside of Australia
A. saligna	T	N	Important species for overseas planting; also a notable invasive outside of Australia
A. unguiculata	O	N	Critically endangered species in Australia
A. robusta	T	N	Plantation species (timber); also used as windbreaks on farms
Araucaria cunninghamii	T	N	Plantation species (timber)
Atriplex nummularia	O	N	Used for soil and water conservation and improving soil fertility
Callitris oblonga	T	N	Vulnerable species in Australia
C. oblonga subsp. *oblonga*	T	N	Endangered species in Australia
Casuarina cunninghamiana	T	N	Used for soil and water conservation and improving soil fertility and for aesthetic value
C. equisetifolia	T	N	Important species for overseas planting (multipurpose tree)
Corymbia citriodora subsp. *citriodora*	T	N	Subtropical plantation species (timber)
C. citriodora subsp. *variegata*	T	N	Subtropical plantation species (timber)
Corymbia hybrids	T	N	Plantation (timber) hybrid species

Scientific name	Tree (T) or other (O)	Native (N) or exotic (E)	Reasons for priority
C. maculata	T	N	Plantation (timber) species
Cupressus macrocarpa	T	E	Plantation (timber) species; also used as windbreaks
Eucalyptus argophloia	T	N	Vulnerable species in Australia
E. benthamii	T	N	Globally important subtropical cold-tolerant plantation eucalypt; vulnerable species in Australia natural range
E. camaldulensis	T	N	Iconic eucalypt of widest natural range and one of the globally most widely planted eucalypt
E. cladocalyx	T	N	Used for soil and water conservation, durable timber, farm windbreaks
E. cloeziana	T	N	Subtropical plantation species (timber)
E. crebra	T	N	Plantation (timber) species
E. dunnii	T	N	Subtropical cold-tolerant plantation species (timber, fibre)
E. globulus	T	N	Australia's most extensively planted eucalypt and globally extensively planted temperate eucalypt (fibre)
E. globulus subsp. *maidenii*	T	N	Important species for overseas planting
E. grandis	T	N	Important species for overseas subtropical/tropical planting (timber, fibre)
E. gunnii subsp. *divaricata*	T	N	Endangered species
E. horistes	O	N	Mallee (multistemmed eucalypt) for essential oil, bioenergy and environmental restoration
Eucalyptus hybrids	T	N/E	Plantation (timber) hybrids
E. kartzoffiana	T	N	Vulnerable species in Australia
E. melliodora	T	N	Used for soil and water conservation
E. morrisbyi	T	N	Endangered species
E. nitens	T	N	Second most extensively planted eucalypt in Australia (temperate cold-tolerant, for fibre and some timber) after *E. globulus*
E. occidentalis	T	N	Used for soil and water conservation and improving soil fertility
E. pellita	T	N	Tropical plantation species (timber) in Australia and overseas
E. pilularis	T	N	Subtropical plantation species (timber)
E. polybractea	O	N	Low-rainfall plantation mallee species (essential oil), carbon sequestration
E. raverertiana	T	N	Vulnerable species in Australia
E. rudis	T	N	Used for soil and water conservation
E. saligna	T	N	Important species for subtropical overseas planting
E. scoparia	T	N	Vulnerable species in Australia; horticultural planting
E. sideroxylon	T	N	Dryland species used for environmental restoration and durable timber
E. smithii	T	N	Plantation species (fibre and essential oil)
E. tereticornis	T	N	Important species for subtropical/tropical overseas planting (multipurpose)
E. tricarpa	T	N	Plantation (timber) species
E. urophylla	T	E	Plantation (timber) species
Grevillea robusta	T	N	Important species for overseas planting (timber)
Khaya senegalensis	T	E	Plantation (timber) species
Melaleuca alternifolia	T	N	Subtropical plantation species (essential oil)
Pinus caribaea	T	E	Subtropical plantation species also used as hybrid parent (timber)
P. caribaea var. *hondurensis*	T	E	Subtropical plantation species also used as hybrid parent (timber)
P. elliottii	T	E	Subtropical plantation species also used as hybrid parent (timber)

Scientific name	Tree (T) or other (O)	Native (N) or exotic (E)	Reasons for priority
P. pinaster	T	E	Temperate medium-rainfall plantation species (timber)
P. radiata	T	E	Most widely used softwood plantation species in Australia, threatened in parts of natural range
Santalum album	T	E	Low-rainfall plantation species (essential oil)
S. spicatum	T	N	Low-rainfall plantation species (essential oil)
Toona ciliata var. *australis*	T	N	Plantation (timber) species
Wollemia nobilis	T	N	Endangered species of high scientific and amenity value

Note: The list of species included here is alphabetical, not in priority sequence, and is based on recent reviews, including Bush (2011), Griffin et al. (2011), Harwood (2011), Harwood et al. (2007), and Shepherd (2011), as well as uses of Australian forest genetic resources in Australia and overseas, and data collected for this report. The list focuses on species commonly planted on a wide scale for afforestation, plus endangered species with a high profile. Determining priority forest tree species is subjective and depends on the specific purpose of the listing. This list does not include all priority species.
Sources: ABARES; ATSC

Main forest tree and other woody species actively managed for human utilisation

Native forests

Australia's native forest and woody plant species provide a multitude of wood and non-wood products and services (see section 'Forest genetic material supply and utilisation' in Chapter 1 of this report, and Table A1).

A wide variety of tree species are harvested in native forests for wood production in Australia (MPIGA 2008a; ABARES 2011c–h). The following list includes some of the most important: hardwood species—*Corymbia maculata* (spotted gum), *Eucalyptus delegatensis* (alpine ash), *E. diversicolor* (karri), *E. gomphocephala* (tuart), *E. marginata* (jarrah), *E. obliqua* (messmate or stringybark), *E. pilularis* (blackbutt), *E. regnans* (mountain ash), *E. sieberi* (silver-top) and *E. wandoo* (wandoo); and softwood species—*Callitris* spp. (cypress pine). Native eucalypt forests regenerate naturally after harvest, either from existing young trees or from seed, sometimes with controlled fire to promote seedbed formation and very occasionally with planting of seedlings.

Plantations

Hardwood plantation species in Australia include *Acacia mangium* (mangium), *Corymbia maculata* (spotted gum), *Eucalyptus globulus* (blue gum), *E. pilularis* (blackbutt), *E. dunnii* (Dunn's white gum), *E. grandis* (flooded gum), *E. nitens* (shining gum), *Khaya senegalensis* (African mahogany) and *Tectona grandis* (teak) (MPIGA 2008a; ABARES 2011c–h). Softwood plantation species include *Araucaria cunninghamii* (hoop pine), *Pinus caribaea* (Caribbean pine), *P. radiata* (radiata pine), *P. pinaster* (maritime pine), *P. elliottii* (southern pine) and pine hybrids (MPIGA 2008a; ABARES 2011c–h) (Table 5). Almost all hardwood and softwood plantations in Australia are established by planting seedlings or cuttings.

Other species grown on a commercial scale include *Cupressus macrocarpa* and other conifers as windbreaks on farms, and *Santalum spicatum* (Australian sandalwood) for health and beauty products.

Young plants of *Eucalyptus globules*, ABARES

Table 5 provides a list of the main commercial plantation tree and woody plant species that are managed for wood and non-wood uses in Australia (Table A1 lists a larger number of species used in Australia for various uses).

Table 5 Main plantation species currently used in Australia

Species	Native (N) or exotic (E)	Current use a	Type of management system	Area managed ('000 ha)
Acacia mangium	N	1,2	Plantation	27
A. melanoxylon (Australian blackwood)	N	1,5	Plantation	0.1
Araucaria cunninghamii (hoop pine)	N	1,2	Plantation	45
Casuarina cunninghamiana (river she oak)	N	1,5	Plantation	2
Corymbia maculata (spotted gum)	N	1,2,5	Plantation	21
Eucalyptus dunnii (Dunn's white gum)	N	1	Plantation	47
E. globulus (blue gum)	N	1,2	Plantation	538
E. nitens (shining gum)	N	1,2	Plantation	235
E. pilularis (blackbutt) and *E. grandis* (flooded gum)	N	1,2	Plantation	26
Other eucalypts	N	1	Plantation	55
Pinus radiata (radiata pine)	E	1,2	Plantation	773
P. pinaster (maritime pine)	E	1,2	Plantation	42
P. elliottii, P. caribaea (southern pines)	E	1,2	Plantation	150
Other pines	E	1,2	Plantation	6
Other species (e.g. *Grevillea robusta*)	N	1,5, street decoration (6)	Plantation	52
Santalum spicatum (Australian sandalwood)	N	5, health & beauty products (6)	Plantation	8

a 1 = solid wood products, 2 = pulp and paper, 3 = energy (fuel), 4 = non-wood forest products, 5 = used in agroforestry systems, 6 = other.

Sources: National Forest Inventory (MPIGA 2008a); National Plantation Inventory (Gavran & Parsons 2011); ABARES (2012a)

Main forest tree or other woody plant species managed for environmental services or social values

Forest tree and woody plant species in Australia's native forests and vegetation, and environmental plantings provide a wide range of services (Table 6).

In addition to their primary use, forest plantations (Table 5) also provide habitat for flora and fauna species. Surveys in north-east and central-west Victoria found that eucalypt plantations support higher densities of forest birds than nearby cleared farmland, but lower densities than native forest (Loyn et al. 2009).

Forest species used in agroforestry in Australia comprise a wide range of genera. *Eucalyptus* species include both mallees and tall trees (Table 5; Table A1). These plantings can also provide environmental benefits by sequestering carbon, reducing dryland salinity and providing habitat for wildlife (Harwood et al. 2007). *Acacia*, *Casuarina* and species of other genera are also widely used in farm forestry applications for remediation of soil, provision of windbreaks and for on-farm timber and fuelwood (for example, Hall et al. 1972; Bird 2000).

The Australian Government, non-government organisations and farmer groups are actively collaborating to restore native vegetation; forest and woodland species are important for restoring degraded farmland and other ecosystems (Commonwealth of Australia 2011). Local native species are used where their re-establishment is possible, and more adaptable species are used where soils are heavily degraded (Table 6; Table A1). Australia's Biodiversity Conservation Strategy aims to establish continental-scale linkages—that is, very large bands of revegetation—in four regions by 2015.

Australian mining companies are required by law to re-establish vegetation on mine sites once mining has been completed. The amount of seed and number of tree species used in these environmental restoration projects is very large and likely to increase in the future. Some key tree and other woody plant species actively managed or identified for environmental services are listed in Table 6.

Table 6 Main tree and other woody plant species actively managed or identified for selected environmental services

Species	Native (N) or exotic (E)	Environmental service or social value a
Acacia dealbata	N	1,2,3
A. mearnsii	N	1,2,3
Other (local native) *Acacia* species	N	1,2,3,5
Atriplex nummularia	N	1,2
Casuarina cunninghamiana	N	1,2,3,5
Other *Casuarina* species	N	1,2,3,6
Eucalyptus camaldulensis	N	1,3,4,5,7
E. cladocalyx	N	1,2
E. melliodora	N	1,2
E. occidentalis	N	1,2
E. rudis	N	1,2
other (local native) *Eucalyptus* species	N	1,3,4,5

a 1 = soil and water conservation including watershed management, 2 = soil fertility, 3 = biodiversity conservation, 4= cultural values, 5 = aesthetic values, 6 = religious values, 7 = other. Note: Table shows examples rather than a comprehensive listing, and is based on the FAO (2010) classification.

Source: ATSC

Endemic forest tree and other woody species

Australian plant species, including endemic forest tree and other woody species, are recorded in the series publication Flora of Australia (Australian Government 2012c). Among the most extensive types of Australian native vegetation are woodlands dominated by eucalypts and shrublands dominated by acacia. Australia's vegetation is globally unique—85 per cent of the

plant species are endemic; that is, they are not naturally found elsewhere (State of the Environment Committee 2011). The major native forest types include acacias, casuarinas, eucalypts, mangroves and rainforest (Table 3), which are among a large number of native species listed in the National Vegetation Information System (MPIGA 2008a). The level of endemism in forest types varies for different regions and for different species; in eucalypts and acacias it is about 98–99 per cent (Brooker 2000; Murphy et al. 2010).

Assessment of threatened species

The Threatened Species Scientific Committee, established under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), provides advice to the Australian Government Minister for Sustainability, Environment, Water, Population and Communities on amending and updating the national lists of threatened species, threatened ecological communities and key threatening processes. The committee also advises the minister on making or adopting recovery plans and threat abatement plans.

The formal status of 75 nationally listed flora taxa changed between 2002 and 2007 according to EPBC Act listings. Most of the change in conservation status occurred because of improved knowledge and taxonomic revision (DEWHA 2009).

Threatened native species are categorised according to Section 179 of the EPBC Act as follows:

- extinct—there is no reasonable doubt that the last member of the species has died
- extinct in the wild—(a) the species is known to survive only in cultivation, in captivity or as a naturalised population well outside its past range; or (b) it 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
- critically endangered—the species is facing an extremely high risk of extinction in the wild in the immediate future, as determined in accordance with the prescribed criteria
- endangered—(a) the species is not critically endangered; and (b) it is facing a very high risk of extinction in the wild in the near future, as determined in accordance with the prescribed criteria
- vulnerable—(a) the species is not critically endangered or endangered; and (b) it is facing a high risk of extinction in the wild in the medium-term, as determined in accordance with the prescribed criteria
- conservation dependent—the species is the focus of a specific conservation program, the cessation of which would result in the species becoming vulnerable, endangered or critically endangered.

These categories resemble those of the 1994 IUCN Red List Categories and Criteria (IUCN 2012). Australian states and territories also conduct their own independent assessments and place species on their threatened species lists under each jurisdiction's respective legislation. Therefore, a species may be listed as a threatened species in one jurisdiction but not in another. Box 1 describes criteria used for categorising critically endangered, endangered and vulnerable plant species.

Box 1 Criteria for categorisation of threatened plant species

For section 179 of the EPBC Act, a native species is in the critically endangered, endangered or vulnerable category if it meets any of the criteria for the category.

Item	Criterion	Category:		
		Critically endangered	**Endangered**	**Vulnerable**
1	It has undergone, is suspected to have undergone or is likely to undergo in the immediate future:	a very severe reduction in numbers	a severe reduction in numbers	a substantial reduction in numbers
2	Its geographic distribution is precarious for the survival of the species and is:	very restricted	restricted	Limited
3	The estimated total number of mature individuals is: and	very low	low	Limited
	(a) evidence suggests that the number will continue to decline at: or	a very high rate	a high rate	a substantial rate
	(b) the number is likely to continue to decline and its geographic distribution is:	precarious for its survival	precarious for its survival	precarious for its survival
4	The estimated total number of mature individuals is:	extremely low	very low	Low
5	The probability of its extinction in the wild is at least:	50 per cent in the immediate future	20 per cent in the near future	10 per cent in the medium term

Source: Environment Protection and Biodiversity Regulations 2000

Threatened forest tree and other woody species

Under the EPBC Act 1344 plant species are listed as threatened flora (Australian Government 2012a). Of these, 42 species are categorised as extinct, 120 species as critically endangered, 531 species as endangered and 651 species as vulnerable (SEWPaC 2012a). Examples of native tree and woody plant species in these categories are:

- extinct—*Acacia kingiana* and *A. prismifolia* (Diels' wattle)
- critically endangered—*Acacia cochlocarpa* subsp. *velutinosa* (velvety spiral-pod wattle) and *A. unguiculata*
- endangered—30 *Acacia* spp., *Callitris oblonga* subsp. *oblonga*, 25 *Eucalyptus* spp. (such as *E. gunnii* subsp. *divaricata*, and *E. morrisbyi*) and *Wollemia nobilis* (Wollemi pine)
- vulnerable—43 *Acacia* spp., *Callitris oblonga* (pygmy cypress pine), four *Corymbia* spp. and 47 *Eucalyptus* spp. (such as *E. argophloia*, *E. benthamii*, *E. kartzoffiana*, *E. raveretiana*, and *E. scoparia*).

The online Species Profile and Threats (SPRAT) database contains information about threatened species, plus ecological information. The SPRAT database provides information including what the species looks like, its population and distribution, habitat, reproduction and taxonomy. Threatened species of *Acacia*, *Allocasuarina*, *Corymbia* and *Eucalyptus* and some others are listed in Appendix 1. Examples of tree and woody species considered to be threatened from a genetic conservation point of view in all or part of their range are given in Table 7.

Table 7 List of tree and other woody forest species considered threatened in all or part of their range from genetic conservation point of view

Species	Area of species natural distribution in Australia	Average number of trees per hectare	Proportion of species natural distribution that is in Australia (%)	Distribution in the country	Type of threat a	Threat category
Acacia cochlocarpa subsp. *velutinosa*	Probably <100 ha	>100 known wild individuals remaining	100	Local	5,10	High
Eucalyptus benthamii	<10 000 ha	5–1 000	100	Rare/local	1,6	Medium
E. dunnii			100	Local	2	Low
E. raveretiana	124 000 km^2	Probably <100	100	Local	1,3,8	Medium
Wollemia nobilis	Probably <10 ha	~100 known wild individuals	100	Rare	Naturally rare, 11	High

a 1 = forest cover reduction and degradation, 2 = forest ecosystem diversity reduction and degradation, 3 = unsustainable logging, 4 = management intensification, 5 = competition for land use, 6 = urbanisation, 7 = habitat fragmentation, 8 = uncontrolled introduction of alien species, 9 = acidification of soil and water, 10 = pollutant emissions, 11 = pests and diseases, 12 = forest fires, 13 = drought and desertification, 14 = rising sea level, 15 = other.

Note: There are other threatened and endangered forest and woody plant species (Table A1). Australia has prepared recovery plans for many threatened forest and woody plant species, including representatives from the genera *Acacia*, *Callitris*, *Corymbia*, *Eucalyptus*, *Grevillea* and *Melaleuca*.

Sources: ABARES; ATSC; SEWPaC (2012b)

Tree species for which there is insufficient information to determine threat status

If there is insufficient information available to assess tree species nominated for threatened species status, national, state and territory governments use a conservative approach. There are no formal lists of species that have not been nominated as potentially threatened and for which there is insufficient information to determine their threat status.

Systems for documenting forest reproductive material

Forest reproductive materials are documented by various organisations in Australia, including the Australian Tree Seed Centre (ATSC), research organisations, state and territory governments, universities, herbaria, botanical gardens, arboreta and the Southern Tree Breeding Association (STBA). The following are examples of systems for documenting forest reproductive materials in Australia.

Integrated Biodiversity Information System

The Integrated Biodiversity Information System (IBIS) provides the infrastructure, applications and services that support biodiversity informatics for the Australian National Botanic Gardens, the Australian National Herbarium and their partnership with CSIRO Plant Industry, the Centre

for Australian National Biodiversity Research. IBIS links the data held in the various collections of the Australian National Botanic Gardens, the Australian National Herbarium, the Australian Plant Image Index and the Australian Plant Name Index.

Flora of Australia

The Flora of Australia series describes forest and woody plant species, among other components of the flora. Each descriptive volume summarises the current knowledge of between 200 and over 600 species, providing descriptions of taxa at all ranks. The series documents the families, genera and species of flowering plants, conifers, ferns, mosses, liverworts and lichens of Australia and its oceanic islands. The Flora of Australia series will eventually comprise more than 60 volumes covering almost 30 000 species, systematically arranged by family. The series helps identify families, genera, species and infra-species. For each species included in the Flora of Australia there are full Australian synonymies, along with distribution maps, bibliographic information, and notes on ecology and variation. Volumes 11A and 11B together describe 955 species of *Acacia*, and volume 19 describes 506 species of *Eucalyptus* and seven species of *Angophora*.

Vascular Flora

Vascular Flora is a free online database that provides taxonomic and biological information on plant species occurring in Australia, including forest and woody plant species. The database has been derived from the published volumes of the Flora of Australia, of which 17 volumes are currently available online and more are being prepared for online access.

Florabank Species Navigator

Florabank, an Australian Government initiative delivered by Greening Australia and CSIRO, holds information that aims to improve the availability and quality of native seed for revegetation and conservation purposes in Australia. The Florabank Species Navigator is an online resource that brings together biophysical and ecological information about species into an interactive key, and includes a list of species fact sheets. More than 40 species of Box-Gum Grassy Woodland have been added to the Species Navigator, and research is in progress into additional species that will be added to the Florabank website. The research for Species Navigator involves analysing the distribution, climatic and soil parameters of each species, as well as ecological data.

Australian Tree Seed Centre

CSIRO's Australian Tree Seed Centre (ATSC) uses a web-based database to track accessions. Data have been accumulated since 1962, covering over 22 000 seedlots of predominantly Australian native species. Data include provenance information about collected seed (geographic, edaphic, germination and other data), as well as comprehensive information on destinations to which seed has been dispatched. Electronic data on provenance and progeny tests conducted on a large number of species in Australia and overseas are also kept by the ATSC.

Southern Tree Breeding Association

The Southern Tree Breeding Association (STBA) uses an online database (DATAPLAN®) to store and record all tree improvement information in its programs (including pedigrees, performance measurements and trial information) and in those of its associates. DATAPLAN® contains information on breeding populations of *Eucalyptus globulus*, *E. nitens*, *Pinus radiata*, *P. sylvestris*, *P. contorta*, *Picea abies* and *Betula pendula*, among other species of emerging commercial interest. Data and information from about 27 programs are represented in DATAPLAN®,

including observations on more than 1.5 million different genotypes (trees). This database is linked to the TREEPLAN® genetic evaluation system, which analyses tree improvement data collected across Australia to improve the quality of the genetic material used in industrial plantations (McRae 2010).

Current state of forest reproductive material identification and utilisation

Seed of forest species is collected, documented and regenerated in Australian collections, and is also exported to other countries for various uses.

Generally, the genetic source of seed is controlled and known both for the major plantation programs and for native forest regeneration. For example, genetically improved seed is generally available and used by the major plantation industries for species such as *Eucalyptus globulus*, *E. dunnii*, *E. nitens* and *Pinus radiata*. Seed of acceptable (and often local) provenance is generally used for native forest regeneration after logging or extensive wildfire.

Table 8a shows that about 90 kilograms of seed of two major *Eucalyptus* species and 1860 kilograms of seed of *Pinus* species is used annually in plantations in Australia. The seed is mostly derived from genetically improved trees.

Table 8a Quantity of seeds produced annually for use in Australia and current state of identification of forest reproductive material of the main forest tree and other woody species in Australia

Species	Native (N) or exotic (E)	Total quantity of seeds used (kg)	Quantity of seeds from documented sources (provenance locality/delimited seed zones) (kg)	Quantity of seeds from tested provenances (provenance trials established and evaluated) (kg)	Quantity of seeds that is genetically improved (from seed orchards) (kg)
Eucalyptus globulus	N	60	– a	– a	~60
E. nitens	N	30	– a	– a	~30
Pinus caribaea and hybrids	E	260	– a	– a	~260
P. radiata	E	1600	– a	– a	~1600

a Information was not readily available.

Note: Genetically improved hardwood seed in Australia is usually sown as pure seed without chaff, and viability can be well over one million plants per kilogram (kg). The figures were inferred from NPI plantation estate and available ATSC records.

Source: ATSC

Table 8b Estimated number of seedlings (or vegetative propagules) planted annually for the major plantations species, and the state of identification of the reproductive material

Species	Native (N) or exotic (E)	Total number of seedlings planted (million)	Quantity of seedlings from documented sources (provenance locality/delimited seed zones)	Quantity of seedlings from tested provenances (provenance trials established and evaluated)	Quantity of vegetative reproductive material used	Number of seedlings that are genetically improved (million)
Eucalyptus globulus	N	22	– **a**	– **a**	– **a**	~22
E. nitens	N	18	– **a**	– **a**	– **a**	~18
P. caribaea and hybrids	E	6	– **a**	– **a**	– **a**	~6
P. radiata	E	37	– **a**	– **a**	>10%	~37

a Information was not readily available.

Note: The figures were inferred from NPI plantation estate and available ATSC records.

Source: ATSC

Australia has evaluated morphological, adaptive, production and molecular characteistics for many commercially important plantation forest species (Table 9).

Table 9 List of forest species for which genetic variability has been evaluated

Species scientific name	Native (N) or exotic (E)	Morphological traits	Adaptive and production characters assessed	Molecular characterisation
Corymbia spp. (spotted gum complex) **a**	N	Yes	Yes	Yes
C. torelliana x C. citriodora	N	Yes	Yes	Yes
Eucalyptus grandis	N	Yes	Yes	Yes
E. globulus	N	Yes	Yes	Yes
E. camaldulensis	N	Yes	Yes	Yes
E. nitens	N	Yes	Yes	Yes
E. pellita	N	Yes	Yes	Yes
E. urophylla	E	Yes	Yes	Yes
E. grandis x E. urophylla	N x E	Yes	Yes	Yes
Melaleuca alternifolia	N	Yes	Yes	Yes
Pinus caribaea	E	Yes	Yes	Yes
P. elliottii	E	Yes	Yes	Yes
P. pinaster	E	Yes	Yes	
P. radiata	E	Yes	Yes	Yes

a Spotted gum complex includes *C. maculata*, *C. henryi*, *C. citriodora* subsp. *citriodora* and *C. citriodora* subsp. *variegata.*

Sources: ATSC; ABARES

Information on forest genetic resources as part of a national forest survey

Australian states and territories collect information on native forest types. The federal government then gathers this information from the states and territories and reports it as part of a five-yearly Australia's State of the Forests Report (MPIGA 2008a).

Genetic conservation strategies/programs

Australia's Biodiversity Conservation Strategy is a guiding framework for conserving the country's biodiversity, with the vision that Australia's biodiversity is healthy and resilient to threats, and valued both in its own right and for its essential contribution to Australia's existence (NRMMC 2010). The strategy is also a guiding policy framework for the diverse mix of Australian, state, territory and local government and private sector approaches to biodiversity conservation. Australia's Biodiversity Conservation Strategy includes 10 targets to be achieved by 2015 (Box 2). Australia aims to establish by 2015 a national long-term biodiversity monitoring and reporting system (NRMMC 2010).

Box 2 Targets of Australia's Biodiversity Conservation Strategy by 2015

1. Achieve a 25 per cent increase in the number of Australians and public and private organisations who participate in biodiversity conservation activities.
2. Achieve a 25 per cent increase in employment and participation of Indigenous Australians in biodiversity conservation.
3. Achieve a doubling of the value of complementary markets for ecosystem services.
4. Achieve a national increase of 600 000 km^2 of native habitat managed primarily for biodiversity conservation across terrestrial, aquatic and marine environments.
5. 1000 km^2 of fragmented landscapes and aquatic systems are being restored to improve ecological connectivity.
6. Four collaborative continental-scale linkages are established and managed to improve ecological connectivity.
7. Reduce by at least 10 per cent the impacts of invasive species on threatened species and ecological communities in terrestrial, aquatic and marine environments.
8. Nationally agreed science and knowledge priorities for biodiversity conservation are guiding research activities.
9. All jurisdictions will review relevant legislation, policies and programs to maximise alignment with Australia's Biodiversity Conservation Strategy.
10. Establish a national long-term biodiversity monitoring and reporting system.

Australia's Biodiversity Conservation Strategy functions as a policy umbrella over other more specific national frameworks, including:

- National Framework for the Management and Monitoring of Australia's Native Vegetation (NRMMC 1999)
- Australian Weeds Strategy (NRMMC 2007a)
- Australian Pest Animal Strategy (NRMMC 2007b)
- Australia's Strategy for the National Reserve System 2009–2030 (NRMMC 2009).

A range of programs and activities are conducted in Australia for in situ and ex situ conservation of forest genetic resources (described in the following chapters).

3 In situ genetic conservation

In situ conservation of forest trees and woody plant species means maintaining a population in its natural habitat, within its natural ecological communities, while retaining its natural genetic variation and capacity for evolutionary processes. In practice, in situ conservation of forest genetic resources involves varying degrees of human intervention, ranging from conservation to intensive management of forests for various uses.

Australia's forest types are conserved in situ in various tenures (Figure 1):

- nature conservation reserves (22 million hectares)—Crown lands formally reserved for environmental, conservation and recreational purposes
- multiple-use forest (9 million hectares)—Crown lands managed for a range of uses, including wood production
- forest on 'other Crown lands' (11 million hectares)—Crown lands used for a variety of purposes
- private forest (38 million hectares)—forests on privately owned land
- leasehold forest (65 million hectares)—forest on privately managed leased Crown land generally used for grazing
- unresolved tenure (1.5 million hectares)—forests for which ownership status has not been determined.

In addition to conservation in the 147 million hectares of native forests, forest and other woody plant species are conserved on other lands. For example, Australia's rangelands, which cover about three-quarters of Australia or about 600 million hectares (Lesslie et al. 2006), carry a large range of forest tree and woody plant species. Australian farmers play an important role in the in situ conservation and management of native forest and other woody plant species, as much of Australia's native forest and woody plant species exist on private land including agricultural or pastoral land.

Australia's forest reserves

Australia's native forest reserves hold a rich range of in situ forest genetic resources. A large proportion of native forests consisting of a wide range of forest species (including *Acacia*, *Callitris*, *Casuarina*, *Eucalyptus* and *Melaleuca* species) are protected in conservation reserves. Seed of many endemic species including *Eucalyptus*, *Acacia* and *Melaleuca* is collected from in situ reserves in the wild (Table 16).

Australia is committed through its National Forest Policy Statement to maintain an extensive and permanent native forest estate, and to manage the native forest estate in an ecologically sustainable manner to conserve the values forests can provide for current and future generations, including biological diversity, heritage, Indigenous and other cultural values.

The aim of the forest reservation system is to place in nature conservation reserves a minimum of 15 per cent of the pre-1750 distribution of each forest type, 60 per cent of the existing distribution of each forest type if vulnerable, 60 per cent of existing old-growth forest, 90 per

cent or more of high-quality wilderness forests, and all remaining occurrences of rare and endangered forest ecosystems (including rare old-growth forests).

In the five years to 2008, national representation of forests in formal public nature conservation reserves increased by 1.1 million hectares to 23 million hectares, which is 16 per cent of Australia's forests (MPIGA 2008a). The level of conservation of forest genetic resources is linked to the level of conservation of forest biodiversity in Australia's forests in reserves.

Regional forest agreement areas

For native forest wood production areas, the Australian and some state governments have negotiated regional forest agreements (RFAs) (Map 2). RFAs are 20-year plans for the conservation and sustainable management of Australia's native forests established under the National Forest Policy Statement. The RFAs provide for a comprehensive, adequate and representative (CAR) reserve system for forest biodiversity conservation. Within the RFA areas, the reserve system comprises:

- formal CAR reserves on publicly managed land-tenures, which can only be revoked with parliamentary approval
- informal CAR reserves on public land, which are protected through administrative instruments by public authorities
- private CAR reserves, which are areas of private land managed in the long term for the protection of CAR values under secure arrangements, including proclamation under legislation, contractual agreements such as conservation covenants, and independently certified forest management systems.

In some areas, some forest values may be managed as prescribed in a code of practice or management plan. These areas are additional to the areas discussed in this section.

IUCN protected areas

In 1982, the International Union for Conservation of Nature (IUCN) recommended that at least 10 per cent of each biome should be in protected across categories I–VI (MPIGA 2008a):

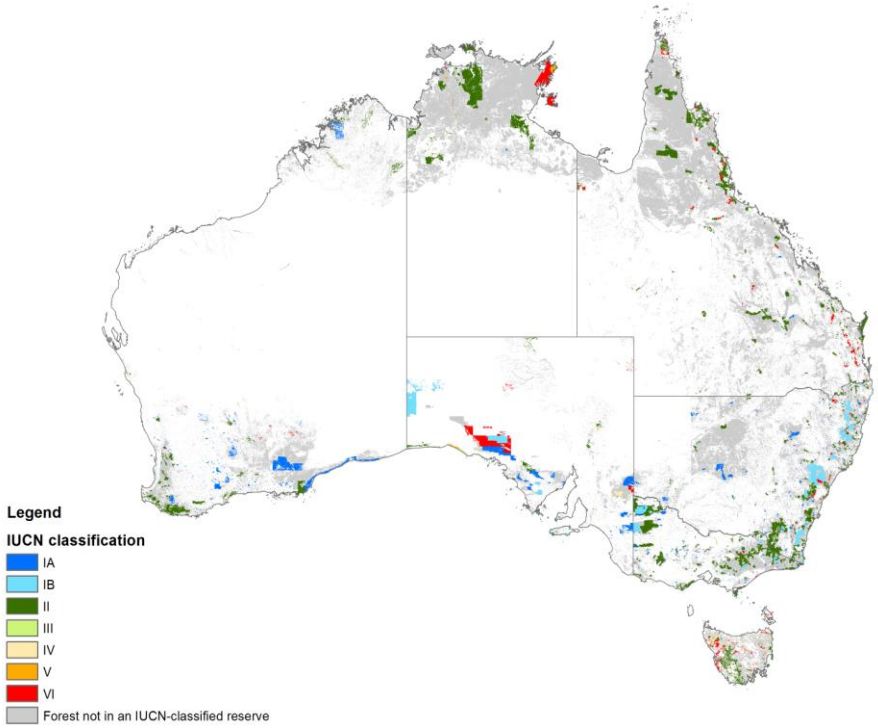
- Ia Strict nature reserve: protected area managed mainly for science
- Ib Wilderness area: protected area managed mainly for wilderness protection
- II National park: protected area managed mainly for ecosystem conservation and recreation
- III Natural monument: protected area managed for the conservation 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.

In 2008, 23 million hectares of Australia's forests were in dedicated formal conservation reserves in the IUCN categories I–VI (Map 4). The proportion of Australia's forests in IUCN recognised nature conservation reserves increased from 11 per cent in 1998 to 15 per cent in 2008 (ABARES 2012a).

Of Australia's 18 broad national forest types, 13 have reservation levels that exceed the 10 per cent threshold recommended by IUCN; only three forest types (acacia, callitris and eucalypt medium-height woodland) are represented below this level. In the RFA areas, the IUCN target has been exceeded significantly for most forest types.

The distribution of forest in IUCN categories I–VI is shown in Map 4. The IUCN stresses that protected areas should not be seen as isolated entities, but part of broader conservation landscapes, including both protected area systems and wider conservation approaches implemented across the landscape (Dudley 2008).

Map 4 Forest cover by IUCN reserve category classification



Note: Forest areas mapped include woodlands. The total area of forest is derived from Australia's State of the Forests Report (MPIGA 2008a).

Sources: MPIGA 2008a

World Heritage

Australia's 17 recognised World Heritage areas cover 7.3 million hectares, of which about 4.6 million hectares is forested (MPIGA 2008a, Table 16, Figure 18, pp. 26–27). As a signatory to the World Heritage Convention, Australia is obliged to identify, protect and conserve places on the World Heritage List. Examples of forested World Heritage areas in Australia include Purnululu National Park and Shark Bay in Western Australia, Kakadu National Park in the Northern Territory, the Wet Tropics and Fraser Island in Queensland, Gondwana Rainforests in New South Wales, and the Tasmanian Wilderness.

Programs for in situ conservation of forest genetic resources

The National Reserve System is vital to protecting Australia's terrestrial biodiversity. It is the nation's commitment to future generations that land is vital to the survival of our unique native species and ecosystems, and that associated cultural values will be protected in perpetuity (NRMMC 2009).

The National Reserve System Strategy 2009–2030 (NRMMC 2009) is an important step towards long-term protection of Australia's biodiversity, and the next 20 years will be a critical period for biodiversity conservation in Australia. The strategy will continue to guide the work on the National Reserve System. Each state and territory will prepare a five-year plan to implement the strategy, which will support the strategy and reflect any regional differences in conserving biodiversity across the landscape.

The National Reserve System has already protected large areas of native forests in Australia (MPIGA 2008a). The proportion of native forests in formal public nature conservation reserves has increased significantly, from 11 per cent (17.6 million hectares) reported in 1998 to 16 per cent (23 million hectares) in 2008 (MPIGA 2008a). The parks, reserves and protected areas in the National Reserve System are important means of conserving biodiversity, including in situ conservation of forest genetic resources.

The Australian Government is investing $180 million over five years to accelerate development of the National Reserve System. Under the Caring for our Country initiative, partners can apply for help from the Australian Government to buy land for new reserves. The government can provide up to two-thirds of the cost of purchase of an approved property, which is then owned and managed by the partner as part of the National Reserve System. The landowner signs a perpetual conservation covenant in which they agree to protect a part of their property that will remain protected even if the land is sold. The landowner can continue to earn a living from the rest of their land, and can receive help from the covenanting organisation to manage their protected area. The initiative particularly focuses on the remaining bioregions with very low levels of protection, including the arid lands of Central Australia and the Mitchell grass country of north-west Queensland. The Australian Government is also targeting areas of global conservation significance, including the world's largest relatively intact subtropical savannah, which stretches across Australia's north from Cape York to the Kimberley.

There are significant ongoing programs and activities for conserving native forest and other woody plant species in Australia. For forests covered by RFAs, state governments have developed criteria that include broad benchmarks for the in situ conservation of forest biodiversity (MPIGA 2008a, Indicator 1.1c, 'Area of forest in protected area categories'). In the RFA regions, significant additional areas of forest were included in nature conservation reserves and in reserves in multiple-use public forests to meet those criteria. There were relatively high reservations of rainforests (35 per cent of the pre-1750 distribution), mangroves (32 per cent) eucalypt tall open forests (29 per cent) and eucalypt low open forests (29 per cent) (MPIGA 2008a).

Criterion 3 of the Australian Forestry Standard® released in 2007 sets requirements to protect and maintain the elements of the biological diversity of forests, including:

- ecosystem diversity, by maintaining the range of ecosystems across the landscape
- species diversity, by maintaining forest-dependent species

- genetic diversity, by maintaining representative species populations across their range.

Most states and territories have guidelines and management plans for conserving the genetic diversity of commercially significant native forest species. The aim in regenerating native production forests is to maintain local gene pools and the approximate composition and spatial distribution of the species (including non-wood product and understorey species) that were present before harvesting. Codes of forest practice, such as those in Victoria and Tasmania, require native forests to be sown with species that approximate the natural mix of canopy trees at a harvested site, while allowing for those species that will regenerate naturally. Seed to be sown is to be collected either from the stand to be harvested or from the nearest similar ecological zone. Management plans also include specifications for selecting seed trees of good form and health. In Western Australia, guidelines specify the seed sources to be used for rehabilitating areas cleared for bauxite mining in jarrah (*E. marginata*) forest (MPIGA 2008a).

The area of tree plantings of native species has rapidly expanded in Australia over the past decade. Gene flow from these plantations into surrounding native forests (a phenomenon called 'introgression', where infiltration of genes occurs from one species into another through hybridisation) could change the genetic make-up of local populations of native trees (MPIGA 2008a). Breeding strategies and genetic resource management plans aim to avoid gene flow that could degrade the genetic diversity of native forests. Strategies include carefully selecting species and provenances, manipulating flowering times, flower abundance and silvicultural practices such as isolation distances, using buffer zones of non-interbreeding species, and closer planting to reduce the area of tree crowns able to produce flowers.

Under the EPBC Act, many threatened forest and woody plant species are conserved in situ as part of recovery plans (Table 10). Phytophthora dieback (*Phytophthora cinnamomi*) has been listed as a key threatening process because of the threat it poses to Australia's biodiversity, including forest and woody plant species. A National Threat Abatement Plan was prepared and released in 2001. The broad goals of the plan were to protect endangered or vulnerable native species and communities from *P. cinnamomi*, and prevent further species and communities becoming endangered by reducing the chance of their exposure to the pathogen.

The Australian Government, states and territories has a range of programs and legislation which, either directly or indirectly, inhibit land clearing (SEWPaC 2010). The Australian, state and territory governments are committed to reversing the long-term decline in the quality and extent of Australia's native vegetation. This goal is to be achieved, in a unified and consistent manner, through the National Framework for the Management and Monitoring of Australia's Native Vegetation, which is an agreed framework of best practice management and monitoring measures. Land clearing has also recently been listed as a key threatening process under the EPBC Act.

Table 10 Target forest species included within in situ conservation programs/units

Species	Purpose for establishing conservation unit	No. of populations or stands conserved	Total area (ha)
Wollemia nobilis	Only known locality of relict stand	1	<10 **a**
Eucalyptus ovata (black gum) and *Callitris oblonga* (South Esk pine)	Listed as a vulnerable ecological community under the EPBC Act, to protect a significant stand of black gum—South Esk pine forest restricted to the Apsley River on Tasmania's east coast		6.8
E. morrisbyi (Morrisby's gum)	Protect species from fire, grazing and insect damage. Species is confined to a small area at Calverts Hill, and in two other small remnant stands	About 2000 individuals	12.5

a See Table 7. The area of occupancy of *W. nobilis* is less than 10 km^2 (IUCN 2012), but other reports suggest an actual area of less than 10 hectares.

Note: Table 10 shows examples rather than a comprehensive listing of native species conserved in situ. Australia has prepared recovery plans for threatened forest and woody plant species (Table 7).

Sources: ATSC; Carter 2006; Australian Government 2012b

Main constraints to improving in situ genetic conservation programs

The Productivity Commission has identified that the private sector has an important role to play in contributing to in situ biodiversity conservation, but that its contribution is constrained by a number of institutional arrangements, particularly aspects of land tenure, native wildlife legislation, the competitive neutrality framework and taxation arrangements. These factors can increase the relative costs and risks of private conservation activities compared with those of other private land uses. Some of these constraints may be inhibiting conservation of Australia's forests (Byron et al. 2001; Harris-Adams et al. 2012).

Priorities for future in situ conservation

Events such as land-use change, biosecurity incursions and extensive wildfires are recognised as threats to maintaining genetic diversity in native forests as documented in EPBC Act assessments (Table 7). Conservation of native forest genetic resources in ex situ repositories and seed orchards helps safeguard against loss of genetic diversity from these events.

Examples of forest species conserved and used on-farm are given in Chapter 4.

4 Ex situ genetic conservation

Ex situ conservation of forest genetic resources includes conservation as seed, pollen or tissue, and conservation in live collections such arboreta, clone banks and specially established ex situ conservation stands and seed orchards.

Breeding and selection programs for improving commercial wood production have other important benefits in conserving genetic resources ex situ.

Target forest species included in ex situ conservation programs

The ATSC maintains a national seed collection of more than 900 species in around 75 mainly Australian genera including over 240 *Acacia*, 19 *Allocasuarina*, 11 *Casuarina*, 25 *Corymbia*, 330 *Eucalyptus* and 38 *Melaleuca* species (MPIGA 2008a). The ATSC also has a number of provenance progeny tests (many in partnership with state governments and private growers) and seed orchards that serve as ex situ repositories of genetic material for species, including *Acacia crassicarpa* (thick-podded salwood), *A. mangium* (brown salwood), *Corymbia maculata* (spotted gum), *Eucalyptus camaldulensis* (river red gum), *E. cladocalyx* (sugar gum), *E. dunnii* (Dunn's white gum), *E. occidentalis* (swamp yate), *E. pellita* (large-fruited red mahogany), *E. saligna* (Sydney blue gum), *E. sideroxylon* and *E. tricarpa* (red ironbark) (Tables 11, 13, 15 and 16).

Table 10 was prepared based on information collected by ABARES from state and territory collaborators, the ATSC and the Southern Tree Breeding Association (STBA).

In addition to the ATSC national collection, various tree-growing groups and forest and research agencies maintain their own forest seed collections. Several of these organisations, including a number of botanical gardens, are listed in Table 17a and 17b. Table 17a lists organisations with tree breeding and genetic conservation and/or improvement programs that are in place for about 30 Australian native species, most of which are commercially important.

STBA has established ex situ plantations and grafted trees of *E. globulus* in the National Genetic Resource Centre for plantation forestry at Mount Gambier, South Australia. Control-pollinated *E. globulus* seed is collected and stored in refrigerators, and diversity is maintained in numerous field trials spread across temperate Australia.

Currency Creek Arboretum is a largely self-funded specialist eucalypt arboretum that has the main purpose of research into eucalypts (genera *Angophora*, *Corymbia* and *Eucalyptus*). This arboretum, located in South Australia, has the largest ex situ collection of living eucalypt species in the world. Over 900 species, subspecies and varieties—over 8000 individual plants—have been established on this single site since 1993 (6 *Angophora* representatives, 91 *Corymbia* and 830 *Eucalyptus*). Over 660 are mature; that is, they have flowered.

Table 11 Ex situ conservation

Species	Native (N) or exotic (E)	Field plantings: Collections, provenance or progeny tests, arboreta or conservation stands		Clone banks		Germplasm bank: In vitro (including cryopreservation)		Germplasm bank: Seed banks	
		No. stands	No. accessions	No. banks	No. clones	No. banks	No. accessions	No. banks	No. accessions
Acacia auriculiformis	N							1	780
A. cunninghamii	N	around 120 – provenance + progeny trials	876 first-gen selects + 400 families in provenance trials	Several clone banks & clonal seed orchards	around 800	0	0	1	around 50
Eucalyptus argophloia	N	2	42					1	22
E. barberi	N	1	unknown					1	unknown
E. benthamii	N	5	60	0	0	0	0	1	60
E. burdettiana	N							1	4
E. conglomerata	N							1	1
E. crenulata	N							2	2+
E. gunnii	N	1	unknown					2	2+
E. morrisbyi	N	1	unknown					2	4+
E. raveretiana	N							1	12
E. remota	N							1	1
Khaya senegalensis	E	8 provenance trials	> 80 provenances	3 clonal seed orchards	150				
Pinus caribaea var. *hondurensis*	E	Many stands across around 400 ha	25 provenances	Many clone banks + clonal seed orchards					
P. elliottii	E	3 stands	216 bulked	1 clonal seed orchards	around 70				
P. radiata	E	53	621	1	916	1	263	1	772
Santalum spicatum	N	Several commercial trials	1	15					

Note: This table does not include all species conserved ex situ. Table 12 contains a list of species for which seed is kept in a seed bank and Table 15 lists species that are grown in a seed orchard.

Sources: ABARES; ATSC; STBA. Information has been sourced from replies to data requests sent to plantation owners and managers and the STBA, a series of papers with the theme 'Achievements in forest genetic improvement in Australia and New Zealand' in *Australian Forestry* vols 70 (2007) and 71 (2008), presentations at the First and Second Australasian Forest Genetics Conferences and pre and post Conference tours, Hobart 2007 and Perth 2009, presentations and discussions at Research Working Group 1 (Forest Genetics) meetings Hobart 2007 and Fremantle 2009, and ATSC records.

Forests NSW manages its 45-year-old hardwood tree improvement and breeding program from the Grafton Primary Industries Institute's Production Nurseries, Tree and Seed Resources Unit. Clonal seed orchards include lemon-scented gum (*Corymbia citriodora*), *Eucalyptus dunnii*, *E. nitens* and blackbutt (*E. pilularis*).

Queensland has the widest genetic base of *E. argophloia* in seed stands and seed orchards managed by the Queensland Department of Agriculture, Fisheries and Forestry.

South Australia is conserving ex situ in field trials the following native species of commercial importance*: Eucalyptus camaldulensis*, *E. cladocalyx* and *E. globulus*. In South Australia native species of potential commercial importance are also conserved in field trials, namely *Acacia decurrens*, *A. mearnsii*, *A. retinodes*, *A. saligna*, *Eucalyptus aromaphloia*, *E. cneorifolia*, *E. gomphocephala*, *E. horistes*, *E. loxophleba*, *E. occidentalis*, *E. oleosa*, *E. ovata*, *E. petiolaris*, *E. polybractea*, *E. porosa*, *E. rudis* and *E. viminalis*. An extensive network of trials has been established throughout South Australia by the state government and by universities on their own land and in collaboration with private landowners (Bulman & Fairlamb 1998; Boardman et al. 2002).

Tasmania has established the Tasmanian Seed Conservation Centre at the Royal Tasmanian Botanical Gardens, and has entered into an agreement with the Millennium Seed Bank Partnership for seed storage (Harris et al. 2009). Tasmanian endangered eucalypt species *Eucalyptus gunnii* subsp. *divaricata*, *E. barberi*, *E. morrisbyi*, *E. perriniana*, *E. vernicosa* and *E. risdonii* are being grown in conservation seed orchards as a part of this partnership. Forestry Tasmania also have a publicly accesible seed store that specialises in Tasmanian native species and a range of commercial forestry species. This store is also an important ex situ gene bank facility.

The Western Australian Department of Environment and Conservation runs provenance trials of karri (*E. diversicolor*) and associated wood species used for site restocking after wood harvesting. The Forest Products Commission (FPC) of Western Australia and the WA Department of Environment and Conservation have established an extensive network of trials and manage breeding programs for several commercially important and prospective forest species. FPC also has a publicly accesible seed distribution facility, FPC Seed Technologies. This collection is also an important ex situ seed bank.

The National Arboretum Canberra holds a range of Australian native and exotic tree species, including various rare and endangered tree species. The list of species is available on their website.

There are numerous private collections of seeds of forest and woody plant species in Australia, including in the nursery industry. Some collections of forest plantation genetic resources are held by forest industry members and some by industry cooperatives and research organisations. Private collections of forest genetic resources focus on species that are widely cultivated, including species of *Eucalyptus*, *Corymbia* and *Acacia*.

Australia contributes forest genetic resources to international repositories for long-term conservation as a partner in the Millennium Seed Bank Partnership run by the United Kingdom's Royal Botanic Gardens at Kew, the largest ex situ conservation project in the world. Through the Millennium Seed Bank Partnership, the large overseas breeding base populations for some commercial species, Australian forest genetic resources species are also conserved ex situ in various ways overseas.

Main constraints to improving ex situ conservation

Ex situ conservation of long-lived tree species can be achieved by long-term storage of seed (where possible) and by establishment of *in vivo* gene banks. For some species, particularly *Acacia* species that have very long-lived seeds, storage of seed is an effective measure. The main constraint to obtaining comprehensive collections of seed of the endangered *Acacia* species is the remote locations of many species and the cost involved in obtaining collections. For seeds of *Eucalyptus* species, which have a moderate to long (10–20 year) life expectancy in storage, planting in conservation stands is preferable. The land resources and cost of maintenance of ex situ stands of forest genetic resources are the main constraints. Many of the species with these characteristics are from remote areas of the tropics, and establishing and maintaining conservation stands in tropical regions is particularly challenging because of the remoteness and risks of strong winds, fire and pest damage (Gunn 2001; Dawson et al. 2012). For other species with recalcitrant or short-lived seeds, conservation stands are the best solution.

Limited funding for research, sample collection and characterisation of forests and woody vegetation is an ongoing constraint to improving ex situ conservation in Australia.

Other relevant information on ex situ conservation

There is an important role for integrating various ex situ measures into plant conservation programs due to threatening processes on in situ wild populations (Harris et al. 2009; Dunlop et al. 2012). Several of the best seed-source provenances of some eucalypts are no longer available in situ because the original populations no longer exist. Part of the genetic material for blue gum (*E. globulus*) and shining gum (*E. nitens*) is held in existing Australian plantations and special-purpose field trials (Potts et al. 2011).

An example of Australian ex situ forest genetic resource conservation in Western Australia is provided in Box 3 and an example for Tasmania in Box 4.

The Millennium Seed Bank Partnership is the world's largest ex situ plant conservation project. It focuses on global plant life threatened with extinction and on plants of most use for the future. Working with a network of partners across 50 countries, the Millennium Seed Bank Partnership successfully banked seeds of 10 per cent (about 24 000 species) of the world's wild plant species by October 2009, and is aiming to conserve 25 per cent by 2020, targeting plants and regions most at risk from climate change and the increasing impact of human activities.

All six Australian states and the Northern Territory make a major contribution to the Millennium Seed Bank Partnership. The overall priority is to dramatically enhance the ex situ conservation of Australian flora by banking seeds of plant species considered rare or threatened. Australian partners have mobilised a national network called Australian Seed Conservation and Research (AuSCaR), which ensures harmonisation of activities across the project partners. The AuSCaR network ensures teams in each region do not duplicate collections if plant species are found in more than one state. It also ensures collaboration between research groups from each state. AuSCaR has now received support from federal agencies and is expected to evolve into a major contributor to ex situ plant conservation in Australia.

Box 3 Genetic resource conservation of *Eucalyptus marginata* (jarrah) in Western Australia

The ecologically sustainable rehabilitation and regeneration of timber-harvesting areas requires plants that are adapted to local site conditions. In Western Australia, the Department of Environment and Conservation provides the Forest Products Commission with guidelines on seed collection zones for rehabilitating cleared areas and for the species mix to be used in regenerating native forests. Provenance trials are being conducted for *Eucalyptus marginata* (jarrah) and associated understorey species to identify seed collection zones for genetic material that suit the rehabilitation requirements of particular sites. Under the silvicultural guidelines, seedlings for planting should be grown from seed sourced from a seed zone appropriate to genetic management of the species.

Genetically based resistance to the fungal pathogen *Phytophthora cinnamomi* (also called dieback) has been demonstrated in jarrah. Under a long-term selection and screening program, inoculation trials have been carried out and field validation trials have been established to prove the selections. Individuals showing the highest resistance have been propagated and multiplied by tissue culture. The resulting clonal lines have been used in further validation trials, in field plantings, and to establish seed orchards for producing dieback-resistant jarrah for future operational forest rehabilitation planting.

The WA Government's Sustainable Forest Management Guideline No. 1 ('Silvicultural Practice in the Jarrah Forest') describes measures that must be taken to retain jarrah trees that show resistance to *P. cinnamomi*. Such trees are an important genetic resource and a potential source of seed (Department of Conservation and Land Management 2004).

Source: MPIGA 2008a (case study 15, p. 52)

Box 4 *Eucalyptus gunnii* subspecies *divaricata* seed orchard and conservation plantings in Tasmania

Eucalyptus gunnii subsp. *divaricata* (Miena cider gum) occurs at Miena on the Central Plateau in Tasmania, where it intergrades over a clinal gradient with *E. gunnii* subsp. *gunnii* and *E. archeri*. Core populations of this subspecies are highly frost-resistant and the juvenile foliage is of interest to the floriculture industry. Historically, the sap of the subspecies was used by Indigenous Australians and early European settlers and is reported to have an intoxicating effect when fermented. In the past decade, high mortality and poor seed crops coupled with low seedling recruitment have threatened the long-term survival of this taxon in the wild. It is listed as endangered under both Tasmania's threatened species legislation and Commonwealth legislation.

Several institutions have been working to conserve the subspecies. Forestry Tasmania established a conservation planting in 2000 and collected seeds from remaining trees at the Miena population with open-pollinated seed capsules. The University of Tasmania, Forestry Tasmania and the Tasmanian Department of Primary Industries, Parks, Water and Environment jointly established another conservation planting in 2002 using seeds collected by the University of Tasmania from 36 native stand trees in the core/type population in the late 1980s before the death of mature trees. The planting comprises seven complete replicates and four incomplete blocks of single-tree plots.

Source: MPIGA 2008b (case study 18)

5 Use and sustainable management of forest genetic resources

Australia's forest genetic resources play an important role in maintaining and improving plantation forest production and productivity in Australia and globally. Breeding strategies require a base population with broad genetic diversity. Australia's diverse range of native forest gene pools are used in breeding and selection for desirable traits, such as drought and disease resistance.

Native forest genetic resources are vulnerable to a range of threatening processes including vegetation clearing, habitat fragmentation, inappropriate fire frequency and intensity, competition with exotic plants and animals, and the spread of plant pests, diseases and weeds (Harris et al. 2009; Dunlop et al. 2012).

Given the importance of native forest genetic resources for breeding and selection programs, a substantial proportion of the genetic base of native forest plantation species has been brought into seed collections, seed orchards and breeding programs.

Quantity of seed transferred internationally

The Australian Tree Seed Centre (ATSC), based in Canberra, was established in 1962 with a number of functions, including international distribution of seeds of valuable Australian tree species for use in developing countries. The ATSC seed bank holds and supplies high-quality, representative, ex situ samples of Australia's tree and shrub genetic diversity. Initially, the ATSC collected and stored seed mostly on a population or provenance basis, but the emphasis has shifted to collecting seed from individual parent trees. These genetically distinct acquisitions are important for ex situ genetic resource conservation.

The ATSC and other organisations move considerable quantities of acacia and eucalypt seed internationally (Table 12). The numbers presented in Table 12 understate the actual quantities for some species, because some private companies are guarded about reporting species and quantities of germplasm exported. *Acacia mangium* and *Eucalyptus dunnii* are the most exported, by quantity (Table 12) (see also Griffin et al. (2011) and Koskela et al. (2010) for more information on the international movement of Australian tree species).

Table 12 Seed and vegetative propagules transferred internationally per year (average of past five years)

Species	Native (N) or exotic (E)	Quantity of seed (kg) Import	Export	Purpose
Acacia mangium	N/E	43	787	Pulp/timber plantations
A. crassicarpa	N/E		3	Pulp/timber plantations
A. auriculiformis	N/E		14	Pulp/timber plantations
A. cincinnata	N		3	Pulp/timber plantations
Acacia other species	N		4	Various uses
Casuarina equisetifolia	N/E		1	Environmental restoration, energy, pulp, poles
C. equisetifolia subsp. *equisetifolia*	E	1	<1	Environmental restoration, energy, pulp, poles
C.asuarina other species	N/E		<1	Environmental restoration, energy, pulp, poles
Corymbia citriodora subsp. *citriodora*	N		1	Solid wood, pulp
C. maculata	N		<1	Solid wood, environmental restoration
Corymbia other species	N		<1	Various
Chukrasia various species	E		1	Solid wood plantations
Eucalyptus benthamii	N		4	Energy, pulp plantations
E. camaldulensis var. *camaldulensis*	N		1	Energy, pulp, solid wood plantations
E. camaldulensis var. *obtusa*	N	<1	8	Energy, pulp, solid wood plantations
E. camaldulensis subsp. *simulata*	N		39	Energy, pulp, solid wood plantations
E. deglupta	E	<1	<1	Pulp, solid wood plantations
E. dunnii	N		640	Energy, pulp, solid wood plantations, research
E. globulus subsp. *globulus*	N		1	Pulp, solid wood plantations
E. grandis	N		42	Solid wood plantations, research
E. nitens	N		<1	Pulp, solid wood plantations
E. pellita	N/E	4	12	Pulp, solid wood plantations
E. radiata	N		1	Essential oil
E. tereticornis subsp. *tereticornis*	N		3	Pulp, energy, solid wood plantations
E. urophylla	E		3	Pulp, solid wood plantations
Eucalyptus other species	N/E		8	Various
Grevillea robusta	N	9	1	Solid wood plantations
Khaya senegalensis	E	500	<10	Solid wood plantations
Pinus radiata	E		<1	Solid wood plantations
Pinus other species	E	<1	1	Solid wood plantations
Pterocarpus macrocarpus	E	7		Solid wood plantations
Pterocarpus other species	E	1		Solid wood plantations
Santalum album	E	2	<1	Solid wood plantations
Swietenia macrophylla	E	1		Solid wood plantations
Tectona grandis **a**	E	38	18	Solid wood plantations

a Estimated 400 000 tissue culture plantlets were imported.

Sources: ATSC, states and private industry. Some private industry respondents did not provide commercial-in-confidence information. The data presented in this table are indicative and represent most of the germplasm exchange.

Species subject to tree improvement programs

The main species subject to tree improvement programs in Australia are eucalypt and pine species. Tree species currently subject to improvement in Australia include *Corymbia citriodora* subsp. *variegata*, *C. henryi*, *C. maculata*, *Eucalyptus camaldulensis*, *E. cladocalyx*, *E. cloeziana*, *E. dunnii*, *E. globulus*, *E. grandis*, *E. nitens*, *E. occidentalis*, *E. pellita*, *E. pilularis*, *E. saligna*, *E. sideroxylon/E. tricarpa*, *Pinus brutia*, *P. pinaster* and *P. radiata* (Table 13). Table 13 lists the

species in various tree improvement programs in Australia and the main improvement objectives.

Table 13 Forest tree improvement programs

Species	Native (N) or exotic (E)	Improvement program objective						Agency
		Timber	Pulp-wood	Energy	MP	NWFP	Other	
Acacia crassicarpa	N/E	Yes	Yes					CSIRO/Queensland DAFF
A. mangium	N/E	Yes	Yes					CSIRO/Queensland DAFF
Araucaria cunninghamii	N	Yes	Yes					Forestry Plantations Queensland Pty Ltd
Corymbia citriodora subsp. *citriodora*	N	Yes	Yes	Yes			ER	Queensland DAFF
C. citriodora subsp. *variegata*	N	Yes	Yes	Yes			ER	Queensland DAFF, Forests NSW
C. henryi	N	Yes		Yes			ER	Queensland DAFF, Forests NSW
Corymbia hybrid	N	Yes	Yes	Yes				Queensland DAFF
C. maculata	N	Yes					ER	Australian Low Rainfall Tree Improvement Group
C. torelliana	N	Yes	Yes	Yes				Queensland DAFF
Eucalyptus argophloia	N	Yes	Yes	Yes			ER	Queensland DAFF, CSIRO
E. benthamii	N		Yes	Yes				CSIRO
E. biturbinata	N	Yes	Yes	Yes				Queensland DAFF
E. camaldulensis	N	Yes	Yes				ER	Australian Low Rainfall Tree Improvement Group, Queensland DAFF
E. cladocalyx	N	Yes		Yes			ER	Australian Low Rainfall Tree Improvement Group
E. cloeziana	N	Yes						Queensland DAFF
E. dunnii	N	Yes	Yes					CSIRO/Forests NSW, seedEnergy Pty Ltd, Queensland DAFF
E. globulus	N	Yes	Yes		Yes			Southern Tree Breeding Association, Forest Products Commission Western Australia, Australian Bluegum Plantations, HVP Plantations
E. grandis	N		Yes					Queensland DAFF
Eucalyptus hybrids	N	Yes	Yes					Private industry, CSIRO, Forests NSW
E. longirostrata	N	Yes	Yes	Yes				Queensland DAFF, CSIRO
E. moluccana	N	Yes					ER	Queensland DAFF
E. nitens	N	Yes	Yes		Yes			Private industry, Forestry Tasmania
E. occidentalis	N	Yes					ER	Australian Low Rainfall Tree Improvement Group
Eucalyptus oil mallee species	N			Yes		Yes		Oil Mallee Association, Cooperative Research Centre for Future Farm Industries
E. pellita	N	Yes	Yes					CSIRO/Queensland DAFF
E. pilularis	N	Yes						Forests NSW, Queensland DAFF
E. punctata	N	Yes		Yes				CSIRO, Queensland DAFF

E. saligna	N	Yes					CSIRO
E. sideroxylon/E. tricarpa	N	Yes				ER	Australian Low Rainfall Tree Improvement Group
E. tereticornis	N	Yes				ER	Queensland DAFF
Grevillea robusta	N	Yes					CSIRO/Queensland DAFF
Khaya senegalensis	E	Yes					Northern Territory Government/ Queensland DAFF, African Mahogany Genetics Joint Venture
Melaleuca alternifolia	N				Yes		Australian Tea Tree Association
Pinus brutia	E	Yes				ER	Australian Low Rainfall Tree Improvement Group, Forest Products Commission Western Australia
P. caribaea	E	Yes	Yes				Forestry Plantations Queensland Pty Ltd
P. elliottii	E	Yes	Yes				Forestry Plantations Queensland Pty Ltd
P. pinaster	E	Yes	Yes				Forest Products Commission Western Australia
P. radiata	E	Yes	Yes	Yes			Southern Tree Breeding Association, Forests NSW, Forests Products Commission Western Australia
Tectona grandis	E	Yes					Elders Forestry Ltd., Subtropical Tree Improvement Alliance

Note: MP: multipurpose tree improvement program, NWFP: Non-wood forest product, ER: Environmental remediation. Other improvement program objectives include breeding for resistance to pests and diseases.

Sources: ABARES; ATSC; STBA; Montoya (2010). Information has been sourced from replies to data requests sent to plantation owners and managers and the STBA, a series of papers with the theme 'Achievements in forest genetic improvement in Australia and New Zealand' in *Australian Forestry* vols 70 (2007) and 71 (2008), presentations at the First and Second Australasian Forest Genetics Conferences and pre and post Conference tours, Hobart 2007 and Perth 2009, presentations and discussions at Research Working Group 1 (Forest Genetics) meetings Hobart 2007 and Fremantle 2009, and ATSC records.

Data for species subject to tree improvement programs

Information on tree species improvement trials is reported in Table 14. The genetic resources of many species used in tree improvement programs are conserved in seed orchards (Table 15) as described in Chapter 4.

Table 14 Tree improvement trials

Species	Native (N) or exotic (E)	Plus trees No. a	Provenance trials		Progeny trials		Clonal testing and development			
			No. of trials	No. of provenances	No. of trials	No. of families	No. of tests	No. of clones tested	No. of clones selected	No. of clones used
Araucaria cunninghamii	N	876 of first generation	20	50	c. 100	c. 900	0	0	0	0
Eucalyptus dunnii	N				3	150				
E. globulus	N		91	30	87	3 836	c. 20	c. 100	0	0
Eucalyptus hybrids	N/E						c. 10	c. 100	0	0
E. nitens	N				4	150				
Khaya senegalensis	E	150	8	>80	6	60	10	180 (400) **b**	10	0
Pinus caribaea var. *hondurensis*	E	c. 1 000	c. 15	25	c. 100	c. 1 000				
P. elliottii	E	c. 450	c. 6	5	c.20	c. 300				
P. radiata	E		52	5	241	8 878				
Tectona grandis	E	0	2	8	3	20	4	20	10	10

a Number of plus trees listed only if program is beginning, and only first generation seed orchards have been established.

b For number of clones of *Khaya senegalensis* tested, two estimates of 400 and 180 were received from different experts. These differences were probably due to some clones being included at different sites in multilocation trials.

Note: This table shows the subset of species listed in Table 13 for which trial data were provided by various contacts.

Sources: ABARES; ATSC; STBA. Information has been sourced from replies to data requests sent to plantation owners and managers and the STBA, a series of papers with the theme 'Achievements in forest genetic improvement in Australia and New Zealand' in *Australian Forestry* vols 70 (2007) and 71 (2008), presentations at the First and Second Australasian Forest Genetics Conferences and pre and post Conference tours, Hobart 2007 and Perth 2009, presentations and discussions at Research Working Group 1 (Forest Genetics) meetings Hobart 2007 and Fremantle 2009, and ATSC records.

Table 15 Seed orchards (seed-bearing)

Species	Seed orchards a		
	Number **b**	Generation **b**	Area (ha)
Araucaria cunninghamii	10	1, 1.5 and 2	29
Corymbia citriodora			
C. maculata	5	1 or 2	12
C. variegata			
Eucalyptus botryoides	1		2
E. cladocalyx	14	1	30
E. cloeziana			
E. dunnii	8	1,2	16
E. globulus	CSOs	1,2,3	30
E. grandis	4	1	10
E. nitens	3	1,2	12
E. occidentalis	6	1	12
E. pellita	2		4
E. pilularis	CSOs	1	4.9
E. saligna	5	1	10
Khaya senegalensis	3 CSOs, 1 SSO	1	3,1
Pinus brutia	4	1	8
P. caribaea var. *hondurensis*	6	1, 1.5, 2	c. 30
P. elliottii	1	1, 2	c. 10
Pinus hybrids	3 (of F1 selects)	2 (F2 seed produced)	c. 10
P. pinaster	CSOs	1	25
P. radiata	2	1, rolling front	2
Tectona grandis	0	0	0

a Seed orchards are plantations specifically planted and managed for seed production, not natural seed stands.

b Generation refers to 1st, 2nd, 3rd, etc. breeding cycle. F1 means first generation, or, a hybrid derived from a cross between two genetically different parents and F2 means second generation or the progeny of an F1 hybrid. SSO = seedling seed orchard. CSO = clonal seed orchard.

Sources: ABARES; ATSC; STBA. Information has been sourced from replies to data requests sent to plantation owners and managers and the STBA, a series of papers with the theme 'Achievements in forest genetic improvement in Australia and New Zealand' in *Australian Forestry* vols 70 (2007) and 71 (2008), presentations at the First and Second Australasian Forest Genetics Conferences and pre and post Conference tours, Hobart 2007 and Perth 2009, presentations and discussions at Research Working Group 1 (Forest Genetics) meetings Hobart 2007 and Fremantle 2009, and ATSC records.

Information systems established for tree breeding programs

The STBA uses an online database (DATAPLAN®) to store and record all tree improvement information (including pedigree, various performance measurements and trial information) on its programs and those of its associates. This database is linked to the TREEPLAN® genetic evaluation system, which analyses tree improvement data collected across Australia to progress the quality of the genetic material used in industrial plantations (Kerr et al. 2011).

State government organisations in Queensland and Western Australia have well-developed databases of comprehensive trial information including tree pedigrees and measurement data.

Plant Breeder's Rights (PBR) are used in Australia to protect new varieties of plants that are distinguishable, uniform and stable. IP Australia's online searchable database contains information on all PBR varieties in Australia, including forest and woody plant species.

Species of which quantities of improved reproductive materials can be made available

Quantities of improved reproductive materials can be made available for some species (Table 16). The material available is mainly seed, but pollen has also been made available for some species. Seed is available from the ATSC, various organisations and private collectors.

Eucalyptus dunnii, Forests NSW

Table 16 Type of reproductive material available

Genus	Type of material	Available for national and international requests a	
		Commercial	**Research**
Acacia mangium	Seed (improved)	Yes	Yes (restrictions apply)
A. auriculiformis	Seed (improved)	Yes	Yes (restrictions apply)
A. crassicarpa	Seed (improved)	Yes	Yes (restrictions apply)
Acacia various species	Seed (wild)	Yes	Yes (restrictions apply)
Casuarina various species	Seed (wild)	Yes	
Corymbia maculata	Seed (improved)	Yes	Yes (restrictions apply)
C. variegata	Seed (improved)	Yes	
Eucalyptus botryoides	Seed (improved)	Yes	
E. camaldulensis subsp. *simulata*	Seed (improved)	Yes	Yes (restrictions apply)
E. camaldulensis var. *camaldulensis*	Seed (improved)	Yes	Yes (restrictions apply)
E. camaldulensis var. *obtusa*	Seed (improved)	Yes	Yes (restrictions apply)
E. cladocalyx	Seed (improved)	Yes	Yes (restrictions apply)
E. dunnii	Seed (improved)	Yes	Yes (restrictions apply)
E. globulus	Seed (improved)	Yes	
E. grandis	Seed (improved)	Yes	Yes (restrictions apply)
E. nitens	Seed (improved)	Yes	
E. occidentalis	Seed (improved)	Yes	
E. pellita	Seed (improved)	Yes	Yes (restrictions apply)
E. saligna	Seed (improved)	Yes	Yes (restrictions apply)
E. tricarpa	Seed (improved)	Yes	
E. tereticornis subsp. *tereticornis*	Seed (improved)	Yes	Yes (restrictions apply)
Eucalyptus various species	Seed (wild)	Numerous species	Numerous species
E. viminalis	Seed (improved)	Yes	
Grevillea robusta	Seed (improved)	Yes	Yes (restrictions apply)
Pinus brutia	Seed (improved)	Yes	
P. caribaea var. *hondurensis*	Seed (improved)	Yes	
Pinus hybrid	Seed (improved)	Yes	
P. pinaster	Seed (improved)	Yes	
P. radiata	Seed (improved)	Yes	

a All materials available for national requests were also available for international requests.

6 National programs, research, education, training and legislation

National programs

The Commonwealth, state and territory governments and the private sector are committed to managing Australia's forest resources in a sustainable manner. This commitment is reflected in Australia's strategic directions, policies and programs. Under a commitment made in the 1992 National Forest Policy Statement to inform the public, Australia reports on forest sustainability, including conservation of forest genetic resources, using the framework of criteria and indicators of the Montreal process (see also Chapter 3 section, 'Australia's forest reserves').

Active institutions

The main institutions actively engaged in using and improving forest genetic resources are listed in Table 17a. There are numerous other organisations and enterprises involved to various and lesser degrees. A number of organisations mainly contributing to conserving endemic forest genetic resources are listed in Table 17b.

Eucalypt forest, ABARES

Table 17a Institutions involved with use and improvement of forest genetic resources

Name of institution	Type of institution	Activities or programs	Contact information
Australian Bluegum Plantations Pty Ltd	Private company	*Eucalyptus globulus*	Dr Ben Bradshaw Ben.Bradshaw@austgum.com.au http://www.austgum.com.au/
Gunns Ltd **a**	Private company	*E. nitens*	Not applicable **a**
CSIRO	Commonwealth government research agency	*Pinus radiata*; native species (ATSC)	David Bush atsc@csiro.au http://www.csiro.au/
Forest Products Commission Western Australia (WA)/Department of Agriculture and Food WA	State government enterprise/department	*P. radiata*, *P. pinaster*, *E. globulus*	Ian Dumbrell ian.dumbrell@agric.wa.gov.au http://www.agric.wa.gov.au/
Elders Forestry Ltd	Public company	*E. globulus*	Ockert Leroux Ockert.Leroux@eldersforestry.com.au http://www.eldersforestry.com.au/
HQPlantations Pty Ltd (formerly Forestry Plantations Queensland Pty Ltd)	Private company	*Araucaria cunninghamii*, *P. caribaea*, *P. elliottii*	Dr Dominic Kain Dominic.Kain@hqplantations.com.au http://www.hqplantations.com.au
HVP Plantations	Private company	*E. globulus*, *E. nitens*	Stephen Elms selms@hvp.com.au http://www.hvp.com.au/
Forestry Tasmania	State government agency	*E. nitens*, Tasmanian endemic spp.	Dr Dean Williams dean.williams@forestrytas.com.au http://www.forestrytas.com.au/
Forests NSW	State government enterprise	*E. pilularis*, *P. radiata*	Dr Ross Dickson rossd@sf.nsw.gov.au http://www.forests.nsw.gov.au/
Southern Tree Breeding Association	Association/non-government organisation, not-for-profit	*E. globulus*, *P. radiata*	Dr Tony McRae tmcrae@stba.com.au http://www.stba.com.au/

a Placed in administration in September 2012.

Sources: ABARES; STBA; STBA

National coordination mechanisms through different institutions

The conservation of, and research on, forest genetic resources in Australia is supported by many institutions, their various activities and programs (Table 17b).

Table 17b Institutions and networks contributing to research and conservation of forest genetic resources

Name of institution	Activities or programs	Contact information
Adelaide Botanic Garden	Conservation; South Australian Seed Conservation Centre	http://www.environment.sa.gov.au/botanicgardens/Visit/Adelaide_Botanic_Garden
Australian Macadamia Society	Funds conservation and research through the Australian Macadamia Conservation Trust	http://macadamias.org/
Australian Botanic Garden, Mt Annan	Conservation and research; plant bank	http://www.rbgsyd.nsw.gov.au/annan
Australian National Botanic Gardens, Canberra	Conservation and research; Australian National Botanic Gardens Seed Bank; Australian National Herbarium; Centre for Australian National Biodiversity Research; Integrated Botanical Information System	http://www.anbg.gov.au/gardens/living/seedbank/index.html
Australian Network for Plant Conservation Inc.	Promotes plant conservation	http://www.anbg.gov.au/anpc/about.html
Australian Seed Bank Partnership	Seed collection and conservation; 14 partners	http://www.seedpartnership.org.au/
Brisbane City Botanic Gardens	Seed collection, conservation; Brisbane Botanic Gardens Conservation Seed Bank; research at University of Queensland and Griffith University	http://www.brisbane.qld.gov.au/facilities-recreation/parks-and-venues/parks/city-botanic-gardens/index.htm
Cooperative Research Centre for Forestry	Research on forest management and molecular markers	www.crcforestry.com.au
Currency Creek Arboretum	Seed conservation and research on eucalypts	http://www.dn.com.au/Currency_Creek_Arboretum.html
CSIRO	Seed collection and research; Australian Tree Seed Centre; Australian National Herbarium; Centre for Australian National Biodiversity Research	http://www.csiro.au
Queensland Department of Agriculture, Fisheries and Forestry	Collection of genotypes of *Corymbia citriodora* subsp. *variegata*, *Eucalyptus dunnii*, *E. longirostrata*, and *E. argophloia*	http://www.daff.qld.gov.au
WA Department of Environment and Conservation	Conservation; Threatened Flora Seed Centre; breeding programs for mallee eucalypt species	http://www.dec.wa.gov.au
Northern Territory Department of Land Resource Management	Conservation; NT Seed Bank	http://www.lrm.nt.gov.au
Forest Products Commission Western Australia	Genetic improvement of hardwood and softwood species of importance to Western Australia	http://www.fpc.wa.gov.au

Name of institution	Activities or programs	Contact information
Forest & Wood Products Australia	Invests in research	http://www.fwpa.com.au/
Gondwana Link	Conservation	http://www.gondwanalink.org/index.aspx
Forest Biotechnology Group (Victorian Department of Primary Industries, and the University of Melbourne)	Research into the molecular basis of tree development for improvement of tree and wood characteristics by utilising biotechnology	http://www.dpi.vic.gov.au/agriculture/innovation-and-research/biotechnology/biotechnology-research/forestry-and-biotechnology
Greening Australia	Conservation; Florabank; One Billion Trees Program; Bushcare Support; Bush for Greenhouse; National Corridors of Green; Farm Forestry Support; Green Miles	http://www.greeningaustralia.org.au/
Griffith University	Seed conservation and research; Queensland Seeds for Life; Environmental Futures Centre	http://www.griffith.edu.au/
National Arboretum Canberra	Conservation	http://www.nationalarboretum.act.gov.au/
Royal Botanic Gardens Melbourne	Conservation, Victorian Conservation Seedbank	http://www.rbg.vic.gov.au/
Royal Botanic Gardens and Domain Trust	Collection and research; NSW Seedbank; Plant Bank, Australian Botanic Garden, Mt Annan	http://www.rbgsyd.nsw.gov.au/welcome
Royal Tasmanian Botanical Gardens, Department of Primary Industries, Parks, Water and Environment	Conservation; Tasmanian Seed Conservation Centre; SeedSafe	http://www.rtbg.tas.gov.au/ http://www.dpiw.tas.gov.au/inter.nsf/Home/1?Open
Rural Industries Research and Development Corporation	Funds research; Agroforestry and Farm Forestry	http://www.rirdc.gov.au/
Southern Tree Breeding Association	Collection and research; National Genetic Resource Centre, Mt. Gambier for blue gum and pine	http://www.stba.com.au/
University of Queensland	Seed conservation and research; Queensland Seeds for Life; Integrated Seed Research Unit	http://www.seedpartnership.org.au/partners/qld-uq

Note: Table 17b does not include all the institutions and networks contributing to research and conservation of forest genetic resources in Australia.

Trends in support for forest genetic resources research

Overall, there has been a decline in research investment in the forest sector in the 10 years to 2008 in real terms, with some increased investment by the Australian Government but significantly lower investment by state agencies (Research Priorities and Coordination Committee 2008). The total expenditure on forestry research in Australia has increased an average of about 3 per cent per year in nominal terms since 1982, but has slowly declined

(0.45 per cent per year) in adjusted terms (1982 dollars) (Turner & Lambert 2010). Total expenditure on forestry research and forest products research in 2007–08 in Australia was estimated at $87.8 million, comprising $61.0 million on forestry research and $26.8 million on forest products research (Turner & Lambert 2010). When expenditure such as administration and surveys were included, total expenditure was about $105.8 million.

Research on native forests and exotic species plantations generally declined, whereas that on surveys in native forests and native species in plantations increased from 2001–02 to 2007–08 (Turner & Lambert 2010). Similarly, research capacity declined in traditionally strong research areas such as pests and diseases and fire behaviour, and increased in newer areas such as carbon and forest bioenergy (Turner & Lambert 2010). Trends in research investment on forest genetics over time were not available.

There has been a steady decline in the number of forestry graduates from Australian universities; in response, industry has recruited experts from overseas, particularly from New Zealand and South Africa (de Fégely 2010). Forest & Wood Products Australia has provided a recent overview of the programs and gaps in forestry education and training in Australia (de Fégely 2010). Forest genetics is not offered as a specific course at Australian universities, although management of forest genetic resources is covered in a number of subjects in forest management and biodiversity conservation courses.

Data on the budget allocated to forest genetics research across Australia were not available for this study. Some of this information is commercial-in-confidence, and some is difficult to collect as it is not always disaggregated from other forest research.

Universities and courses explicitly covering forest genetic resources

Universities and other institutions do not offer many subjects in forest genetics and breeding. A range of courses relevant to sustainable management of forests and forestry is offered by various institutions (Table 17c), including subjects that cover forest genetics to varying levels.

Eucalyptus shelter belt in the foreground, Mark Parsons

Table 17c Institutions and courses covering conservation and management of forest genetic resources

Institution/program	Courses covered	Contact information
Edith Cowan University	Bachelor of Science (Sustainable Forestry) is designed to equip graduates with the skills and knowledge necessary to contribute to the production forestry industry and also incorporate sustainability objectives in their work	http://handbook.ecu.edu.au/CourseStructure.asp?disyear=2006&CID=722&USID=0&UCID=0&UID=0&Ver=3&HB=HB&SC=UG
James Cook University	Undergraduate/postgraduate degree programs on Genetics and Genomics; and a course on Ecological and Conservation Genetics	http://www-public.jcu.edu.au/courses/sustainability/index.htm
National Forestry Masters Program (collaboration between several universities including the Australian National University and the University of Melbourne)	Role of genetics in improving profitability of Australia's hardwood and softwood plantations	http://www.forestry.org.au/masters/descriptions.htm
Southern Cross University	Bachelor of Forest Science and Management provides sustainable resource management training	http://www.scu.edu.au/coursesin2013/?action=matrix&command=matrix_temp_load&spk_no=10164
University of Queensland	Courses in Environmental Management (Tropical Forests) and Applied Science (Tropical Forest Management) equip graduates with the necessary knowledge, skills and self-confidence to assist in effective and successful management as applied to forests	http://www.uq.edu.au/study/
University of Tasmania, including National Centre for Future Forest Industries	Postgraduate research on eucalypt population genetics and gene flow between plantations and native forests to develop better conservation strategies; understand the sequence of evolution in Eucalyptus and the evolutionary processes; and determine the genetic basis of interaction of species of Eucalyptus with dependent mammals, insects and fungi	http://www.utas.edu.au/plant-science/research/eucalypt-genetics

Note: There are no specific courses in forest genetics taught in Australia; however, forest genetics and breeding are covered in research work in masters and doctorate studies, including at other universities in the context of broader ecological research that can include research on tree species biological diversity.

Needs and priorities for research to support the conservation and sustainable use of forest genetic resources

Australia's forestry Research Priorities and Coordination Committee (2008) did not identify any specific priority for research on forest genetics. However, it did identify three key areas of research on forests that are relevant for the sustainable management and conservation of forest genetic resources. These are:

- multidisciplinary analyses of strategies and development of decision-support tools to integrate or segregate production and conservation at different scales and in different forest types
- improved monitoring and reporting for forest biodiversity and habitat surrogates
- long-term, operational-scale, ecological and management experiments to determine the effects of repeated cycles of forest management activities, and time to recovery, for sensitive species of plants.

The Institute of Foresters of Australia has proposed that research is needed in the following areas:

- forest genetic structure (gene pools) in native forest communities to provide a basis for conservation and use of forest genetic resources
- gene flows from plantations to native forests to assess the risk of genetic pollution (introgression) (IFA 2007).

Legislation relevant to forest genetic resources

Australia includes six self-governed states and two self-governed mainland territories. The powers and responsibilities of the Commonwealth are defined in the Australian Constitution, which does not specifically cover environmental powers. Most environmental legislation rests with the states and territories, although the Commonwealth has substantial powers to enact laws affecting the environment and sustainable development. There are shared responsibilities between the Commonwealth and state or territory governments in some agriculture, forests and biological diversity matters.

Australian states and territories have legislation in place for conserving native vegetation, including regulations on land clearing. Legislation for conserving native vegetation helps in situ conservation of forest tree and woody plant species in woodlands and pastoral lands not included in forest reserve systems.

Commonwealth, state and territory legislation provide for sustainable management of forests and thereby support conservation of forest genetic resources. Examples of relevant legislation are provided in Table 18. Australia maintains a national list of threatened flora species or communities under the *Environmental Protection and Biodiversity Conservation Act 1999*. After a species or community is listed as threatened, a range of recovery actions is put in place to prevent extinction and improve the status of the species, including the formulation of recovery plans for threatened species and ecological communities and threat abatement plans for key threatening processes.

Table 18 Legislation relevant to forest genetic resources

Jurisdiction	Legislation
Commonwealth	*Aboriginal and Torres Strait Islander Heritage Protection Act 1984* *Environmental Protection and Biodiversity Conservation Act 1999* **a** *Native Title Act 1993* *Plant Breeder's Rights Act 1994* *Quarantine Act 1908* **b** *Regional Forest Agreements Act 2002* **c**
New South Wales	*National Parks and Wildlife Act 1974* *Native Vegetation Act 2003* *Threatened Species Conservation Act 1995* *Plant Diseases Act 1924*
Victoria	*Parks Victoria Act 1998* *National Parks Act 1975* *Wildlife Act 1975* *Flora and Fauna Guarantee Act 1988* *Planning and Environment Act 1987* *Plant Health and Plant Products Act 1995*
Queensland	*Biodiscovery Act 200* *Forestry Act 1959* *Nature Conservation Act 1992* *Plant Protection Act 1989* *Vegetation Management and Other Legislation Amendment Act 2009*
South Australia	*Forestry Act 1950* *National Parks and Wildlife Act 1972* *Wilderness Protection Act 1992* *Native Vegetation Act 1991* *Plant Health Act 2009*
Western Australia	*Conservation and Land Management Act 1984* *Wildlife Conservation Act 1950* *Plant Diseases Act 1914* *Soil and Land Conservation Act 1945*
Tasmania	*National Parks and Reserves Management Act 2002* *Nature Conservation Act 2002* *Threatened Species Protection Act 1995* *Plant Quarantine Act 1997*
Australian Capital Territory	*Environment Protection Act 1997* *Land (Planning and Environment) Act 1991* *Nature Conservation Act 1980* *Plant Disease Act 2002*
Northern Territory	*Biological Resources Act 2006* *Territory Parks and Wildlife Conservation Act* *Territory Parks and Wildlife Conservation Regulations* *Plant Diseases Control Act 1979*

a The EPBC Act (Cwlth) applies to all states and territories (including external territories). The Australian Government intends to revise this to establish new national approaches to the conservation of Australia's natural environment and biodiversity, with a focus on regions and ecosystems (Australian Government 2012). **b** Currently under revision. **c** Applies to RFA areas in New South Wales, Tasmania, Victoria and Western Australia.

Tree breeders' rights and patents are administered by the Australian Government agency IP Australia under the *Plant Breeder's Rights Act 1994*. The Plant Breeder's Rights (PBR) searchable database contains information on all PBR varieties in Australia and AusPat is the Australian patents database.

The *Aboriginal and Torres Strait Islander Heritage Protection Act 1984* and the *Native Title Act 1993* can limit access to forest in certain areas to protect the interests of Indigenous communities.

To safeguard Australia's forests and forest genetic resources, phytosanitary measures are implemented under the *Quarantine Act 1908* to prevent the introduction of pests. Phytosanitary restrictions are imposed on imports of seeds and nursery stock of forest and woody plant species from certain countries of origin. This includes bans on high-risk imports; for example, *Pinus* seeds from areas or countries where *Fusarium circinatum* (pine pitch canker) is known to occur. Within Australia, state or territory legislation is used to impose interstate or intrastate phytosanitary restrictions on movement of seeds and nursery stock to mitigate spread of quarantine pests, which are present in Australia but are restricted to certain areas and under official control; for example, *Puccinia psidii* (myrtle or eucalypt rust).

Australia has been building a stronger biosecurity system that identifies and targets quarantine risk material. The *Quarantine Proclamation 1998* provides the legislative basis for controlling the entry of animals, plants and other goods of quarantine concern into Australia. Subsection 62 of the Quarantine Proclamation provides that importing living plants (other than Orchidaceae tissue culture) into Australia is prohibited unless the Director of Quarantine has granted a permit to import the plant.

Subsection 63(1) of the Quarantine Proclamation provides that importing into Australia a seed (other than a seed of a kind of plant mentioned in Schedule 5 to the Quarantine Proclamation) is prohibited unless a Director of Quarantine has granted a permit for its importation. Schedule 5 to the Quarantine Proclamation lists all seeds that have been assessed as 'permitted seeds'—that is, seeds that can be imported for direct planting without the need for treatment, certification and or post-entry quarantine to manage exotic seed-borne diseases.

Australia's import conditions for forest genetic materials can be accessed from the Department of Agriculture, Fisheries and Forestry's import conditions database. This database is being redeveloped and will be named the Biosecurity Import Conditions (BICON) database.

Box 5 provides a summary of requirements for importing forest genetic materials including seeds and nursery stock.

Box 5 Import conditions for forest germplasm

Import conditions for seeds

Seed of *Pinus* spp. and *Pseudotsuga menziesii* is only permitted from countries free from *Fusarium circinatum* (pitch canker). Seed must be accompanied by phytosanitary certification from the country of origin confirming freedom from pitch canker. Seed is also subject to mild heat treatment or dipping in sodium hypochlorite to address external seed-borne pathogens. The treatment can occur before export to Australia or on arrival.

Seed of other permitted coniferous species is subject to mild heat treatment or dipping in sodium hypochlorite to address external seed-borne pathogens. This can occur before export or on arrival.

Myrtaceae seed from countries with guava rust (*Puccinia psidii*) must be treated with an approved fungicide and grown in a government post-entry quarantine facility for disease screening. Seed from countries free of guava rust must be accompanied by a phytosanitary certificate from the country of origin and must be treated with an approved fungicide before release from quarantine.

Import conditions for nursery stock

DAFF regulates the import of live forestry plants for a number of quarantine pests including *Phytophthora ramorum* (sudden oak death) and other exotic *Phytophthora* species, exotic strains of guava rust, and *Ophiostoma ulmi* (Dutch elm disease). As a general rule, imported live plants of forestry and amenity significance require 2 years growth in a government post-entry quarantine facility for disease screening.

However, tissue-cultured plants that are host species for sudden oak death are allowed only from countries free from *P. ramorum* and must be grown in a government post-entry quarantine facility for disease screening.

Tissue-cultured plants of *Pinus radiata* from New Zealand, if not derived from seed of New Zealand origin, must be grown in a government post-entry quarantine facility. If tissue-cultured plants have been derived from seed of New Zealand origin they can be released on arrival without any post-entry quarantine screening.

Import conditions for pollen

Pine pollen is permitted from countries free from pitch canker, subject to appropriate phytosanitary certification. There are no current conditions for pollen from other forestry species and they are subject to pest risk analysis on a case-by-case basis.

Within Australia, conditions can be imposed on the interstate or intrastate movement of forest genetic materials under state, territory or Commonwealth legislation to safeguard 'pest-free areas' against pest introduction, providing a pest meets the criteria of 'quarantine pest' as defined by the International Plant Protection Convention. These criteria can include restricted distribution and official control. For instance, most states restricted movement of plant material from the family *Myrtaceae* following the detection of myrtle rust (*Puccinia psidii* sensu lato; anamorph *Uredo rangelii*) in Australia. Restrictions now apply to all myrtaceous plant material including nursery stock of current and potential host plants, fruits, cut flowers and foliage, seeds, mulch and machinery and equipment associated with their production.

The legislation underpinning sustainable management of forest genetic resources is listed in Table 18.

Initiatives necessary for greater visibility for forest genetic resources

The Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) provides a legal framework for a range of environmental protection and biodiversity conservation initiatives. Australia's Biodiversity Conservation Strategy 2010–2020 recognises that the government's investment in developing and implementing biodiversity policies and programs has achieved a range of biodiversity and conservation goals. Many of these achievements have resulted from the commitment and ongoing work of regional bodies, local community groups and individuals.

Key components of the national approach to protecting biodiversity under the EPBC Act include identifying and listing threatened species, ecological communities and key threatening processes, the proposed listing of 'ecosystems of national significance', and recovery actions. These mechanisms provide a framework from which regional approaches to recovery and other conservation planning activities can be developed and implemented.

Specific awareness programs for forest genetic resources

There are no specific awareness programs for forest genetic resources. However, the many institutions and programs that promote sustainable forest management, biodiversity conservation and forest biosecurity achieve outcomes contributing to conservation of genetic diversity in forest species (Table 17b).

Needs and priorities for raising awareness of forest genetic resources issues

Based on the authors' assessment, raising awareness of forest genetic resource issues is a moderate to high priority (Table 19).

Table 19 Awareness-raising needs

Needs	Priority level
Prepare targeted forest genetic resources information	Medium
Prepare targeted forest genetic resources communication strategy	Medium
Improve access to forest genetic resources information	Medium
Enhance forest genetic resources training and education	High
Improve understanding of benefits and values of forest genetic resources	Medium

7 Regional and international collaboration

International engagement

International organisations, agreements, treaties, conventions or trade agreements to which Australia is a party and that are directly or indirectly relevant to the sustainable use, development and conservation of forest genetic resources include the:

- Food and Agriculture Organization of the United Nations (FAO) and its Commission on Genetic Resources for Food and Agriculture (CGRFA)
- United Nations Forum on Forests (UNFF)
- Convention on Biological Diversity (CBD)
- World Trade Organization (WTO)
- World Intellectual Property Organization (WIPO) and its Intergovernmental Committee on Intellectual Property and Genetic Resources, Traditional Knowledge and Folklore (IGC)
- International Union for the Protection of New Varieties of Plants (UPOV) established under the International Convention for the Protection of New Varieties of Plants (ICPNVP)
- Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)
- United Nations Framework Convention on Climate Change (UNFCCC)
- United Nations Commission on Sustainable Development (CSD)
- International Tropical Timber Agreement (ITTA)
- World Heritage Convention
- Ramsar Convention on Wetlands
- International Plant Protection Convention (IPPC)
- WTO Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement).

International collaboration

Australia participates in a number of bilateral, multilateral, sub-regional and regional activities that are directly or indirectly related to forest genetic resources. Table 20 lists some of these activities that Australia has participated in over the past 10 years.

Table 20 Overview of the main activities carried out through networks and their outputs

Network name	Activities	Genus/species involved
South Pacific Regional Initiative on Forest Genetic Resources (SPRIG)	Capacity building and establishment of genetic conservation strategies	Many
Australian Centre for International Agricultural Research (ACIAR)	A range of bilateral and multilateral forest research activities	Many
Australian Agency for International Development (AusAID)	Supported a workshop in Fiji in 2007 on Development of a Pacific Islands Regional Research and Development Agenda and Action Plan for Improved Governance in the Conservation, Management and Sustainable Utilisation of Forest Genetic Resources	Many
Asia Forest Partnership (AFP)	Fosters regional cooperation in research, dissemination of knowledge, and technology transfer	Many
Asia-Pacific Forestry Commission (APFC)	A forum for discussing regional forestry issues, including future directions for the forestry activities by FAO in the region, and for progressing practical work aimed at promoting the adoption of sustainable forest management practices	Many
Asia-Pacific Network for Sustainable Forest Management and Rehabilitation (APFNet)	Capacity building, information sharing, regional policy dialogues and pilot project	Many
International Union of Forest Research Organizations (IUFRO)	Research	Many
Center for International Forestry Research (CIFOR)	Research	Many
Bioversity International	Research that promotes conservation and use of tree species	Many
Millennium Seed Bank	Ex situ conservation	Many
World Agroforestry Centre (formerly International Centre for Research in Agroforestry (ICRAF))	Research	Many

The South Pacific Regional Initiative on Forest Genetic Resources commenced in December 1996 as an Australian Agency for International Development (AusAID)-funded project involving government forestry organisations in Australia, Fiji, Samoa, Solomon Islands, Tonga and Vanuatu. The initial project was three years and a second phase ran for five years from 2001 to 2006. CSIRO Forestry and Forest Products, Queensland Forest Research Institute and the private consulting company Forestry Technical Services Pty Ltd (FORTECH) managed the project. They worked with local personnel in hands-on skill upgrading through joint seed collections, planting and assessment of field trials, in-service training, work attachments in Australia, scholarships, meetings and workshops. The project also contributed regularly to the Secretariat of the Pacific Community newsletter and helped with equipment for seed collection and storage.

The Australian Centre for International Agricultural Research (ACIAR) has funded a range of bilateral and multilateral forest research activities aimed at sustainable use of forest genetic resources. ACIAR has worked primarily in the Asia-Pacific region through collaborative research projects involving research institutions from Australia and developing countries. Projects were selected based on their contribution to reducing rural poverty and the benefits they could deliver to the collaborating countries. The ACIAR forestry program has supported research on deployment of forest species for improving tree-growing practices, and encouraged using wood and non-wood products for the benefit of farmers and local communities. Past research has resulted in a rapid increase in the number of eucalypts and acacias grown on farms in China and South-East Asia, and has helped to build strong rural industries in those countries. More recent research has assisted with the conservation and improved access to germplasm for important local species in the Pacific including *Endospermum medullosum*, *Santalum austrocaledonicum*, *Canarium indicum* and *Flueggia flexuosa*.

Australia continues to support international agricultural research centres that deal with forestry issues, such as the International Centre for Research in Agroforestry, and the Center for International Forestry Research. Australia is a donor to the Global Environment Facility, which finances biodiversity conservation, among other activities, in developing countries.

Current International Union of Forest Research Organizations activities relevant to Australian tree breeders and geneticists include working groups on conifer and hardwood breeding and genetic resources.

The private sector is directly engaged in international collaborations on a commercial basis. The Southern Tree Breeding Association (STBA) is involved in international collaboration on tree improvement programs with organisations in Sweden and France. The STBA DATAPLAN® and TREEPLAN® software systems are being used to house STBA's tree improvement data and undertake species-wide genetic evaluations for tree improvement in *Betula pendula*, *Picea abies*, *Pinus contorta*, *P. pinaster* and *P. sylvestris*.

Based on the authors' assessment of Australia's international collaborations over the past 10 years, and limited consultation with relevant agencies, some needs and priorities for future international collaboration are briefly summarised in Table 21.

Table 21 Awareness-raising needs/needs for international collaboration and networking

Needs	Priority level
Understanding the state of diversity	Medium
Enhancing in situ management and conservation	Medium
Enhancing ex situ management and conservation	Medium
Enhancing research	Medium
Enhancing education and training	High
Enhancing legislation	Low
Enhancing information management and early warning systems for forest genetic resources	Medium
Enhancing public awareness	Medium

Small eucalypt planting in Australia, ABARES

8 Access to forest genetic resources and sharing of associated benefits

International agreements

In November 2010 the Conference of the Parties to the Convention on Biological Diversity adopted the 'Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization'. The 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. Australia signed the Protocol on 20 January 2012.

All Australian governments have accepted that access to biological resources in Australia should meet responsibilities under Article 15 of the Convention on Biological Diversity. The Australian Government is holding discussions with state and territory governments, the research community, Indigenous communities and industry stakeholders to plan Australia's response to the Nagoya Protocol.

Australia is a member of the World Intellectual Property Organization and its Intergovernmental Committee on Intellectual Property and Genetic Resources, Traditional Knowledge and Folklore. Australia is also a member of the International Union for the Protection of New Varieties of Plants.

National legislation and policies

Under Australia's federal system, each state or territory government manages access to biological resources in its jurisdiction under its own laws. In 2002 all governments endorsed the nationally consistent approach for access to and use of Australia's native genetic and biochemical resources, to promote consistency in regulating and managing access to genetic resources.

Legislative frameworks to regulate access to genetic resources and benefit sharing include:

- *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth)
- *Environment Protection and Biodiversity Regulations 2000* (Cwlth)
- *Biodiscovery Act 2004* (Qld)
- *Biological Resources Act 2006* (NT)

Other Australian jurisdictions are continuing to work on genetic resources policy development.

The *Patents Act 1990* provides intellectual property (IP) protection for inventions that are new, not obvious and otherwise meet the legislative criteria. An invention that involves forest genetic resources, like any other invention, may become the subject of patent protection but the Act does not refer specifically to forest genetic resources.

The *Plant Breeder's Rights Act 1994* provides IP protection for new varieties of plants that meet the legislative criteria. The period of IP protection for trees and vines is 25 years, while other plant varieties have 20 years of IP protection.

The *Quarantine Act 1908* and state and territory legislation provide protection against spread of pests, diseases and weeds by regulating movement of forest genetic resources and other biological materials. For example, there are national and interstate restrictions on transfer of plant species that are hosts of *Puccinia psidii* (myrtle or eucalypt rust) (see Chapter 6 section 'Legislation relevant to forest genetic resources' and Table 18).

Accessibility of Australian forest genetic resources

Australian forest genetic resources are generally highly accessible, with a very large amount of material having been dispersed throughout Australia and the world (for example, Griffin et al. 2011; Koskela et al. 2010). Until the early 2000s, the ATSC supplied seed free-of-charge to some developing countries. However, ATSC seed supply is now on a cost-recovery basis and remains subject to relevant state, territory and Commonwealth legislation.

More efficient international transfers of forest genetic resources could occur by addressing inconsistent, time-consuming import and quarantine regulations in certain countries (Koskela et al. 2010). Research and development of economically viable treatments and/or testing of germplasm that would allow it to be declared free of serious pathogens (such as *P. psidii* and *Fusarium circinatum*, pine pitch canker) would also benefit the movement of germplasm.

Regrowth of mountain ash (*Eucalyptus regnans*), Michael Ryan

Eucalyptus camaldulensis seeds, John Davidson

A clone of potted hedge plants of *Eucalyptus globulus* maintained in a juvenile condition in a glasshouse by repeated harvest of cuttings (Note: Plants ready for a harvest on the right side, recently harvested on the left. Note proliferation of new juvenile shoots ideal for making cuttings), John Davidson

9 Contribution of forest genetic resources to food security, poverty alleviation and sustainable development

Forest and other woody plant genetic resources can play an important role in sustainable development including food supply and poverty alleviation. In addition to direct use as food, forest and woody plant resources contribute to food production systems through their various other uses (see Chapter 1 section, 'Forest genetic material supply and utilisation').

Food security

Few Australian forest and woody plant species are currently used as food sources in Australia, although they can still contribute to specific dietary needs of some people. The main native forest species used in Australia as food resources are listed in Table 22.

Table 22 Some tree and other woody plant species used in Australia for food or livelihoods

Species	Common name	Native (N) or exotic (E)	Use for food [a]	Use for livelihoods [b]
Acacia spp.	wattles	N	Yes	Yes
A. victoriae	sattleseed	N	Yes	Yes
Acronychia acidula	white aspen	N		Yes
A. oblongifolia	white aspen	N	Yes	Yes
Backhousia citriodora	lemon myrtle	N		Yes
Citrus australasica (formerly *Microcitrus australasica*)	Australian finger lime	N	Yes	Yes
Citrus australasica x (*Fortunella* sp. x *C. reticulata* 'Calamondin')	'Australian Sunrise' citrus	N/E	Yes	Yes
C. glauca (formerly *Eremocitrus glauca*)	desert lime	N	Yes	Yes
Davidsonia sp.	Davidson plum	N	Yes	Yes
Kunzea pomifera	muntries	N	Yes	Yes
Macadamia spp.	macadamia	N	Yes	Yes
Santalum acuminatum	quandong	N	Yes	Yes
Solanum centrale	bush tomato	N	Yes	Yes
Syzygium anisata (formerly *Backhousia anisata*)	anise myrtle	N		Yes
Syzygium luehmanii	ribbery	N	Yes	Yes
Tasmannia lanceolata	mountain pepper	N		Yes
Terminalis ferdinandiana	Kakadu plum	N	Yes	Yes

a Potential for use for food security—already in use as food in remote areas of Australia. **b** Provides income to Indigenous communities and thus improves livelihoods.

Note: Many more species of Australian origin are used as important food sources internationally. This table does not include exotic forest or woody plant species used as food in Australia, such as numerous fruit and nut tree species used in horticultural industries.

Sources: CSIRO (2006); Ryder et al. (2008); Clarke (2012)

Australian wattle seeds (various *Acacia* species) and quandong (*Santalum acuminatum*) fruit are becoming increasingly valuable food crops. Traditionally, Indigenous communities used the seeds of some wattles for food. Native Australian wattle species are prolific seeders and can be used for food, particularly in times of severe food shortage and famine (Harwood 1994). *Cassia brewsteri* (Leichhardt bean) and related species have been studied for their potential as a source of vegetable gums for food and industrial applications (Cunningham et al. 2002).

Emerging native food species include *Atriplex* species (saltbush), *Eucalyptus olida* (strawberry gum), *Solanum chippendaleai* (Tanami apples) and *Syzygium* species (in addition to *S. anisata* and *S. luehmanii*) (Clarke 2012).

Food from native species tends to be oversupplied in current niche markets. Potential scale-based opportunities exist but there is currently a failure to develop potential markets due to lack of technology and the current status of industry (Clarke 2012).

According to the National Strategy for Food Security in Remote Indigenous Communities, food security is determined by local food supply and Indigenous people's capacity and resources to access and use the food (COAG 2009, Box 6). The Australian Government recognises the important role of local traditional food in supporting food security in remote Indigenous communities (Australian Government 2012d). Australia is also addressing its national food needs through a National Food Plan (Australian Government 2012e).

Box 6 Food security

Food security is defined as: 'the ability of individuals, households and communities to acquire appropriate and nutritious food on a regular and reliable basis using socially acceptable means.'

Food security is determined by people's local 'food supply' and their capacity and resources to 'access and use that food'.

Food supply refers to 'the availability, cost, quality, variety and promotion of foods for local population groups that will meet nutritional requirements'.

Food access refers to 'the range of physical and financial resources, supports, and knowledge, skills and preferences that people have to access and consume nutritious food'.

Source: COAG 2009

There is great potential for managing forest resources for food as Australian forest foods become more appreciated nationally and globally. As an example, *Macadamia integrifolia* and *M. tetraphylla* (macadamia nuts) are harvested and sold in large-scale commercial quantities in Australia and overseas. Australia is the world's leading producer of macadamia nuts, which are native to Australia, and the industry is worth over $100 million per year. The remainder of the native foods industry (excluding macadamia) is worth an estimated $18.5 million annually. Its substantially larger export potential is yet to be realised because it cannot guarantee regular supplies of high-quality produce (Clarke 2012).

Forest gardens or food forests have become one of the key concepts in permaculture in Australia, and they mimic the architecture and beneficial relationships of a natural forest (Permaculture Institute 2012). Food forests are designed and managed ecosystems that are rich in biodiversity and productivity. They can be designed to produce food, produce forage for beneficial insects, pollinators, poultry and song birds, create wildlife habitat and create beauty and a sense of wellbeing.

CSIRO is working with Indigenous communities and Australian industry to learn more about 'bush tucker' or 'bushfood' (that is, any food native to Australia and used as sustenance and for medicinal purposes by Indigenous Australians). A research program on bush produce (Altyerre-ipenhe 2011) operated through the former Desert Knowledge Cooperative Research Centre (funded from July 2003 – June 2010). Research focused on developing guidelines to help people with a commercial interest in bush foods, in both the research and industry sectors. Guidelines were developed within the social and cultural context of central Australia. The guidelines may be used to assist other Indigenous groups around Australia in developing their own best practice guidelines (Altyerre-ipenhe 2011).

Australian wattles are grown in Africa, alongside a number of native African wattles, for wood and shelter. With the help of Indigenous people from communities in the Australian deserts, CSIRO scientists have made seed collections of *Acacia colei* and other edible-seeded wattles, and have worked with farmers in Niger to develop farm-scale acacia plantations (Harwood 1994). *Acacia colei* var. *colei* is used as a multipurpose windbreak in the Republic of Niger, protecting annual crops and providing firewood, mulch and edible seed.

Poverty alleviation

Australia's approach to alleviating global poverty includes strengthening frameworks for sustainable and inclusive economic growth that will benefit the poor, supporting interventions that enable the poor to improve their productivity, encouraging governments, institutions and donors to be more accountable to the poor, and reducing the vulnerability of the poor. Box 7 provides an example of the role Australian forest genetic resources play in poverty alleviation in Vietnam.

Acacia seed pod, ATSC

Box 7 Alleviation of poverty in Vietnam

Vietnam has a population of about 85 million. Ten per cent of the population still live in poverty and many of them live in mountainous rural areas. Since 1998, Vietnam has implemented a large program to reforest 5 million hectares. As a result the forest area—native forest and plantations—has increased from just over 8 million hectares in 1995 to about 13.7 million hectares. Vietnam has at least 2.8 million hectares of plantations. About half of Vietnam's plantations are species of eucalypts, acacias, casuarinas and melaleucas. This includes nearly 400 000 hectares of *Acacia* species (230 000 hectares of acacia hybrid) and some 586 000 hectares of eucalypts. At least one-third of these plantations is owned by smallholder farmers. About 70 per cent of the non-rubber tree plantation genetic material has originated from Australia.

Vietnamese plantation owners are now planting improved genetic material. The Vietnamese Government reports that the average productivity of tissue-culture-based *Eucalyptus* plantations increased from 8–10 cubic metres per hectare per year to 15 cubic metres per hectare per year, and improved *Acacia* plantations have yielded 20–25 cubic metres per hectare per year or more. There is strong evidence of substantial economic benefits that farmers derive from growing acacias and eucalypts. In some areas where these plantations have been developed, more than 65 per cent of the total annual income of poorer households is derived from forestry.

These results have been achieved through two collaborative projects implemented from 1993 to 2004 by the Forest Science Institute of Vietnam and the Australian Centre for International Agricultural Research (ACIAR), involving the selection and provision of tree germplasm. ACIAR's Impact Assessment Analysis almost a decade after the end of some of the projects found that investment of $1.5 million in these forest research activities in Vietnam had resulted in a net present value of the benefits of about $129 million (an implied benefit–cost ratio of 79:1) with an internal rate of return of 32 per cent. About two-thirds of the benefits flowed to consumers through lower prices, but the rest of the benefits went to producers, including the large number of smallholder farmers who planted the better quality genetic material.

Source: Bartlett (2011).

Appendix A: Australian priority species

This appendix provides a list of Australian species contained on the REFORGEN database (FAO 2012a) supplemented by a range of additional species. The list does not comprehensively cover all native or introduced tree species, but includes species that are: (a) of national or international importance for forestry, (b) threatened or endangered in their natural range (species listed in the online Species Profile and Threats Database, which draws on the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), particularly species from the *Eucalyptus* and *Acacia* genera), and (c) woody weeds. Threat levels under the EPBC Act listed here include, in decreasing order of threat, critically endangered, endangered and vulnerable. Some species that have state conservation rare/threatened status (including locally threatened populations) but are not on the national EPBC list are described as 'at risk'. Use codes are: U1 = solid wood products; U2 = pulp and paper; U3 = energy (fuel); U4 = non-wood forest products (food, fodder, medicine, etc.); U5 = used in agroforestry systems; U6 = other. Services and values codes are: S1 = soil and water conservation including watershed management; S2 = soil fertility; S3 = biodiversity conservation; S4 = cultural values; S5 = aesthetic values; S6 = religious values; S7 = other. Origins include N (native) and E (exotic). Invasive status is essentially as per REFORGEN, except that the invasive status of a few species has been changed to non-invasive based on more recent data. An invasive species is a species that is non-native to Australia and whose introduction and spread causes, or is likely to cause, socio-cultural, economic or environmental harm or harm to human health (FAO 2012b).

Table A1 List of Australian species organised by higher priority native and exotic species, lower priority exotics, and woody invasive species

Species	Origin	Use	Invasive?	Threat level	Trials	Reproductive material
1. Higher priority native and exotic species						
Acacia acuminata	N	S1 **a**		Endangered		
A. ammophila	N			Vulnerable		
A. ampliceps	N					
A. aneura	N					
A. anomala	N			Vulnerable		
A. aphylla	N			Vulnerable		
A. aprica	N			Endangered		
A. araneosa	N			Vulnerable		
A. aristulata	N			Endangered		
A. ataxiphylla subsp. *magna*	N			Endangered		
A. attenuata	N			Vulnerable		
A. auratiflora	N			Endangered		
A. auriculiformis **b**	N	U1,U2			Yes	Orchard seed
A. awestoniana	N			Vulnerable		
A. axillaris	N			Vulnerable		
A. bakeri	N					
A. blayana	N					
A. brachypoda	N			Endangered		

Species	Origin	Use	Invasive?	Threat level	Trials	Reproductive material
A. bynoeana	N			Vulnerable		
A. caerulescens	N			Vulnerable		
A. carnei = A. carneorum						
A. carneorum	N			Vulnerable		
A. celsa	N					
A. chapmanii subsp. *australis*	N			Endangered		
A. chincillensis	N			Vulnerable		
A. cincinnata	N					Difficult to procure
A. cochlocarpa subsp. *cochlocarpa*	N			Endangered		
A. cochlocarpa subsp. *velutinosa*	N			Critically endangered		
A. colei **b**	N	U4				
A. constablei	N			Vulnerable		
A. coriacea	N					
A. courtii	N			Vulnerable		
A. cowleana	N	U4				
A. crassicarpa	N/E	U1,U2			Yes	Orchard seed
A. cretacea	N			Endangered		
A. crombiei	N			Vulnerable		
A. curranii	N			Vulnerable		
A. dealbata **b**	N	U4	Yes			
A. decurrens	N	S1	Yes			
A. denticulosa	N			Vulnerable		
A. depressa	N			Vulnerable		
A. deuteroneura	N			Vulnerable		
A. difficilis	N					
A. enterocarpa	N			Endangered		
A. eremophiloides	N			Vulnerable		
A. flocktoniae	N			Vulnerable		
A. forrestiana	N			Vulnerable		
A. georgensis	N			Vulnerable		
A. glandulicarpa	N			Vulnerable		
A. gordonii	N			Endangered		
A. grandifolia	N			Vulnerable		
A. guymeri	N			Vulnerable		
A. handonis	N			Vulnerable		
A. holosericea **b**	N					
A. imitans	N			Endangered		
A. insolita subsp. *recurva*	N			Endangered		
A. lanuginophylla	N			Endangered		
A. latzii	N			Vulnerable		
A. lauta	N			Vulnerable		

Species	Origin	Use	Invasive?	Threat level	Trials	Reproductive material
A. leptalea	N			Endangered		
A. leptocarpa	N					
A. lobulata	N			Endangered		
A. macnuttiana	N			Vulnerable		
A. mangium **b**	N/E	U1,U2			Yes	Orchard seed
A. mearnsii **b**	N	U4			Yes	
A. melanoxylon **b**	N	U1			Yes	Orchard seed
A. menzelii	N			Vulnerable		
A. midgleyi	N					
A. murrayana	N					
A. orites	N					
A. robusta **b**	N	U1,U6				
A. paradoxa	N		Yes			
A. pendula	N					
A. peuce	N			Vulnerable		
A. pharangites	N			Endangered		
A. phasmoides	N			Vulnerable		
A. pickardii	N			Vulnerable		
A. pinguifolia	N			Endangered		
A. porcata	N			Endangered		
A. praemorsa	N			Vulnerable		
A. praetermissa	N			Vulnerable		
A. pruinocarpa	N					
A. pubescens	N			Vulnerable		
A. pubifolia	N			Vulnerable		
A. purpureopetala	N			Vulnerable		
A. pycnostachya	N			Vulnerable		
A. pygmaea	N			Endangered		
A. ramiflora	N			Vulnerable		
A. recurvata	N			Endangered		
A. rhamphophylla	N			Endangered		
A. rhetinocarpa	N			Vulnerable		
A. riceana var. *axillaris*	N			Vulnerable		
A. ruppii	N			Endangered		
A. salicina	N	S1				
A. saligna **b**	N	S1	Yes			
A. sciophanes	N			Endangered		
A. shirleyi	N					
A. solenota	N			Vulnerable		
Acacia sp. Graveside Gorge	N			Critically endangered		
A. spilleriana	N			Endangered		
A. splendens	N			Endangered		

Species	Origin	Use	Invasive?	Threat level	Trials	Reproductive material
A. stenophylla	N					
A. subflexuosa subsp. *capillata*	N			Endangered		
A. terminalis subsp. *terminalis*	N			Endangered		
A. torulosa	N					
A. tumida	N	U4				
A. undoolyana	N			Vulnerable		
A. unguicula	N			Critically endangered		
A. vassalii	N			Endangered		
A. victoriae	N					
A. volubilis	N			Endangered		
A. wardellii	N			Vulnerable		
A. whibleyana	N			Endangered		
Acronychia acidula	N	U4				
Adansonia gregorii	N					
Agathis robusta	N	U1				
Allocasuarina decaisneana	N					
A. defungens	N			Endangered		
A. emuina	N			Endangered		
A. fibrosa	N			Vulnerable		
A. fraserana	N					
A. glareicola	N			Endangered		
A. portuensis	N			Endangered		
A. robusta	N			Endangered		
A. simulans	N			Vulnerable		
A. thalassoscopica	N			Endangered		
A. tortiramula	N			Vulnerable		
Araucaria bidwillii	N	U1,S4				
A. cunninghamii **b**	N	U1			Yes	
Ardisia elliptica	E					
Atherosperma moschatum	N	U1				
Atriplex nummularia **b**	N	U5				
Backhousia citriodora	N	U4		At risk	Yes	Clones, seed
Banksia integrifolia	N	S5				
Blephocarya involucrigera	N					
Brachychiton populneus	N	U5				
Callitris columellaris	N					
C. endlicheri	N	U1				
C. glauca	N	U1				
C. intratropica	N					
C. oblonga	N			Vulnerable		
Callitris oblonga subsp. *oblonga*	N			Vulnerable		
C. preissii	N		Yes			

Species	Origin	Use	Invasive?	Threat level	Trials	Reproductive material
C. robusta	N		Yes			
Canarium australianum	N					
Cassia brewsteri	N	U4			Yes	
Castanospermum australe	N	U1				
Casuarina cristata	N	S1			Yes	
C. cunninghamiana **b**	N	U1,U3,S1				
C. equisetifolia **b**	N/E	U1,U2,U3				
C. glauca	N	S1				
C. obesa	N	S1				
Citrus australasica	N	U4				
C. glauca	N	U4				
Citrus hybrid 'Australian Sunrise'	E	U4				
Corymbia citriodora subsp. *citriodora*	N	U1,U4			Yes	Orchard seed
C. citriodora subsp. *variegata* **b**	N	U1			Yes	Orchard seed
C. clandestina	N			Vulnerable		
C. henryi	N	U1			Yes	Orchard seed
C. leptoloma	N			Vulnerable		
C. maculata **b**	N	U1,S1			Yes	Orchard seed
C. rhodops	N			Vulnerable		
C. torelliana	N	S5			Yes	
C. xanthope	N			Vulnerable		
Cupressus lusitanica	E	S5	Yes			
C. macrocarpa **b**	E	U5	Yes		Yes	
Elaeocarpus grandis	N	U4				
Erythrophleum chlorostachys	N	U1				
Eucalyptus absita	N			Endangered		
E. acaciiformis var. *linearis = E. nicholii*	N			Vulnerable		
E. accedens	N	U5				
E. acmenioides	N	U1			Yes	
E. agglomerata	N	U1			Yes	
E. alligatrix subsp. *limaensis*	N			Vulnerable		
E. alligatrix subsp. *miscella*	N			Vulnerable		
E. aquatica	N			Vulnerable		
E. archeri	N					
E. argillacea	N					
E. argophloia **b**	N	U1,U3,S1		Vulnerable	Yes	Orchard seed
E. argutifolia	N			Vulnerable		
E. articulata	N			Vulnerable		
E. astringens	N	S1			Yes	
E. badjensis	N		Yes		Yes	
E. balanites	N			Endangered		

Species	Origin	Use	Invasive?	Threat level	Trials	Reproductive material
E. barberi	N					
E. baxteri	N					
E. beaniana	N			Vulnerable		
E. beardiana	N			Endangered		
E. bennettiae	N			Vulnerable		
E. benthamii **b**	N	U1,U2,U3	Yes	Vulnerable	Yes	Orchard seed
E. biterranea	N					
E. bosistoana	N	U1			Yes	
E. botryoides	N	U1			Yes	
E. brassiana	N	U1,U2				
E. brevipes	N			Endangered		
E. brookeriana	N			At risk		Orchard seed
E. burdettiana	N			Endangered		
E. cadens	N			Vulnerable		
E. caleyi subsp. *ovendenii*	N			Vulnerable		
E. camaldulensis **b**	N	U1,U2, U3,S1	Yes	At risk (locally)	Yes	Orchard seed, cuttings
E. camfieldii	N			Vulnerable		
E. cannonii	N			Vulnerable		
E. ceracea	N			Vulnerable		
E. cerasiformis	N			Vulnerable		
E. cladocalyx **b**	N	U1,U4, U5,S1	Yes		Yes	Orchard seed
E. cloeziana **b**	N	U1	Yes		Yes	Orchard seed
E. cneorifolia	N					
E. conglomerata	N			Endangered		
E. coolabah	N					
E. copulans	N			Endangered		
E. cordata	N					
E. cornuta	N					
E. coronata	N			Vulnerable		
E. crebra **b**	N	U1,U3,S1	Yes			
E. crenulata	N			Endangered		
E. crispata	N			Endangered		
E. crucis subsp. *crucis*	N			Vulnerable		
E. crucis subsp. *praecipua*	N			Endangered		
E. cuprea	N			Endangered		
E. deglupta	E	U1				
E. delegatensis	N	U1				
E. diversicolor	N	U1			Yes	
E. dives	N					
E. dolorosa	N			Endangered		
E. dorrigoensis	N	U1,U2,U3				

Species	Origin	Use	Invasive?	Threat level	Trials	Reproductive material
E. dunnii **b**	N	U1,U2	Yes	Locally threatened	Yes	Orchard seed
E. exserta	N					
E. fastigata	N	U1				
E. fraxinoides	N	U1				
E. glaucescens	N				Yes	
E. glaucina	N			Vulnerable		
E. globoidea	N	U1				
E. globulus **b**	N	U1,U2	Yes	Locally threatened	Yes	
E. globulus subsp. *maidenii* **b**	N	U1,U2				
E. gomphocephala	N					
E. grandis **b**	N	U1,U2	Yes		Yes	Orchard seed
E. gunnii	N			Endangered		
E. gunnii subsp. *divaricata*	N			Endangered		Orchard seed
E. hallii	N			Vulnerable		
E. hemiphloia	N	U1,U3				
E. horistes **b**	N	U4,S1	Yes		Yes	
E. imlayensis	N			Endangered		
E. impensa	N			Endangered		
E. infera	N			Vulnerable		
E. insularis	N			Endangered		
E. johnsoniana	N			Vulnerable		
E. johnstonii	N					
E. kabiana	N			Vulnerable		
E. kartzoffiana	N			Vulnerable		
E. kochii	N	U4				
E. laevopinea	N					
E. langleyi	N			Vulnerable		
E. lateritica	N			Vulnerable		
E. leprophloia	N			Endangered		
E. longirostrata	N	U1,U3,S1	Yes			
E. loxophleba	N	U4,S1	Yes			Orchard seed
E. leucoxylon	N	U3,S1	Yes		Yes	
E. macarthurii	N	U1				
E. macrandra	N			Vulnerable		
E. macrorhyncha	N					
E. macrorhyncha subsp. *cannonii*	N			Vulnerable		
E. major	N	U1,S1			Yes	
E. marginata	N	U1	Yes			
E. mckieana	N			Vulnerable		
E. melliodora **b**	N	U4,S1	Yes		Yes	
E. merrickiae	N			Vulnerable		

Species	Origin	Use	Invasive?	Threat level	Trials	Reproductive material
E. microcorys	N	U1				
E. microtheca	N			Locally threatened		
E. mitrata	N			Vulnerable		
E. molucanna	N				Yes	
E. mooreana	N			Vulnerable		
E. morrisbyi	N			Endangered		Orchard seed
E. morrisii	N					
E. muelleriana	N	U1			Yes	Orchard seed
E. nicholii	N	S5		Vulnerable		
E. nitens **b**	N	U1,U2	Yes		Yes	Orchard seed
E. obliqua	N	U1	Yes			
E. occidentalis **b**	N	U1,S1	Yes		Yes	Orchard seed
E. ochrophloia	N					
E. ovata	N					
E. pachycalyx subsp. *banyabba*	N			Endangered		
E. pachycalyx subsp. *waajensis*	N			Endangered		
E. paedoglauca	N			Vulnerable		
E. paludicola	N			Endangered		
E. parramattensis subsp. *decadens*	N			Vulnerable		
E. parvifolia	N			Vulnerable		
E. parvula	N			Vulnerable		
E. pellita **b**	N/E	U1,U2,U3	Yes		Yes	Orchard seed
E. perriniana	N	S5		At risk		Orchard seed
E. phylacis	N			Endangered		
E. pilularis	N	U1	Yes		Yes	Orchard seed
E. platydisca	N			Vulnerable		
E. polybractea **b**	N	U4,S1	Yes		Yes	Orchard seed
E. propinqua	N	U1	Yes		Yes	
E. pruiniramis	N			Endangered		
E. pulverulenta	N			Vulnerable		
E. pulvigera	N			Vulnerable		
E. pumila	N			Vulnerable		
E. punctata	N	U2,S1	Yes		Yes	
E. quadrangulata	N	U1				
E. radiata	N	U4	Yes		Yes	Orchard seed
E. raveretiana	N			Vulnerable		
E. recta	N			Endangered		
E. recurva	N			Endangered		
E. reducta	N					
E. regnans	N	U1	Yes		Yes	
E. remota	N					

Species	Origin	Use	Invasive?	Threat level	Trials	Reproductive material
E. resinifera	N	U1			Yes	
E. rhodantha var. *rhodantha*	N			Vulnerable		
E. risdonii	N					
E. robertsonii subsp. *hemisphaerica*	N			Vulnerable		
E. robusta	N	U1				
E. rubida subsp. *barbigerorum*	N			Vulnerable		
E. rubida subsp. *canobolensis*	N			Endangered		
E. rudis **b**	N	S1				
E. saligna **b**	N	U1	Yes		Yes	Orchard seed
E. scoparia	N			Vulnerable		
E. sideroxylon **b**	N	U1,U3	Yes		Yes	
E. sieberi	N	U1			Yes	
E. smithii **b**	N	U2,U4	Yes		Yes	Orchard seed
Eucalyptus sp. Howes Swamp Creek	N			Vulnerable		
E. steedmanii	N			Vulnerable		
E. strzeleckii	N			Vulnerable		
E. suberea	N			Vulnerable		
E. synandra	N			Vulnerable		
E. tereticornis **b**	N	U1,U2,U3	Yes		Yes	
E. tetrapleura	N			Vulnerable		
E. tetrodonta	N					
E. tricarpa **b**	N	U1,U3	Yes		Yes	Orchard seed
E. urophylla **b**	E	U1,U2				
E. vernicosa	N	S5				Orchard seed
E. viminalis	N	U1				
E. virens	N			Vulnerable		
E. wandoo	N					
E. wetarensis	E	U1				
E. youmanii	N					
Eucryphia lucida	N	U4				
Flindersia australis	N					
F. brayleyana	N					
Grevillea pteridifolia	N					
G. robusta **b**	N	U1,S5	Yes		Yes	Orchard seed
Khaya senegalensis **b**	E	U1	Yes			
Kunzea pomifera	N	U4				
Leptospermum petersonii	N	U4			Yes	
Leucaena leucocephala	E	U5	Yes			
Lophostemon confertus	N	U1				
Macadamia integrifolia	N	U4		Vulnerable		

Species	Origin	Use	Invasive?	Threat level	Trials	Reproductive material
M. tetraphylla	N	U4		Vulnerable		
Maranthes corymbosa	N/E					
Melaleuca alternifolia **b**	N	U4	Yes		Yes	Orchard seed
M. cajuputi	N/E	U4				
M. halmaturorum	N					
M. leucadendra	N/E	U4				
M. uncinata	N	U4				
Melia azedarach	N/E	U1	Yes			
Nothofagus cunninghamii	N	U1				
Pinus brutia	E	U1	Yes		Yes	Orchard seed
P. canariensis	E	S5	Yes			
P. caribaea **b**	E	U1	Yes			
P. caribaea var. *bahamensis*	E	U1	Yes		Yes	Orchard seed
P. caribaea var. *caribaea*	E	U1	Yes			
P. caribaea var. *hondurensis* **b**	E	U1	Yes			
P. elliottii **b**	E	U1	Yes		Yes	
P. halepensis	E		Yes			
P. pinaster **b**	E	U1	Yes		Yes	Orchard seed
P. radiata **b**	E	U1,U2	Yes		Yes	
Pittosporum undulatum	N		Yes			
Santalum acuminatum	N	U4			Yes	
S. album **b**	E	U4	Yes		Yes	
S. lanceolatum	N					
S. spicatum **b**	N	U4	Yes			
Senna siamea	E	U4				
Sesbania formosa	N	U4				
Syncarpia glomulifera	N	U1				
Syzygium armstrongii	N					
S. forte	N					
S. nervosum	N					
Tasmannia lanceolata	N	U4				
Tectona grandis	E	U1	Yes			
Toona ciliata **b**	N	U1				
Wollemia nobilis	N	S5		Endangered		
2. Lower priority exotics						
Acacia peregrinalis	E		Yes			
Azadirachta indica	E	U4	Yes		Yes	
Betula pendula	E	S5				
Casuarina junghuhniana	E		Yes			

Species	Origin	Use	Invasive?	Threat level	Trials	Reproductive material
Chukrasia tabularis	E		Yes			
C. velutina	E		Yes			
Cupressus sempervirens	E	S5	Yes			
Ficus carica	E		Yes			
Miconia calvescens	E		Yes			
Morella faya	E		Yes			
Parkinsonia aculeata	E		Yes			
Paulownia tomentosa	E	U1	Yes			
Picea abies	E	S5	Yes			
Pinus contorta	E		Yes			
P. jeffreyi	E		Yes			
P. muricata	E		Yes		Yes	
P. nigra	E		Yes			
P. oocarpa	E				Yes	
P. pinea	E		Yes			
P. ponderosa	E		Yes			
P. sylvestris	E		Yes			
P. taeda	E	U1	Yes		Yes	
P. tecunumanii	E					
Pistachia chinensis	E	S5	Yes			
Pterocarpus indicus	N/E					
Swietenia humilis	E					
S. macrophylla	E					
Terminalia microcarpa	E					
3. Woody exotic invasive species						
Acacia catechu	E		Yes			
A. farnesiana	E		Yes			
A. fleckii	E					
A. karroo	E		Yes			
A. laeta	E		Yes			
A. nilotica	E		Yes			
Ailanthus altissima	E		Yes			
Annona glabra	E		Yes			
Caesalpinia decapetala	E		Yes			
Calotropis procera	E		Yes			
Cinnamomum camphora	E		Yes			
Citharexylum spinosum	E		Yes			
Crataegus monogyna	E		Yes			
Dalbergia sissoo	E		Yes			
Eugenia uniflora	E		Yes			
Ligustrum lucidum	E		Yes			

Species	Origin	Use	Invasive?	Threat level	Trials	Reproductive material
L. sinense	E		Yes			
Phoenix canariensis	E		Yes			
Pithecellobium dulce	E		Yes			
Podocarpus dalcatus	E		Yes			
Prosopis glandulosa	E		Yes			
P. pallida	E		Yes			
Psidium cattleianum	E		Yes			
P. guajava	E		Yes			
Rhamnus alaternus	E		Yes			
Ricinus communis	E		Yes			
Robinia pseudoacacia	E		Yes			
Salix cinerea	E		Yes			
Schinus terebinthifolius	E		Yes			
Solanum mauritianum	E		Yes			
Spathodea campanulata	E		Yes			
Syzygium cumini	E		Yes			
Tamarix aphylla	E		Yes			
T. ramosissima	E		Yes			
Ulex europaeus	E		Yes			
Ziziphus mauritiana	E	U4	Yes			

a Used as a host for parasitic *Santalum* spp. (sandalwood). **b** Species of particular Australian and/or international importance for forestry (genetic priority species) based on recent reviews (Bush 2011; Griffin et al. 2011; Harwood 2011; Harwood et al. 2007; Shepherd et al. 2011) and the authors' assessments.

Sources: This table is derived from the list of Australian species in the REFORGEN database (FAO 2012a) updated by ABARES and ATSC.

Glossary

ABARES	Australian Bureau of Agricultural and Resource Economics and Sciences
ACIAR	Australian Centre for International Agricultural Research
ATSC	Australian Tree Seed Centre
AuSCaR	Australian Seed Conservation and Research
CAR	comprehensive, adequate and representative
CRA	comprehensive regional assessment
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DAFF	Department of Agriculture, Fisheries and Forestry
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
FAO	Food and Agriculture Organization of the United Nations
FPC	Forest Products Commission
FWPA	Forest & Wood Products Australia Limited
IBIS	Integrated Botanical Information System
IP	intellectual property
IPPC	International Plant Protection Convention
IUCN	International Union for Conservation of Nature
IUFRO	International Union of Forest Research Organizations
MPIGA	Montreal Process Implementation Group for Australia
NFI	National Forest Inventory
NFPS	National Forest Policy Statement
NPI	National Plantation Inventory
NRMMC	Natural Resource Management Ministerial Council
PBR	Plant Breeder's Rights
REFORGEN	FAO global system on forest genetic resources
RFA	regional forest agreement
RIRDC	Rural Industries Research and Development Corporation
SPRAT	Species PRofile and Threats (database)
STBA	Southern Tree Breeding Association
WTO	World Trade Organization

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