Criterion 5

Maintenance of forest contribution to global carbon cycles

This criterion, which comprises only one indicator, quantifies and reports the effects of forest management and forest land-use change on greenhouse gas emissions and sequestration. Forests are an important component of the global carbon cycle, and the flux in forest carbon stocks is a key indicator of sustainable forest management.

Forests NSW

Cross-section of radiata pine (*Pinus radiata*). Annual growth sequesters carbon dioxide from the atmosphere; wider rings near the centre indicate faster growth and therefore more rapid uptake of carbon dioxide. During photosynthesis, about one tonne of carbon dioxide is captured from the atmosphere and combined with water taken up from the soil to produce about one cubic metre of wood. About 0.7 tonnes of oxygen is returned to the atmosphere.

Key findings

- Australia's forests sequester (absorb) more greenhouse gases from the atmosphere than they emit (release) and therefore help to offset Australia's contribution to global greenhouse gas emissions. Plantations offset about 3.5% and managed native forests about 5.5% of total Australian greenhouse gas emissions in 2005. Additional storage in wood products offset a further 1% of emissions.
- Deforestation, mainly for agriculture but also for urban development, was responsible for about 9% of total Australian greenhouse gas emissions in 2005. Carbon emissions from deforestation declined from about 70 million tonnes in 2002 to 53.3 million tonnes in 2005.
- A net amount of greenhouse gases equivalent to 43.5 million tonnes of carbon dioxide (11.9 million tonnes of carbon) was sequestered in managed native forests in 2005. About 3.8 million tonnes of carbon, or 0.06% of the total stock of biomass carbon in native forests, was removed yearly as roundwood (logs). Therefore, in 2005, about three times more carbon was sequestered than was removed or emitted in managed native forests subject to harvest and regrowth from prior harvest.
- Extensive wildfires in native forests during the reporting period released large amounts of greenhouse gases into the atmosphere. Over time, those emissions are expected to be offset by new forest growth since total native forest carbon stocks have changed little over the long term (i.e. 1989–2004).
- Fire in managed native forests caused greenhouse gas emissions equivalent to 1.3 million tonnes of carbon dioxide in 2005, a year of below-average fire impact (Indicator 1.3b). Those emissions were likely replaced in subsequent new forest growth.

Indicator 5.1a

Contribution of forest ecosystems and forest industries to the global greenhouse gas balance

Rationale

This indicator provides information on the contribution of Australian forests to the global carbon cycle. Forest management can have a significant positive or negative impact on the global carbon cycle.

Key points

- Australia's forests sequester (absorb) more greenhouse gases from the atmosphere than they emit (release) and therefore help to offset Australia's contribution to global greenhouse gas emissions.
- A net amount of greenhouse gases equivalent to 43.5 million tonnes of carbon dioxide was estimated to be sequestered in managed native forests in 2005.
- Plantations offset about 3.5% and managed native forests about 5.5% of total national greenhouse gas emissions in 2005. Additional storage in wood products offset a further 1% of emissions.
- The removal of carbon from native forests by timber harvesting was relatively constant over the period from 2001 to 2005: about 3.8 million tonnes of carbon or 0.06% of the total stock of biomass carbon in native forests was removed annually as roundwood.
- Extensive wildfires in native forests during the reporting period released large amounts of greenhouse gases to the atmosphere. Over time, those emissions are expected to be offset by new forest growth.
- Fire in managed native forests caused greenhouse gas emissions equivalent to 1.3 million tonnes of carbon dioxide in 2005. Those emissions will likely be replaced progressively in subsequent new forest growth.
- Deforestation, mainly for agriculture but also for urban development, was responsible for about 9% of total national greenhouse gas emissions in 2005.
- Carbon emissions from deforestation declined from about 70 million tonnes in 2002 to 53.3 million tonnes in 2005.

International concern about the effects of increased atmospheric concentrations of greenhouse gases, such as carbon dioxide (CO_2), on climate has focused attention on the global carbon cycle.[1] This indicator quantifies and reports on the effects of forest management and forest land-use change on net greenhouse gas balances at the national level.

Forests account for almost 60% of the carbon that exists in the vegetation and soils of the earth's land surface.[2] They absorb carbon dioxide from the atmosphere during photosynthesis and release it by respiration and the decay or burning of plant material. Forests can remove carbon dioxide from the atmosphere and store it in woody tissue in early-to-mid successional phases, but in mature forests the net exchange with the atmosphere is usually low, with the growth of young trees balanced by the death and decay of mature trees.

The amount of carbon stored in Australian forest landscapes can change over time because of:

- variation in climatic factors such as temperature and rainfall
- the natural developmental or successional dynamics of the forest
- disturbances such as harvesting, fire, storms and outbreaks of pests and diseases
- loss of forest area due to agricultural and urban expansion (clearing/deforestation[3])
- increases in forest area due to the establishment of commercial plantations and environmental plantings, the expansion and thickening of native forest, and the growth of exotic woody weeds.

1 Greenhouse gases other than carbon dioxide are accounted for here by converting them to carbon dioxide equivalents.

2 About half the dry weight of a tree is carbon. One tonne of carbon is equivalent to 3.67 tonnes of carbon dioxide.

3 Deforestation is used here to mean the conversion of forest land to cropland, grassland and urban infrastructure.

Forest management activities such as site preparation and planting, fertiliser application, spraying for pests and weeds, pruning and thinning can also influence the uptake and release of greenhouse gases. An aim of forest management is to minimise net greenhouse emissions within the constraints imposed by other management objectives. However, site-level greenhouse gas emissions should not be interpreted as a measure of sustainability. Rather, the greenhouse consequences of forest management are best interpreted at larger scales because it is the net effect across the landscape rather than local changes that influences the global atmosphere.

Once wood has left the forest, its role in the carbon cycle is determined by factors such as:

- change in the stock of wood and wood products in service
- the decay of redundant wood and paper products (mostly in landfill)
- the reduction of fossil-fuel emissions due to the substitution of wood for energy generation
- energy used and emissions produced during wood processing and transport.

Accounting for changes in carbon in the land sector is a significant challenge. The Australian Greenhouse Office (AGO) has developed the National Carbon Accounting System (NCAS) to calculate net greenhouse gas emissions and provide estimates for national reporting (see box).

According to the AGO, woody biomass (in plantations, commercial native forests and conservation forests) covers about 14% (108 million hectares) of Australia (Figure 46). This differs significantly from the estimates of forest cover given elsewhere in this report but is used in this indicator for the reasons outlined in Indicator 1.1a.

National Carbon Accounting System

The NCAS tracks emissions (sources) and removals (sinks) of greenhouse gases from Australian land-based systems. It underpins National Greenhouse Gas Inventory reporting and provides a basis for emissions projections. Significant land-based emissions and removals of greenhouse gases in Australia occur in the transition between forest and agricultural land uses; the integration of stock and change data on all forest and agricultural land is therefore essential.

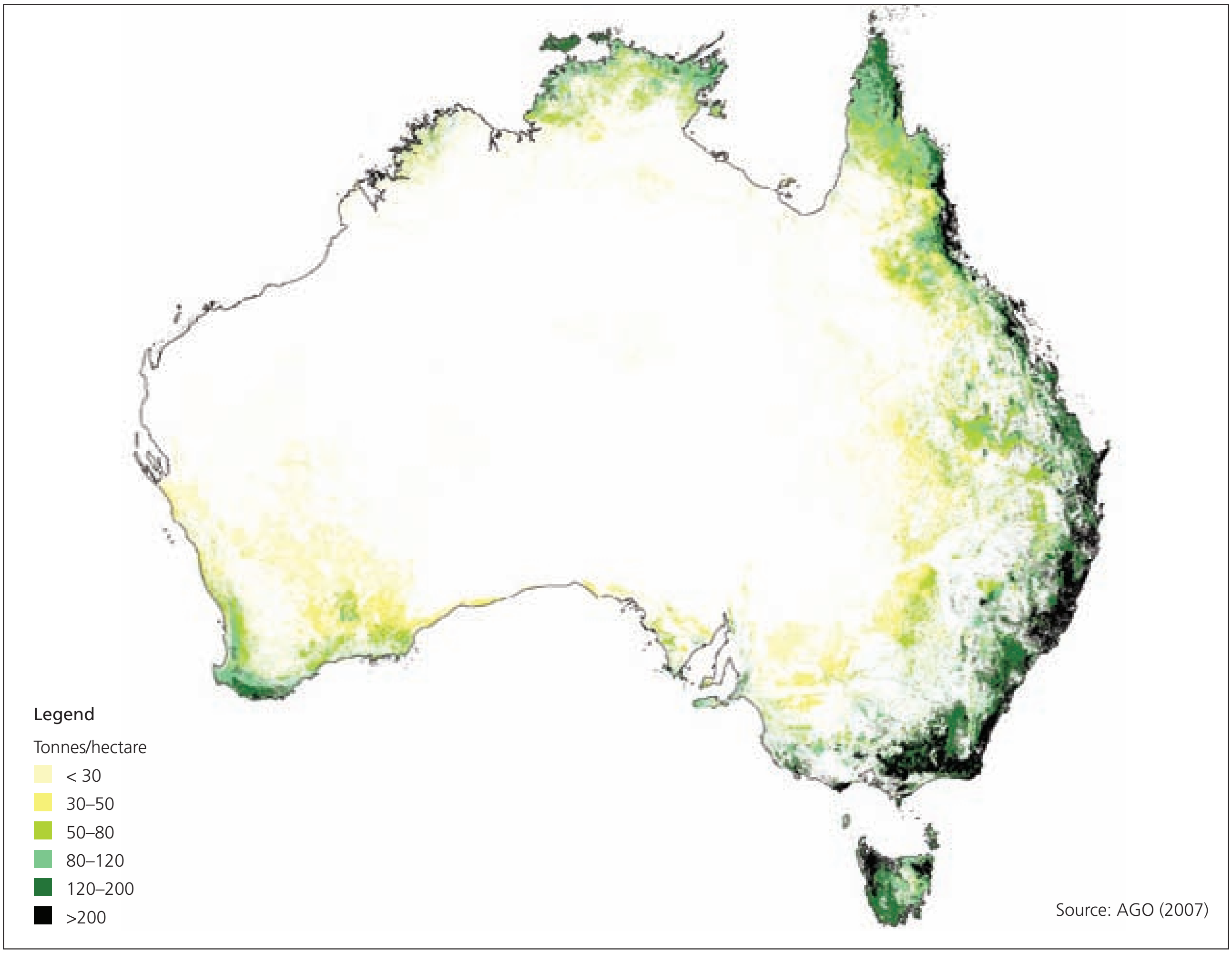
Early in the development of the NCAS, it was determined that sample-based measurement of carbon stock or stock change at the scales necessary for location-specific management or to monitor changes from pre-1990 levels was not feasible. Instead, an integrated approach using remote sensing, empirical and process modelling and intensive validation was adopted. Satellite images are used to determine changes in land cover, while a hybrid of verified empirical and process models is used to estimate the cycling of carbon and nitrogen in plant biomass, dead organic matter, soils and offsite products, and the emission and removal of greenhouse gases. This approach integrates a wide range of spatially referenced data and modelling to estimate carbon stock change and greenhouse gas emissions at fine temporal and spatial scales.

The implementation of the NCAS required the compilation of a critical mass of resource information based on relatively fine-scale, continent-wide satellite imagery for the 1972–2004 period. However, the total wooded area calculated by the AGO using those data differs from the area of forest estimated by the National Forest Inventory (NFI; Indicators 1.1a, 1.1b and 1.1c). The NFI estimates 149 million hectares of forest in Australia, while the AGO estimates a 'woody extent' of about 108 million hectares. Indicator 1.1a provides more information on the role of the NFI and the NCAS in meeting Australia's forest reporting needs.

Two different sets of rules are used in Australia for carbon accounting. One is under the United Nations Framework Convention on Climate Change (UNFCCC), the other under the Kyoto Protocol, which is an addition to that treaty. Carbon dioxide emissions from wildfire are not reported under either of these conventions. Kyoto Protocol rules do not count native forests and also exclude harvested wood products, with all the emissions assumed to occur at harvest. UNFCCC numbers include harvested wood products. Adopting an approach in carbon accounting that assumes that all emissions occur at harvest (as is the case under the Kyoto Protocol) gives a higher emission value than other approaches. In practice, a delay occurs in emissions following harvest because many wood products are stored in service for a significant time. The delay is increased when retention in landfill is also considered. Recent Australian research shows more than 95% of the carbon in wood remains in landfill after more than 30 years.

In this indicator, all carbon pools have been considered to the extent that available information allows. The exception is Table 82, which has been compiled using UNFCCC guidelines, with the separate addition of data on wood products in service.

Figure 46: Woody biomass distribution in Australia, 2004



Native forests

Australia's total tree biomass in native forests (i.e. above-ground woody biomass plus roots and including forests in conservation reserves but excluding soil carbon) held 6.56 billion tonnes of carbon in 2004 (Figure 47). This is equivalent to keeping 24 billion tonnes of carbon dioxide out of the atmosphere, or 46 years of Australia's current total emissions from all sources. It is also equivalent to about 3.3% of all the carbon emissions arising from human activities worldwide since 1800. Eucalypt open forests and open woodland together store 57% of the total carbon.

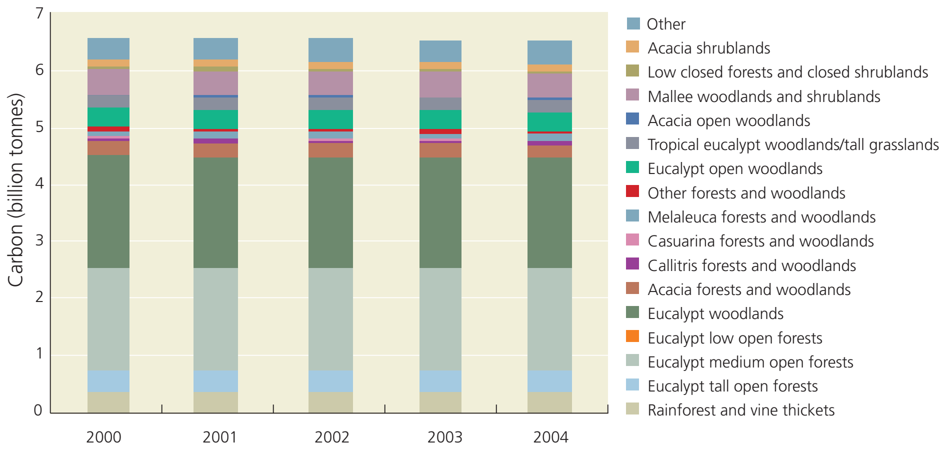
The amount of carbon in native forest total tree woody biomass reported here is about 20% lower than that reported in SOFR 2003. This is not a real decline; it is due partly to changes in the way forest extent is analysed and mainly to the fact that it is now possible to account for forest condition.

There was little real change in carbon in native forest total tree woody biomass in the period from 2000 to 2004, even though land clearing was still taking place, albeit at a lower level than previously reported (Figure 47). The amount of carbon held in native forest tree woody biomass is expected to increase as broadscale clearing of native forest (estimated by the AGO at about 260,000 hectares per year from 2000 to 2004) is reduced over time under legislative restrictions and as regrowth occurs in at least some previously cleared areas (Indicator 1.1d).

There was also almost no change (a decrease of 0.7%) between 1989 and 2004 in the amount of carbon held in native forest total tree woody biomass, although there was significant change in some forest groups (Table 76). Those groups that increased are generally known to have both thickened (i.e. the vegetation increased in density) and increased in extent, in some cases (such as the callitris forests and woodlands) probably due to reduced fire frequency. Those forest groups, such as eucalypt open woodlands, that decreased by more than 2% between 1989 and 2004 are known to have been affected the most by broadscale clearing, firewood collection and mortality due to a variety of causes, including different kinds of dieback and from bushfires. Other forest groups were probably in near-equilibrium, with growth about equal to decay.

Harvesting from managed native forests (that is, forests subject to harvest and regrowth from prior harvest) averaged around 11.8 million cubic metres of roundwood per year in the period from 2001 to 2005. About 3.8 million tonnes of carbon – equivalent to about 0.06% of the total carbon stored in native forests and 14.1 million tonnes of carbon

Figure 47: Total carbon in total tree biomass (above-ground plus roots) of native forests, 2000 to 2004, by forest vegetation group



Source: Derived from AGO data

dioxide – was removed.[4] This small removal was exceeded by new growth: about 43.5 million tonnes of carbon dioxide, equivalent to about 11.9 million tonnes of carbon, was estimated to have been sequestered in managed native forests in 2005 after taking into account the decay of slash produced during harvesting (Table 82). Therefore, yearly sequestration of carbon in 2005 was about three times yearly emissions and removals arising from managed native forests subject to harvest and regrowth from prior harvest.

Because the carbon stored in native forest biomass, including in nature conservation reserves, is 20 times more than that contained in forest plantations, wood in service and wood in landfill combined, it has a dominant effect on the overall amount of carbon stored by the forest sector. Harvesting (<1% of the native forest outside nature conservation reserves annually), planned and unplanned fires (see Indicator 3.1b) and other periodic and infrequent disturbances therefore had little impact on national average total native forest carbon stock over the longer term.

Plantations

Carbon stock in forest plantations rose during the reporting period (Figure 48), due almost entirely to the expansion and growth of hardwood plantations. In 2004, 84 million tonnes of carbon (equivalent to 308 million tonnes of carbon dioxide) was stored in the standing stock of plantation total tree biomass. This amount was equivalent to 53% of Australia's total annual emissions from all sources.

About 6 million tonnes of carbon – 6% of the total stock and equivalent to 22 million tonnes of carbon dioxide – was removed in the plantation log harvest in 2004. This was more than replaced by new growth, with total carbon stock rising by about 18% between 2000 and 2004, from 72 million to 85 million tonnes of carbon.

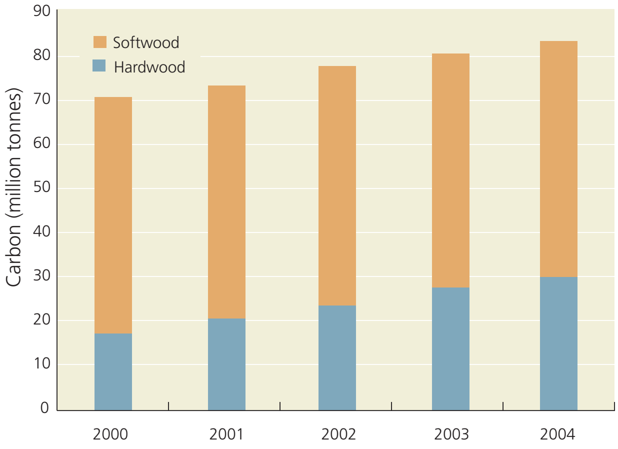
Table 76: Change in carbon storage in native forest total tree biomass (above-ground plus roots), 1989 to 2004

Forest vegetation groups with a net increase (+) of carbon over the period			Forest vegetation groups with a net decrease (–) of carbon over the period		
Forest type	Mt C	%	Forest type	Mt C	%
Acacia open woodlands	+2.6	+9.5	Melaleuca forests and woodlands	–5.8	–4.9
Acacia shrublands	+9.2	+7.9	Eucalypt open woodlands	–9.4	–2.8
Acacia forests and woodlands	+13.0	+5.5	Eucalypt tall open forests	–7.0	–1.9
Casuarina forests and woodlands	+0.9	+2.9	Low closed forest and closed shrublands	–1.0	–1.8
Tropical eucalypt woodlands/tall grasslands	+4.7	+2.4	Mallee woodlands and shrublands	–7.4	–1.7
Callitris forests and woodlands	+1.1	+2.1	Eucalypt low open forests	–0.4	–1.5
Other	+4.2	+1.1	Eucalypt medium open forests	–27.6	–1.5
			Other forests and woodlands	–0.9	–1.4
			Rainforest and vine thickets	–3.9	–1.0
			Eucalypt woodlands	–17.6	–0.9

Mt C = million tonnes of carbon
Source: Derived from AGO data

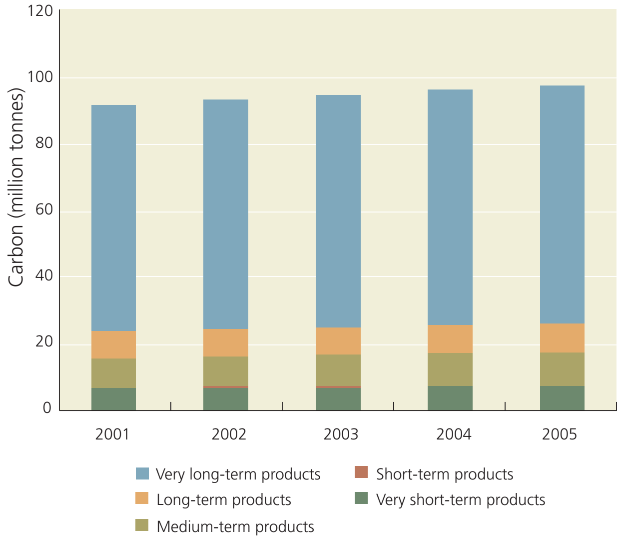
4 Roundwood removals include saw and veneer logs, sleepers, wood-based panels, paper and paperboard, fencing, mining timbers, poles and piles. The density of carbon in hardwood is assumed to be 0.325 t C/m^3.

Figure 48: Carbon storage in forest plantations, 2000 to 2004



Source: Derived from AGO data

Figure 49: Carbon stored in wood products in service, 2001 to 2005



Note: See Richards et al (2007) for an explanation of the components of each of the five product pools. In general terms, the range is: very short term, 1–3 years; short term, 3–10 years; medium term, 10–30 years; long term, 20–50 years; very long term, 30–90 years.

Source: Derived from AGO data

Carbon stored in wood products in service

The AGO has developed a model to estimate carbon flux in wood products. It accounts for logs harvested within Australia from native forests and plantations, processing, imports and exports, recycling, entry and decomposition in landfill, use for bioenergy and other losses to the atmosphere. The model was derived using production, consumption, export and import data reported since recording began in 1944.[5]

On average, carbon accumulated in wood products in service by 1.6% per year in the period from 2001 to 2005 (Figure 49), the bulk of it stored in very long term products such as timber used for construction. In 2004, 97 million tonnes of carbon was stored in wood products in service, equivalent to 356 million tonnes of atmospheric carbon dioxide and 61% of Australia's total annual emissions from all sources.

Carbon stored in wood products in landfill

Total net carbon stock in wood and wood products in landfill increased by about 2.3% per year in the period from 2001 to 2005 (Figure 50), due almost entirely to a rise in the volume of very short term products such as paper. Landfill volumes of very long term products such as waste timber remained constant. One reason for this is that much timber is now recycled, with demand for recycled solid wood close to exceeding supply. In 2004, 143 million tonnes of carbon (equivalent to 525 million tonnes of carbon dioxide) was stored in landfill. This was nearly 50% more than for wood products in service and 90% of Australia's total annual emissions from all sources.

The inclusion or exclusion of the landfill carbon store (and therefore emissions from landfill) is very significant for the forest sector. The annual increases in the landfill carbon store in effect provide a growing base for additional emissions. Future annual emissions from this store could potentially exceed inputs. At issue particularly, is uncertainty over greater methane (CH_4) emissions from landfill, although these are increasingly flamed off (a burning process that converts methane to the less greenhouse-powerful carbon dioxide) or captured and used for energy production (offsetting the need for fossil fuels). Further research is required to determine the proportions of carbon emitted as carbon dioxide and methane from landfill.

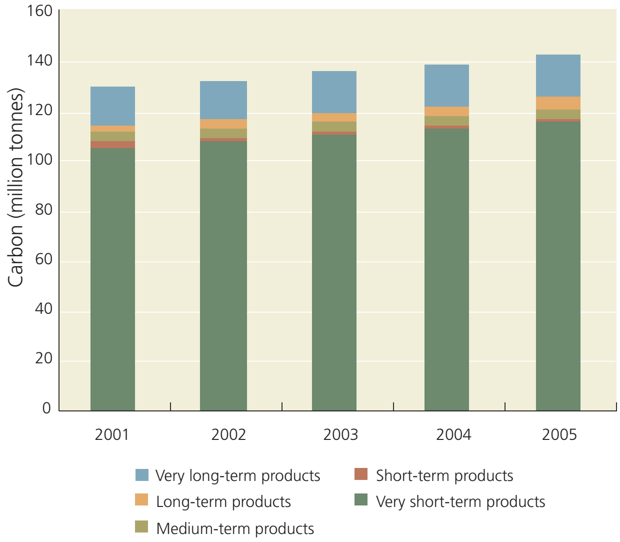
Forest soils

Uncertainty exists in the calculation of the flow of carbon into and out of forest soils. On-ground carbon (in litter) and below-ground carbon (in organic matter) are important in the carbon cycle, but soil carbon is difficult and expensive to measure. Soil type is an important factor, with higher clay content leading to greater carbon-carrying capacity. Climate is also a factor: carbon-carrying capacity tends to decline in drying soils and increase in moistening soils.

The AGO has estimated carbon both in biomass (above-ground and roots) and in soils for Australia's native forest types in 2004 (Table 77).

5 Richards et al (2007).

Figure 50: Carbon stock in products in landfill, 2001 to 2005



Note: See Richards et al (2007) for an explanation of the components of each of the five product pools. In general terms, the range is: very short term, 1–3 years; short term, 3–10 years; medium term, 10–30 years; long term, 20–50 years; very long term, 30–90 years.

Source: Derived from AGO data

On average, soil carbon constitutes about 46% of the carbon in the combined biomass and soil pools. Casuarina and callitris forests and woodlands contain the highest proportion of soil carbon, tropical eucalypt woodlands the lowest. Total soil carbon under native forest is 5.51 billion tonnes (20.2 billion tonnes carbon dioxide equivalent); this was equivalent to about 39 times Australia's total net greenhouse gas emissions from all sources in 2005.

In managed native forests (i.e. those forests subject to harvest and regrowth from prior harvest), change in soil carbon is believed to be insignificant because emissions caused by harvesting are balanced in a given inventory period by re-accumulation through regrowth. This reasoning is also used in the accounting rules set out by the UNFCCC.

Research by the Cooperative Research Centre for Greenhouse Accounting has shown that soils under forests and woodlands sometimes have more carbon in them than the agricultural systems they replace or are converted to, and sometimes less. For plantations, there is typically a long-term increase in soil carbon after some possible early losses. These effects are dependent on the pre-establishment condition and establishment technique (Polglase et al 2000). Notably, soil carbon stocks generally decline under pine plantations established on land that had previously carried pastures, but not on land formerly under broadleaved forests. In the case of pines, the loss of carbon is associated with a large loss of nitrogen from the soil.

Table 77: Carbon storage in soils in relation to biomass in native forest types, 2004

Vegetation type	Soil (Mt)	Biomass, including roots (Mt)	Biomass + soil (Mt)	Soil carbon as a proportion of total carbon (%)
Tropical eucalypt woodlands/tall grasslands	109.2	201.0	310.1	35.2
Other forests and woodlands	39.3	61.6	100.8	39.0
Acacia shrublands	82.9	126.4	209.3	39.6
Acacia open woodlands	20.9	30.2	51.1	40.9
Acacia forests and woodlands	180.4	247.0	427.4	42.2
Mallee woodlands and shrublands	328.9	432.3	761.2	43.2
Eucalypt woodlands	1,482.2	1,912.1	3,394.3	43.7
Low closed forests and closed shrublands	45.4	57.1	102.5	44.3
Rainforest and vine thickets	320.6	402.1	722.6	44.4
Eucalypt low open forests	19.5	24.0	43.5	44.8
Eucalypt tall open forests	303.3	356.4	659.7	46.0
Melaleuca forests and woodlands	98.6	111.4	210.0	46.9
Eucalypt medium open forests	1,674.4	1,795.8	3,470.2	48.2
Other	375.9	386.7	762.6	49.3
Eucalypt open woodlands	335.7	330.7	666.4	50.4
Callitris forests and woodlands	52.7	50.4	103.0	51.1
Casuarina forests and woodlands	37.1	30.9	68.0	54.5
Total native forest	5,506.7	6,556.1	12,062.8	45.7

Mt = million tonnes

Note: Soil carbon masses are for forest extant in 2004; estimates for later years and time-series data are not available. Soil carbon is relatively stable; the rate of change depends on initial soil carbon levels and past management practices. Masses have been determined from the available soil carbon inventory of native forest systems throughout Australia (Webbnet Land Resource Services 2002). Totals may not tally due to rounding.

Source: Derived from AGO data

Table 78: Summary of carbon storage in forests and wood products, Australia

	Stock (Mt)			
Storage pool and year	Carbon	Carbon dioxide	Annual change (%)	Storage as a percentage of Australia's net 2005 emissions (%)
Native forests, including conservation reserves (excluding soil carbon), 2004	6,560 (54%)	24,075	–0.3%	4,610[a]
Soil carbon under native forests in 2004	5,507 (46%)	20,210	Insufficient data	3,870[a]
Total carbon in native forests in 2004	12,065 (100%)	44,285	Insufficient data	8,480[a]
Plantations (excluding soil carbon), 2004	84	308	+4.6 (2001–04)	53
Wood and wood products in service, 2005	97	356	+1.5 (2001–05)	61
Wood and wood products in landfill, 2005	143	525	+2.3 (2001–05)	90

Mt = million tonnes

a Equivalent to 46, 39 and 85 years of Australia's 2005 net emissions from all sources (522.2 Mt CO_2 equivalents – see Table 82).

Source: Derived from AGO data

Research has improved models for determining soil carbon flux in major land-cover conversion from forest to non-forest where there are consistent large declines in carbon stocks. A model for soil carbon under plantations is expected to be available soon, but one for native forests will take longer because of the need to take into account a wide variety of ecosystems, forest types and maturation states.

Table 78 summarises carbon storage in forests and wood products in Australia.

Fire

Forest fires emit carbon dioxide, methane and other greenhouse gases. Severe forest fires have little impact on national forest carbon storage levels over the long term. For example, the 2002–03 Victorian and New South Wales alpine fires burned more than 1.3 million hectares (Indicator 3.1b) and were estimated to have released the equivalent of 40 million tonnes of carbon dioxide, or about 0.17% of the carbon stock in native forests. Biomass burning (planned and unplanned fire) in managed native forests used for timber production in 2005 caused an estimated 1.3 million tonnes of carbon dioxide equivalent emissions (Table 82), which was about 0.02% of the total native forest carbon stock. Those losses can be compared to the estimate that native forests managed for wood production (multiple-use public forests – 6% of Australia's forests) alone sequestered 43.5 million tonnes of carbon dioxide in new forest growth in one year (2005). Charcoal (black carbon) deposited during forest fires, although comprising only a few per cent of the original biomass, is a very long-term carbon storage sink.

Firewood

An estimated 4.5–5.5 million tonnes of firewood is burned for cooking and heating in Australia each year (see Indicator 2.1c), causing emissions equivalent to about 2.5–3.0 million tonnes of carbon (9–11 million tonnes of carbon dioxide). Nationally, firewood is consumed by about 23% of households, two-thirds of which are located in rural areas. Seventy two per cent of the locations where merchants source firewood are in low-rainfall, low-biomass forests.[6]

The use of firewood for domestic heating generally causes fewer greenhouse gas emissions than equivalent heating using other energy sources, such as gas and fossil-fuel-generated electricity,[7] although to some extent this is determined by the management regime operating in the forest and the efficiency of the burning process. Generally, little net carbon dioxide is produced per unit energy by efficiently (>60% efficiency) burning firewood collected from harvest residues and other materials obtained from sustainably managed native forests. Burning firewood collected from a coppiced plantation also produces very few greenhouse gas emissions, and may result in a net sequestration of carbon, because the use of coppicing avoids many of the emissions that occur in new plantations (e.g. those caused by nursery operations, weed control, cultivation and the planting of new seedlings). In plantations grown for sawlogs, the use of harvesting residues, thinnings and other material for firewood requires little energy over and above that used for producing the sawlogs.

Forest management and silviculture

The main greenhouse gas emissions from forest management and silviculture arise from the combustion of diesel fuel by machinery. In calculating those emissions, it is necessary to also take into account emissions caused by the original production of the diesel. The average value for production and consumption combined is 3.1 kg of carbon dioxide per litre (equivalent to 0.84 kg of carbon per litre).

Fuel usage rates for personal transport and chainsaw operation are negligible in a typical commercial forest harvesting operation. More significant is the fuel used in log extraction and transport. Estimates of diesel consumption

6 Driscoll et al (2000).

7 Paul et al (2003). Electricity generation in Australia from fossil fuels, mainly coal, usually produces about 1.0 kg CO_2/kWh.

Wood used in buildings is a long-term carbon sink.

rates in Tasmanian native forest operations range from 2.6 to 4.1 litres per tonne of green timber loaded onto a truck (assuming the operation of a skidder, an excavator at the landing and an excavator at the coupe workfront). If 4 litres is required, carbon dioxide emissions would be about 1.2% of that sequestered during tree growth.

Most new plantations are now established on former farmland. The establishment phase – site preparation, nursery maintenance and the planting of seedlings – is estimated to cause emissions of about 0.12 tonnes of carbon (0.44 tonnes of carbon dioxide) per hectare, which is about 1% of the average amount sequestered by plantations in one year (Table 79). Over the long term, carbon dioxide emissions caused by plantations are likely to be lower than those caused by agricultural production because, in contrast to annual crops, forest plantations need to be established only once in a 10–35-year period. It is estimated that, for a plantation rotation that includes up to three thinning events and the application of fertiliser and pesticides by helicopter, total carbon emissions are around 1.5% of the carbon sequestered in tree growth.

Transport

Given the size of Australia, emissions caused by the transport of products may be greater than those caused by production and processing. Lighter products such as wood require less energy to transport than materials such as steel and concrete. Moreover, it takes about 10 tonnes of raw material to make 1 tonne of cement and about 14 tonnes of iron ore to make 1 tonne of steel. While those raw materials are often found in very remote locations and need to be shipped long distances for processing, most plantations are close to urban centres and major transport routes. Many of the native forests used for timber production are also in or near the more populated regions of Australia.

Logs and sawn timber are mostly transported by road using diesel-fuelled trucks. Assuming diesel consumption of about 0.02 litres per tonne per kilometre and an average road-transport distance of 500 kilometres, carbon dioxide emissions caused by the transportation of the 22 million cubic metres (11 million tonnes) of timber and paper

Table 79: Carbon sequestered in some Australian plantations

Plantation type and location	Carbon sequestered in biomass (CO_2 equivalent)	
	t/ha/year	t/ha/rotation
WA, high rainfall[a]	63.9	639
Vic.[b]	55.4	997
Qld/NSW[c]	43.5	566
Tas.[d]	38.0	570
WA, low rainfall[e]	32.3	323
SA/Vic.[f]	25.1	879
NSW[g]	20.2	707
Average	~40[h]	~670

a 10-year-old *Eucalyptus globulus* plantation in the high-rainfall zone (1,023–1,450 mm) of southwest Western Australia.
b 18-year-old *E. globulus* plantation in southeast Gippsland, Vic.
c 13-year-old *E. grandis* plantation in southeastern Qld and northeastern NSW.
d 15-year-old *E. nitens* plantation in Tas.
e 10-year-old *E. globulus* plantation in the low-rainfall zone (590–950 mm) of southwest WA.
f 35-year-old *P. radiata* plantation (with three thinnings) in the Green Triangle of SA and Vic.
g 35-year-old *P. radiata* plantation (with three thinnings) in the ACT and southeastern NSW.
h Equivalent to 10.8 t/ha/year of carbon

Source: www.ensisjv.com/Portals/0/PlantationsAsCarbonSinks_Commentary.pdf (accessed July 2007)

products consumed by Australians each year would be about 333,000 tonnes, or 0.4% of total annual emissions by Australia's transport sector (Table 80).

Building with wood

Wood products normally require less energy to make and therefore emit less carbon dioxide during manufacture than alternative materials such as steel, concrete and aluminium.

Work is under way in Australia to produce a life cycle inventory for forests (softwood plantations and regrowth eucalypts) and about 100 wood products during 2008.

A typical wood-framed house provides net storage of carbon (Table 80), while a steel-framed house is a net emitter of carbon to the atmosphere (Table 81). This is reflected in the 'storage in harvested wood products' part of Australia's national carbon accounting (Figure 49). In one study applying the TimberCAM carbon-accounting model and excluding potential storage in paper products, it was estimated that up to 70% of the carbon in commercial logs remained in long-term storage, either in products in use or in landfill, or through avoided fossil-fuel use.[8]

8 Gardner et al (2004).

Table 80: Emission and storage of carbon in the manufacture of building materials (kg/m^3)

Building material	Carbon released in manufacture	Carbon stored in product	Net carbon released
Treated timber	22	250	–228[a]
Glue-laminated timber	82	250	–168[a]
Structural steel	8,132	15	8,117
Reinforced concrete	182	0[b]	182
Aluminium	6,325	0	6,325

a A negative value means carbon is stored for the life of the building.

b There is a tiny amount of carbon in the steel reinforcement. The long-term uptake of atmospheric carbon dioxide by concrete (carbonisation) is normally not considered: coatings and other means are usually applied to prevent carbonisation, as it can lead to the corrosion of the reinforcing steel.

Source: Buchanan and Honey (1994)

Table 81: Comparison of material use and effect on carbon storage for a typical 180m^2 house

	Wood-framed house	Steel-framed house
Frame only	13 m^3 of wood	5 t of steel
Total house	21 m^3 of wood	8 m^3 of wood
Total carbon stored (t)	9.7	3.7
Total carbon released to the atmosphere (t)	2.2	6.6
Balance of carbon – tonnes stored (+) or released to the atmosphere (–)	+7.5	–2.9

Note for Tables 80 and 81: New information is expected during 2008 from a life cycle inventory project on wood and wood products.

Source: Turner (1990)

Increasing the use of wood in buildings is therefore a way of significantly reducing Australia's carbon emissions. In New Zealand, new government-funded building projects for structures up to four floors, including the ground floor, will soon be required to at least consider options for using wood or wood-based products as the main structural materials. New building technologies should soon make it possible to replace greenhouse-gas intensive concrete, steel and aluminium with wooden construction in buildings up to 10 storeys high.

Energy from biomass

The wood by-products of timber harvesting, processing and recycling are one of the largest sources of biomass in Australia; an estimated 12 million tonnes (dry weight) of waste wood is generated each year, comprising about 4.2 million tonnes of harvesting residues, 2.8 million tonnes of processing residues and 5.3 million tonnes of salvaged wood (from recycling and demolition projects). The net availability of this wood for bioenergy production is estimated to be about 3 million tonnes across a wide range of regional locations. This amount could potentially be used to meet some of Australia's mandatory renewable energy target while still leaving sufficient residues in the forest to maintain biodiversity and site quality.[9] Of the residues, coarse woody debris is proving to be very important for invertebrate biodiversity.

Twelve billion tonnes of carbon was stored in the biomass and soils of Australia's native forests in 2004.

Australia already generates 650 megawatts (MW) of electricity from biomass; this substitutes for electricity that would otherwise be generated from fossil fuels and therefore offsets carbon dioxide emissions. Projects using or proposing to use woody biomass for energy include Delta Electricity's 60 MW bagasse/wood plant in New South Wales; co-firing wood operations in Liddell, Muja and Wallerawang; Visy's 20 MW co-generation plant at Tumut; Verve Energy's oil mallee project (1 MW initially, 5 MW later); two 45 MW plants by Beacons International; and a 40 MW plant by Western Australia Biomass Pty Ltd. The last three of these ventures are in southwestern Western Australia.

Plantation Energy plans to build a wood-pellet manufacturing plant in Albany, Western Australia, to manufacture and export energy pellets, mainly to Europe. It would source the feedstock from harvesting residues derived from the 120,000-plus hectares of blue gum plantations growing on previously cleared farmland in the Great Southern region; initial production is likely to be 145,000 tonnes a year. The blue gum plantations in the region are grown on a 10-year rotation. An average of 12,000 hectares will be harvested annually, producing more than 2 million tonnes of woodchips for export and around 600,000 tonnes of harvesting residues for bioenergy or other uses.

The pulp and paper sector is a significant user of energy, particularly in mechanical pulping processes. It is also a major producer of renewable energy, using processing waste such as black liquor from chemical pulping. The energy can be used on site or supplied to the electricity supply grid. The pulp and paper sector used more than 50,000 terajoules of

9 In 2007, the Australian Government set a renewable energy target of 20% by 2020.

energy in 2004–05, of which more than 11,000 terajoules (22%) was produced on site from biomass.

Wood wastes also generate a considerable part of the energy used for the kiln drying of timber. The manufacture of wood products generally requires less net energy than manufacture from competing materials.

Australian forestry's yearly carbon account

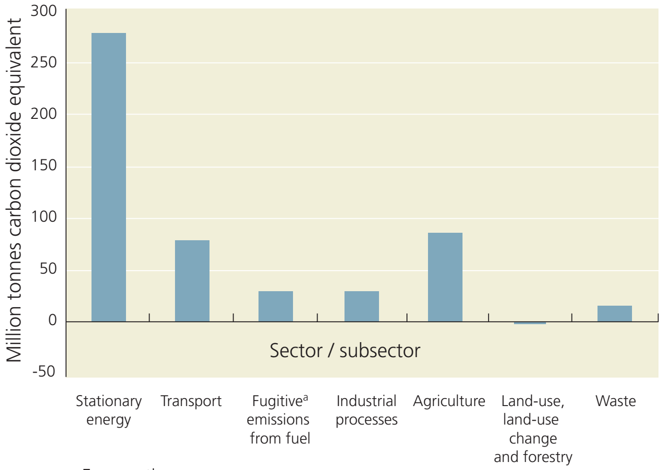
Table 82 summarises carbon sequestration and emissions in Australia's forests and agriculture in 2005.

Overall, native forests, plantations and wood products were net absorbers of greenhouse gases, sequestering a total of 56.5 million tonnes of carbon dioxide equivalent. However, deforestation – the conversion of forests mainly to agriculture – caused a total of 53.3 million tonnes of carbon dioxide equivalent (9% of total national emissions) to be emitted. The result is a net sequestration of 3.2 million tonnes of carbon dioxide equivalent.

Figure 51 shows that 'Land use, land-use change and forestry' was the only sector to show a net annual sequestration of carbon (more carbon stored than emitted), despite the emissions caused by clearing of forests. Forestry is one of the most greenhouse-friendly sectors of the Australian economy: it uses a renewable raw material and generates and uses renewable bioenergy through the burning of residues. Carbon dioxide emissions from forest management and industry are small compared to carbon dioxide sequestered in biomass in native forests and plantations and stored in wood and wood products, both in service and as waste in landfill. A continued reduction in forest clearing and increased use of wood in construction (long-term storage of carbon) will significantly assist Australia in offsetting its overall greenhouse gas emissions.

Commercial harvesting of firewood, Bairnsdale, Victoria.

Figure 51: Australia's net greenhouse emissions, by sector or subsector, 2005



a Evaporative

Source: AGO (2007)

Table 82: Sequestration and emissions in forests and agriculture, 2005

	Mt CO_2 equivalent greenhouse gases[a]	Proportion of total national emissions (%)[b]
Native forests		
Sequestration in managed native forests[c]	–43.5	
Biomass burning (prescribed fire and wildfire)	1.3	
Fuelwood used	10.4	
Net change in native forests	–31.9	~5.5
Plantations[d]		
Plantations established post-1990 on cleared land	–21.9	
Plantations established pre-1990	2.3	
Net change in plantations	–19.6	~3.5
Plantations plus managed native forests	–51.5	9
Wood products		
Storage in harvested wood products	–5.0	1
Agriculture	87.9	15
Deforestation (i.e. conversion to agriculture)	53.3	9
Total Australian emissions (before deducting sinks)	583.3	
Net Australian emissions (after deducting sinks)	522.2	

a A minus sign and green colour in this column means that greenhouse gases are removed from the atmosphere, while red indicates that greenhouse gases are emitted to the atmosphere.

b Green colour in this column means that greenhouse gases are removed from the atmosphere, while red indicates that greenhouse gases are emitted to the atmosphere.

c Forests subject to harvest and regrowth from prior harvest.

d Plantations established before 1990 are assumed to have been established by clearing native forests, even though a significant proportion was established on land that was already cleared. For plantations established after 1990, remote sensing data are used to distinguish the areas established on cleared sites from those established by clearing native forests.

Source: AGO (2007)

References and further reading

AGO (2005abcd, 2006, 2007), Australian Government (2007ab), Buchanan and Honey (1994), CRC for Greenhouse Accounting and FWPRDC (2006, reprinted 2007), Davidson et al (2008), Driscoll et al (2000), Gardner et al (2004), Markewitz (2006), Paul et al (2003), Perez-Garcia et al (2006), Polglase et al (2000), Raison et al (2003), Ranatunga et al (2008, in press), Richards and Brack (2004), Richards et al (2007), Roxburgh et al (2006), Turner (1990), Waterworth et al (2007), Webbnet Land Resource Services Pty Ltd (2002), Ximenes (2006) (list at the back of the report).

Web resources

Australian Greenhouse Office: www.greenhouse.gov.au

National Forest Inventory: www.daff.gov.au/brs/forest-veg/nfi

Integrated biomass fuel production plant, Narrogin, Western Australia.