coverage
currrency
frequency

Factors affecting forest health

Indicator 3.1a

Area and per cent of forest affected by processes or agents that may change ecosystem health and vitality

Rationale

Many agents can affect basic ecological processes in forests. Where these processes are altered beyond some critical threshold they may produce significant changes to the condition of the forest—hence the importance of monitoring this indicator.

Some factors that affect ecological processes in forests are biological (such as introduced species or tree diseases), while others are physical (such as fire, soil salinity or extreme weather events). Overall, there is considerable general information on both classes of factors but relatively little precise data on areas and percentages of forest affected.

As this indicator covers such a large subject area, it has been divided into sections. The following table (Table 59) gives an overview of the various issues covered, and whether they are perceived, by public land managers, as being problems in each State or Territory.

Table 59: Occurrences of processes or agents impacting on forest ecosystem health and vitality by State or Territory

Processes or agents impacting on forested areas	ACT	NSW	NT	Qld	SA	Tas	Vic	WA
Animal pests	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Insect pests	Yes	Yes	–	Yes	Yes	Yes	Yes	Yes
Weeds	Yes	Yes	–	Yes	Yes	Yes	Yes	Yes
Pathogens	Yes	Yes	–	Yes	Yes	Yes	Yes	Yes
Introduction of exotic biota[1]	–	Yes	–	Yes	Yes	Yes	Yes	–
Clearing	–	Yes	–	Yes	–	Yes	Yes	–
Grazing	–	Yes	–	Yes	–	–	Yes	–
River regulation	–	Yes	–	Yes	Yes	–	Yes	–
Salinisation and soil acidification	No	Yes	No	Yes	Yes	Yes	Yes	Yes
Mining	–	–	Yes	Yes	–	Yes	Yes	Yes
Fire	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Climatic events	–	Yes	Yes	Yes	Yes	Yes	Yes	–

Source: National Forest Inventory, 2003.

[1] Exotic biota is defined as any species not endemic to a locality

Fire in Australian forests

The degree of fire impacts varies significantly with location in Australia. The effects of fire are determined by the interaction of vegetation type, fire intensity, seasonality and fire history.

Fire is an inevitable, periodic event in most Australian forests that can have both positive and negative impacts on forest health and vitality. The impact of fire on the biota varies according to ecosystem sensitivity to fire, intensity and frequency, which in turn depends upon many factors including fuel availability, prevailing weather and the season. Whether started by humans or lightning, forest fires occur somewhere in Australia every year. However, although fire is an ecological disturbance, most forests are able to naturally regenerate, given appropriate climatic conditions, proximity to seed and sufficient recovery time between disturbances.

Although individual agencies within the States and Territories keep a range of statistics, there is no comprehensive national database on fire occurrence, cost and impact, and no standard protocol or custodian. Between April 1998 and March 1999, 14.3 million hectares (9 per cent) of Australia's forests were identified through remote sensing as having been burnt by fires. The following year 27.2 million hectares (17 per cent) were burnt by fire. These figures include both wild fires and fuel reduction burns. Furthermore, the definition of wildfire varies: in southern regions, concerted efforts are made to control wildfires; in remote locations in the north of Australia there is little or no control or management of fires.

Charcoal deposits in carbon dated sediments indicate that periodic bushfires have occurred in Australian forests for hundreds of thousands of years. Recurrent fires have been an evolutionary pressure on vegetation, favouring selection for protective mechanisms, and for the ability to regenerate after fires. Some species, especially acacia, require fire for their continued existence and regeneration.

Humans have provided sources of ignition for forest fires for at least 60 000 years. Indigenous people and more recently Europeans deliberately and accidentally caused fires. Indigenous people carried out frequent, regular and wide-scale burning, especially in the drier forest types. The net effect was a mosaic of burnt and unburnt patches. Fires in northern Australia are frequently associated with pastoralism and in these areas there has been little change in the fire regime and, consequently, virtually no change to bushfire hazard or occurrence over the last hundred years. In northern Australia the reduction in mosaic burning practices over the last two hundred years has been associated with fires that are more intense and cover a larger area than previously occurred. The intensity of these fires is still low compared to fires in southern Australia.

The frequency of intense fires in forests increased following European settlement. The increased frequency of intense fires was associated with a reduced occurrence of low intensity fires. For example, based on studies in jarrah (*E. marginata*) forests there was a decline from about three fires per decade under Indigenous management to about one fire per decade under post-European management. During the same time, the average frequency of fires sufficiently intense to cause scarring on trees increased from one in 82 years to one in 13 years.

Most Australian forests contain flammable vegetation and are naturally fire-prone. In addition, many parts of Australia experience periodic drought, which increases the flammability of forests and the likelihood of extensive fires. There is, however, a wide range in the type, frequency and intensity of fire occurrence across the country. Fire and its associated impacts generally decrease in intensity to the north as fire season changes from summer to spring and winter and fuel loads and intensity decrease. Fire is rare in the tropical rainforests of northern Australia and in the temperate and mixed rainforests and wet sclerophyll forests in parts of Tasmania and Victoria; however, even these areas can dry out during prolonged periods of drought and will then burn if ignited.

Fire is also rare in the more arid inland forests, where fuels do not accumulate readily because of low rainfall, relatively low biomass or steep rocky slopes. The quantities of fine fuels are also small in the rangelands used by the pastoral industry, because of grazing by native and exotic species. However, even in these areas large bushfires do occur. This is especially likely in the wake of a heavy wet season that promotes a dense grass and shrub layer which later dries out becoming available fuel when dry conditions return. Nevertheless, these inland forests and woodlands also possess a powerful regenerative capacity.

In the absence of fire, Australian forests—especially eucalypt—accumulate fine fuels reaching fluctuating equilibrium levels of up to 25 tonnes per hectare in 5 to 15 years depending on the forest type. Fuel arrangement also continues to change over time with the potential to increase fire intensity. Fuel comprises fallen leaves, twigs, logs and branches, the bark and foliage on tree trunks and crowns, and the flammable shrub layer. Although this can provide ecological benefits, under severe weather conditions, fires from such heavy fuel loads are extremely intense.

Fire impacts

Fire is a naturally occurring element of many Australian forests and from a human perspective has positive and negative impacts depending on the values and intensity of effects generated. Fires in forests impact on; (i) human lives, assets and values; and (ii) ecological processes and ecosystem structure, species composition, age and function. Fire management practices reflect a range of potentially conflicting objectives in an attempt to reduce the undesirable impacts on these values.

Burning native forest after harvest to promote regeneration

Impacts on people

While bushfires affect the health of forests in both positive and negative ways, their impact on human communities is usually characterised as negative because of the damage they can do to buildings, fences, bridges, power lines, water supplies and streams and commercial timber assets.

Impacts on ecological values

The degree of impact of fire on a forest ecosystem is variable. The rate of recovery after fire varies with the type of vegetation, and the intensity, season and history of previous fires. A range of other factors interact, including the reproductive capacity of the site (e.g., the seed bank), the proceeding climatic conditions, post fire grazing and predation and the prevalence of other disturbances. For example, the impact of a mild, patchy fire in dry sclerophyll forest may not be apparent one or two years later, while an intense fire in wet sclerophyll forest may trigger complete stand replacement, and affect flora, fauna, habitat and landscape for a century or more. Some plants and animals are fire adapted to the extent that they are dependent on periodic fire for habitat maintenance.

The structure and composition of northern savannah forests—as in the Northern Territory, north-western Queensland and the Kimberley region of Western Australia—appear to be a result of burning every year or so, especially where the understorey is dominated by cane grass. A fire in these areas can be very extensive, but the ecological impact is believed to be low, with complete ecosystem recovery apparently occurring within a few months. Variations in the fire frequency and season—between one and four year intervals and between lower intensity winter fires and hotter fires later in the year—are associated with shifts in structure and composition of the forest understorey.

The impact of a single fire is of lesser ecological interest than the cumulative impact of a fire regime. Fire regimes are expressed in terms of frequency (i.e., the interval between fires), intensity, distribution or patchiness of burnt areas, and the season of burning. Frequent low intensity fires can have a large impact compared with one-off, intense fires. Different combinations of these factors can benefit or disadvantage different elements of the ecosystem. Some plant and animal species, especially the 'pioneer species', benefit from frequent fires. Other species are favoured by long fire intervals; in fire-prone landscapes, these are provided for by protected situations such as deep sheltered gullies.

The most dramatic environmental impact is caused by large, high intensity fires. These result in localised and usually temporary loss of plants, animals and habitat, but also stimulate the regeneration of many plant species. The result of such fire can therefore be even-aged regeneration over wide areas, loss of species which prefer frequently or mildly burnt forest, and potential degradation of soils and waterways.

Understanding of forest fire ecology suffers from limited data, the time-frames over which recovery occurs and the complexity of interactions between fire regimes and forest types. Most is known about the ecological impacts of fairly frequent (<10 years interval), high intensity fires, especially in shrublands, woodlands and eucalypt forests around Sydney, New South Wales. There is some knowledge of the impacts of low intensity prescribed fires in eucalypt forests in southern Australia, as well as prescribed fires in tropical woodlands in northern Australia. Least is known about the long-term impacts of infrequent very high intensity fires. The very large and very intense forest fires which occurred in several parts of Australia in the 2002–2003 fire season provide an opportunity for further study.

Fire management

Early forest managers attempted to deal with the potential fire threat through a policy of fire exclusion. This policy remains in force today in some agricultural districts in southern Australia where the main assets are crops, pasture and domestic stock. The policy required that bushfires were rapidly located and suppressed by fire-fighting forces. In some forest areas this policy was also accompanied by strategic burning to remove accumulated forest fuels in narrow strips adjacent to railway lines, roads, farms and settlements.

Fire exclusion generally has not proved to be a successful means of dealing with fires in Australian forests. This is because ignition is inevitable—by lightning or humans. Fires can be very difficult to control, even under relatively mild weather conditions and with a large and expert fire-fighting force. Prescribed burning is not a fire management system in itself, but is only effective when it is an integral part of an holistic approach that also incorporates fire prevention, suppression, education and training, research and law enforcement.

Research findings have led to modifications in burning practices so as to take into account biodiversity values or to protect particular species or forest types, and to ensure smoke from prescribed burning does not cause smoke haze in urban areas. While prescribed burning has become increasingly sophisticated, it has also become more costly and difficult to conduct when these additional community values are applicable. This is especially true in Western Australia, Victoria and New South Wales.

Recent transfers of substantial areas of forest from multiple-use forests to nature conservation reserves have created debate in Australia about which fire regimes are most appropriate to balance protection of life and property with biodiversity and or timber production values.

Across all tenures, the primary aim of fire management is to protect life and property. After this requirement is met, managers of multiple-use forests have a responsibility to ensure that timber and environmental values are not destroyed by fire. Managers of nature conservation reserves have a responsibility to conserve biodiversity that may require a different mix of intensity and frequency to that needed to protect timber assets.

Further reading

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Erosion as a result of high intensity fire in native forest

Animal pests and weeds

There is little information on the extent and percentage of forest affected by animal pests and weeds. Programs to monitor and control damaging agents are in place in most States and Territories in plantations and, to a lesser degree, in native forests.

Australia's agricultural crops and exotic plantations have remained free of many of the major pests and diseases prevalent elsewhere. Native animals and plants have evolved with several pests and pathogens, most of which are listed below. There are strict quarantine procedures at both national and regional levels to minimise the risk of entry of pests and diseases.

In 2000 the National Forest Health Committee released a Generic Forest Incursion Management Plan to prepare for responses to potential new entries of exotic pathogens or invertebrate pests into Australia. A field guide to exotic pests and diseases of forests and timber has also been produced for forest health and quarantine officers. At a regional level, the spread of plant and insect pests and pathogens is controlled by local hygiene and quarantine restrictions.

Surveillance for pests and diseases in native and plantation forests is standard procedure. In some localities, there are control programs in place for feral cats, dogs, foxes, goats, horses, pigs, rabbits, cane toads and other animals, weeds and pathogens, particularly where the impacts are more severe. While the States and Territories collaborate on strategies to combat nationally significant pests, there are significant problems in reporting consistently on animal and plant pests on a national level. Compilations of assessments often combine quantitative data and expert opinion, which may vary within and between States and Territories. They are presented without reference to tenure, forest use or disturbance levels and therefore embody a wide range of perspectives on potential threats to forest health and vitality. For example, the same pest would be managed differently in the context of a nature conservation reserve, a plantation, a nursery and multiple-use forests.

Animal vertebrate pests

Animal (vertebrate) pests are responsible for a suite of destructive impacts including browsing and ring-barking of mature and juvenile vegetation, erosion, competition for food and habitat, and predation on native fauna.

Exotic Species

- Foxes occur across mainland Australia and have had significant impacts on populations of medium-sized ground-dwelling and semi-arboreal mammals. Extensive and expensive baiting control programs have reduced fox populations at some key sites but eradication is not foreseen. Foxes appear to have been recently introduced to Tasmania and The Fox Free Tasmania Taskforce has been established to manage control measures.
- Wild dogs and dingoes are widespread in Australian forests. Their impacts are likely to be greatest on medium to large macropods, however, control is driven largely by their impacts on livestock. Wild dogs and dingoes are usually controlled by baiting.
- Cats are widely distributed across Australia and their impacts are most apparent on small mammals, reptiles and invertebrates in the arid zone and ground-nesting birds particularly on off-shore islands. The impacts of cats on forest fauna is unclear. Given the difficulty in controlling cats using toxic baiting, broad area cat control has rarely been successful.
- Rabbits are a major agricultural and environmental pest across most of Australia. They are a major cause of soil erosion through the prevention of regeneration of native vegetation, foraging on foliage and ring-barking trees. Rabbits probably impact on a wide range of fauna via competition for food and habitat degradation. A concentrated and integrated management program exists for rabbits and includes biological (myxomatosis, calicivirus), chemical (baiting and fumigation) and mechanical control methods (shooting, fencing, warren destruction).

- Pigs have a severe and widespread impact on agricultural and native ecosystems across Australia, particularly in the ACT and Queensland. Rooting of soil causes physical damage and erosion, soil fauna is affected and some pathogens may be transmitted (for example, the fungal pathogen *Phytophthora cinnamomi*). Ground cover is destroyed, the composition of plant communities may change and invasion by weeds often ensues. However, the long-term impacts on plant communities in most ecosystems are unclear.

Native Species

- Adverse impacts on forestry are felt in most States and Territories from some abundant and widespread species of macropods (kangaroos and wallabies). Whilst a number of macropod species have been disadvantaged by European settlement (11 per cent of macropod taxa extinct, 25 per cent of taxa threatened) many species have remained stable or increased in numbers over this period. The presence of widespread and abundant macropods supports a significant industry in rural Australia, based on the sustainable harvesting of a renewable native resource, however such populations also compete with forestry interests, primarily through browsing damage to plantation seedlings and native forest regrowth.
  - For example, wallabies accounted for approximately 80 per cent of browsing damage on regenerated juvenile trees following forest harvesting in Victoria (1994–1996). In Tasmania, wallabies, pademelons and brushtail possums cause significant stocking losses and adversely impact on tree growth by the browsing of foliage in native forest regeneration less than two years old, and eucalypt and *Pinus radiata* plantation less than one year old. In a survey of a 40 hectare eucalypt plantation without browsing control, 77 per cent of seedlings lost more than 50 per cent of their foliage within 18 days of planting. Bark-stripping of young trees by wallabies is prevalent in 10-20 per cent of 3-5 year-old *Pinus radiata* plantations but mortality resulting from ring-barking (girdling) is rare. The use of 1080 poison and shooting are the most common browsing control methods used in Tasmania.
- Parrots are a serious problem in blue gum plantations in south-west Western Australia. The parrots ring-bark stems and cut off the tips of trees, which seriously reduces their commercial value. Parrots are also sometimes a problem in blue gum plantations in western Victoria and south-east South Australia.

A collated assessment by State and teritory jurisdications of the impact of the major animal pests of forest ecosystems is summarised in Table 60.

Table 60: The impact of animal vertebrate pests on ecosystem health and vitality in forest areas according to State or Territory

Animal vertebrate pests	ACT	NSW	NT	Qld	SA	Tas	Vic	WA
Mammals								
Native								
Dingo (*Canis familiaris dingo*)	3	4	1	3	0	–	1	1
Kangaroos (*Macropus* spp.)	5	3	3	3	3	1	3	1
Pademelons (*Thylogale* spp.)	–	1	–	3	0	4	0	–
Possums	3	1	1	3	1	5	1	1
Rats, native	1	1	3	3/4	0	4	3	3
Wallabies	1	3	3	3/4	3	5	5	3
Exotic								
European red fox (*Canis vulpes*)	5	4	1	5	3	2	3	5
Feral cat (*Felis cattus*)	4	4	4	5	–	1	–	3/4
Feral deer	–	3	1	1	1	2	3	–

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Table 60: The impact of animal vertebrate pests on ecosystem health and vitality in forest areas according to State or Territory

Animal vertebrate pests	ACT	NSW	NT	Qld	SA	Tas	Vic	WA
continued from previous page								
Feral dog (*Canis familiaris*)	3	4	3	3	0	–	1	–
Feral donkey (*Equus asinus*)	–	1	4	1	0	–	0	–
Feral goat (*Capra hircus*)	5	3	1	3	1	2	1	1
Feral horse (*Equus caballus*)	2	3	4	1	0	–	1	–
Hare (*Lepus capensis*)	3	1	–	3	5	–	1	–
House mouse (*Mus musculus*)	3	3	3	3	3	–	1	3
Pigs (*Sus scrofa*)	5	3	5	4	1	–	1	3
Rabbits (*Oryctolagus cuniculus*)	5	2/4	3	3	2/5	4	3	3
Rats, exotic (some *Rattus* spp.)	3	1	3	1	1	0	0	1
Amphibians								
Exotic								
Cane toad (*Bufo marinus*)	–	2	5	5	–	0	0	–
Fish								
Exotic								
Carp (*Cyprinus carpio*)	–	1	–	–	–	2	–	–
Birds								
Native								
Bell miner (*Manorina melanophrys*)	–	4	–	–	–	–	0	–
Brush turkey (*Alectura lathami*)	–	–	–	3	–	–	0	–
Cockatoos (*Cacatua* spp.)	–	–	–	–	–	–	3	–
Parrots	–	–	–	–	–	–	0	5
Exotic								
Blackbird (*Turdus merula*)	5	1	–	–	–	–	1	–
Common Myna (*Acridotheres tristis*)	3	–	–	1	–	–	0	–
Starlings/sparrows (*Sturnus vulgaris*/*Passer domesticus*)	1	1	–	4	–	–	1	–

Source: National Forest Inventory, 2003.
Note: Some pests are perceived to have different impacts in production forests than in conservations forests.
When differing impacts are reported the production forest impact is reported first followed by the conservation forests impact.
0 = Reported present but not problematic
1 = Occurs but is not widespread, has little impact, and requires little or no control
2 = Extent and impact are limited but control measures are intensive
3 = Widespread or having adverse impacts
4 = Widespread and having adverse impacts
5 = Very widespread and having severe adverse impact

Damage caused by wallaby grazing on young blue gum (*Eucalyptus globulus*) seedling

Animal invertebrate pests

Eucalypt forests and plantations are regularly browsed by a wide range of native insects including leaf-chewing chrysomelid beetles, scarab beetles, sawflies, leaf skeletoniser moth larvae, and sap-sucking psyllids (Table 61). Infestations are sometimes severe and repeated. Control programs have been conducted in plantations where attacks may result in reduced growth and damaged form. Except for chronic attacks, eucalypts are generally resilient and able to replace their foliage after infestation subsides.

Where control of severe insect infestations in young plantations is required, insecticides are sometimes used. One of the problems with this approach is that the insecticide can also harm beneficial insects, that is, those insects that reduce the population of the pest through predation or parasitism.

The gumleaf skeletoniser (*Uraba lugens*) causes widespread and locally severe defoliation of natural eucalypt stands in all States across a range of climatic and vegetation types, but generally few trees are killed. In plantations, impacts are not usually severe and control is not necessary. For example, in Western Australia this pest has initially been selected as a target species in the newly implemented FORESTCHECK monitoring program, together with jarrah leaf miner (*Perthida glyphopa*) and bullseye borer (*Phoracantha acanthocera*).

Autumn gum moth (*Mnesampela privata*) catepillar

Stick insect outbreaks, for example, the species *Didymuria violescens*, occur cyclically in mature eucalypt forests in high elevation regions in New South Wales and Victoria where entire patches or hillsides of mature eucalypts—for example, manna gum (*Eucalyptus viminalis*), alpine ash (*E. delegatensis*), and mountain ash (*E. regnans*)—are sometimes totally defoliated. Population monitoring and outbreak predictions are made from monitoring egg numbers in soil and litter.

Christmas beetle infestations occur at the forest/cleared land interface, particularly in river red gum (*E. camaldulensis*) communities in Victoria, but also in blue gum (*E. globulus*) and flooded gum (*E. grandis*) plantations in eastern Australia. These pests are difficult to control and breeding strategies are being developed to produce resistant strains of eucalypt. Prolonged chronic outbreaks of sap-sucking psyllids—for example, in river red gum forests in Victoria—which often involve *Cardiaspina* spp., can result in tree dieback and death.

Wingless grasshoppers cause total defoliation in young eucalypt plantations, particularly during droughts, and have been significant in several States including Western Australia and South Australia. Pest management programs are sometimes necessary.

Pests of exotic pine plantations that can reduce the commercial productivity of these forests include the Monterey pine aphid (*Essigella californica*), and the five-spined bark beetle (*Ips grandicollis*).

The sirex wasp (*Sirex noctilio*) generally attacks stressed pine trees (*Pinus* spp). Wasp numbers sufficiently high to cause significant attack do not generally develop in vigorous healthy stands although this has been know to occur. In South Australia and Victoria between 1987 and 1989, the sirex wasp killed more than five million pine trees with a value of $10–12 million (1989 dollars). The National Sirex Control Strategy program facilitates an integrated pest management approach based on ensuring low wasp populations. This is achieved by the maintenance and release of virulent strains of the introduced nematode *Beddingia siricidicola*, as well as a range of parasitising wasps, as biological controls, and by encouraging optimum plantation thinning practices and site selection to minimise the occurrence of stressed trees in areas at risk. Regular trapping and surveillance programs monitor sirex wasp levels, and controls are implemented to avoid major outbreaks.

The Monterey pine aphid, first observed in Australia in 1998 and able to infest a range of pine species, has since been detected in most pine-growing areas in Australia. Thus far, mild to severe defoliations have been recognised in pine plantations in Victoria, New South Wales and South Australia, but the effects on growth yield are still to be assessed. Aphid levels are regularly monitored in most States using standard foliage beating methods during surveys.

The five-spined bark beetle is a serious pine bark beetle pest accidentally introduced from the northern hemisphere that is able to infest all plantation pine species grown in Australia. The beetle has been present in Australia for at least sixty years. Pheromone traps are used to monitor beetle presence and beetle numbers in some States. Population levels build up primarily on fresh harvesting debris or in damaged or severely stressed standing trees. The beetle is also able to spread harmful blue stain fungi such as *Ophiostoma ips*. A range of parasites has been introduced into Australia to limit beetle numbers.

In 2001, red fire ants (*Solenopsis invicta*) native to South America were found in south-east Queensland. This insect pest has the potential to inhabit large areas of forest in coastal Australia and to cause serious impacts on environment values, agricultural production and, because of their painful sting, human lifestyle. A national surveillance and eradication program, funded by all States and the Australian Government, has been set up to eliminate red imported fire ants from Australia.

Table 61: The impact of invertebrate pests on ecosystem health and vitality in forest areas according to State or Territory

Invertebrate pests	ACT	NSW	NT	Qld	SA	Tas	Vic	WA
Army worms (*noctuids*)	–	1	3	1	0	1	0	1
Autumn gum moth (*Mnesampela privata*)	1	3	–	1	3	3	3	-
Bees	4	0	3	3	0	3	3	3
Beetle, African black	–	1	–	1	0	–	0	?
Beetle, Christmas (*Anoplognathus* spp)	3	3/4	3	3	0	1	3	–
Beetle, five-spined bark (*Ips grandicollis*)	1	1	–	4	4	–	-	3
Beetle, leaf/flea (*chrysomelids*)	–	3	3	4	3	1	3	1
Beetle, longicorn (*cerambycids*)	–	0	–	3	1	1	-	3
Beetle, white fringe	–	1	–	3	0	1	0	–
Beetle, monolepta (*Monolepta australis*)	–	1	–	–	–	–	–	3
Borers	–	3	–	–	1	1	4	3
Budworm	–	0	3	1	0	1	0	1
Cup moths (*limacodids*)	–	3	–	3	1	–	0	–
Cut worm	–	0	–	1	0	–	0	–
Grasshoppers (*acridids*)	1	1	3	5	3	3	1	5
Gumleaf skeletoniser (*Uraba lugens*)	–	3	–	3	1	3	4	1
Gum tree scale (*Eriococcus* spp.)	–	3	–	–	–	1	4	–
Leaf miner	1	0	3	–	1	3	3	5
Lerps (psyllids)	4	2/4	3	3	1	3	5	1

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Table 61: The impact of invertebrate pests on ecosystem health and vitality in forest areas according to State or Territory

Invertebrate pests	ACT	NSW	NT	Qld	SA	Tas	Vic	WA
continued from previous page								
Millipedes	1	0	3	0	0	3	3	–
Monterey pine aphid (*Essigella californica*)	–	1	–	3	–	–	1	–
Mosquitoes (*culicids*)	1	1	3	1/3	0	3	3	3
Saw fly (*Perga dorsalis*, *Pergagrapta bella*)	–	3	–	3	3	1	3	1
Stick insects (*phasmatids*)	1	1	3	3	0	1	3	1
Termites (*Cryptotermes*, *Coptotermes* spp.)	–	0	–	–	0	–	5	3
Tramp ant (*Anoplolepis gracilipes*, *Pheidole megacephela*)	–	0	3	–	–	–	–	–
Wasp, European (*Vespula germanica*)	3	0	3	–	–	4	1	–
Wasp, sirex (*Sirex noctilio*)	3	3	–	1	5	3	2	–
Weevils (*curculionids*)	1	0	3	3	1	3	3	1
Wingless grasshopper (*Phaulacridium vittatum*)	1	1	–	1	3	3	1	1
Spring beetle (*Heteronyx* spp.)	–	–	–	–	3	3	–	–

Source: National Forest Inventory, 2003.
Note: Some pests are perceived to have differing impacts between production forests and conservations forests.
When differing impacts are reported the production forest figure is reported first followed by the conservation forests figure
0 = Reported present but not problematic
1 = Occurs but is not widespread, has little impact, and requires little or no control
2 = Extent and impact are limited but control measures are intensive
3 = Widespread or having adverse impacts
4 = Widespread and having adverse impacts
5 = Very widespread and having severe adverse impact

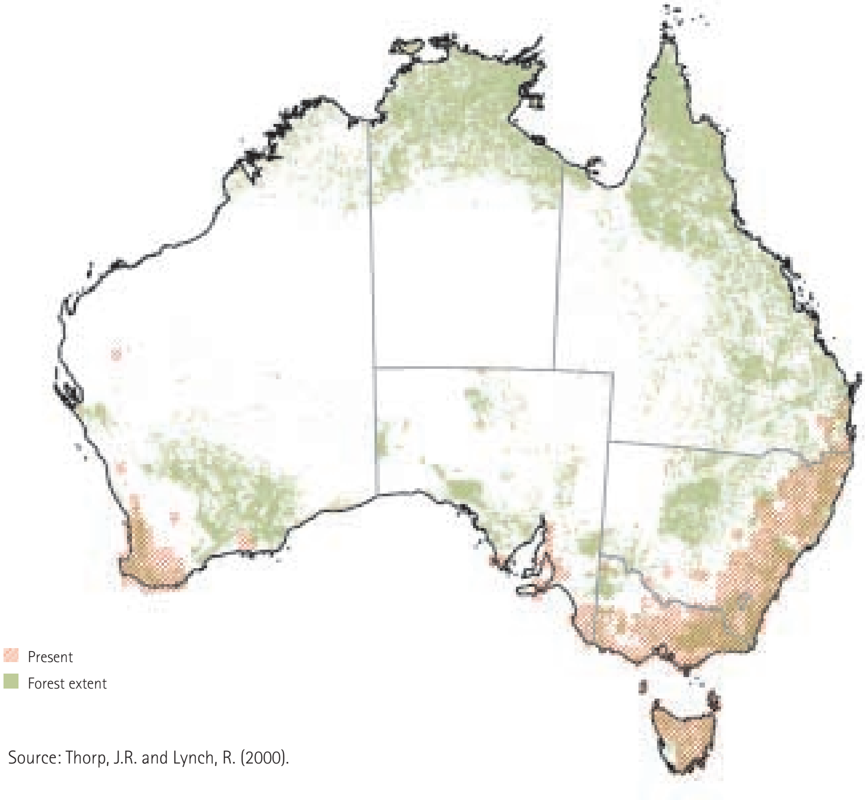
Weeds

Blackberries (*Rubus vulgaris*), gorse (*Ulex europaeus*), lantana (*Lantana camara*) and pampas grass (*Cortaderia* spp.) are examples of exotic plants that have become pests in Australia (Table 62). These species compete with native flora in forests and can reduce biodiversity and other values. These four species are included in the Weeds of National Significance program under the National Weeds Strategy. Pest plants also interfere with crop trees in commercial forest plantations, with concomitant negative effects on human access, tree establishment and growth, and product yield.

Blackberries occur in all jurisdictions, except the Northern Territory (Figure 34). They are the single most widespread pest plant in southern Australia, mainly in regions with annual rainfall of more than 750 millimetres. Current costs and changes in area affected are difficult to calculate, but an estimate of the area affected is 9 million hectares, including non-forested landscapes. Control of blackberry in forests is primarily by spraying with herbicides. Strains of a blackberry rust fungus (*Phragmidium violaceum*), have been introduced into Australia during the past 20 years, but have had limited success as control agents. Victoria has recently implemented an enhanced major long-term strategy for blackberry management and eradication on a statewide basis.

Gorse is more problematic as a weed in Tasmania and southern Victoria than elsewhere in Australia. In Tasmania alone the estimated annual cost of production loss is $1 million and the cost of control and rehabilitation was $700–$1 500 per hectare in 2001.

Figure 34: Distribution of blackberry in Australia



Source: Thorp, J.R. and Lynch, R. (2000).

Lantana infests approximately 4 million hectares, predominantly in the coastal forests and woodlands extending from far north Queensland to southern New South Wales but also occurs to a small extent in parts of the Northern Territory, Western Australia and Victoria. Whole ecosystems and many species are affected and others threatened by this shade-tolerant, invasive pest plant which develops dense shrubby thickets that out-compete native species. Environmental impacts also include major reductions in invertebrate and avian biodiversity. This in turn may increase the severity of crown defoliation dieback in forest overstorey. Lantana is gradually extending further inland. Control measures include introduced sap-sucking insects and fungi that damage leaves. Cutting back the plant, however, results in stimulated shoot proliferation.

Pampas grasses occur as weeds in Victoria, Tasmania, New South Wales, South Australia and Western Australia. National and/or regional weed strategies are in place. In Tasmania a statewide eradication program implemented in 1998 resulted in the removal of tens of thousands of pampas plants.

Other significant exotic pest plants affecting some forest communities include broom and bromes (*Bromus* spp, *Cytisus* and *Teline* spp.), bitou bush (*Chrysanthemoides monilifera* ssp. *rotundata*) and boneseed (*Chrysanthemoides monilifera*), and willows (*Salix* spp.). States most affected by exotic broom species are Victoria, Tasmania, New South Wales and South Australia and forest environments are

Blackberries (*Rubus vulgaris*) in pine forest amongst those invaded. Scotch broom (*Cytisus scoparius*) is particularly invasive across an area of about 50 000 hectares in nature conservation reserve in the Barrington Tops area of New South Wales, and a major protective weed eradication and integrated management program has been implemented.

Bitou bush is listed as a key threatening species in New South Wales. It mainly invades dune vegetation systems, but also encroaches into coastal forest and woodland communities. Biological controls such as bitou tip moth have been used with some success in New South Wales and are part of the management strategy there. Boneseed is more widespread across different environments and is found in southern New South Wales, Victoria, south-eastern South Australia and Tasmania. It is an invader of a range of forest types and is spread by seed. Biological controls have not been successful so far and eradication is by conventional means including fire.

Willows have been recognised as serious invaders of streams within many forested parts of southern Australia; Tasmania, Victoria, New South Wales and the Australian Capital Territory are the most affected. Guidelines for identification and eradication of particular willow species from inappropriate environments have been prepared and implemented in a range of jurisdictions, particularly in the last 5 years. For example, an interstate cooperative program has been conducted for willow removal in the Genoa River catchment in the eastern border region of New South Wales and Victoria. The Tasmanian government has implemented restrictions on the import, sale and planting of particular problematic willow species.

Tall African grasses such as gamba grass (*Andropogon gayanus*) and mission grass (*Pennisetum polystachion*) have particularly severe impacts on forests in northern Australia through their interactions with fire. These species are taller and produce more fuel that cures later than native grasses—hence, they carry higher, hotter flames into the tree canopy, frequently causing tree death.

Strategies to map and collect data on the extent of major environmental weeds in nature conservation reserves in several States are being implemented. As well as being local strategic management tools, such records of weed distribution can facilitate future comparisons and monitoring on a national scale.

Determining the effects of pest plants on productivity and biodiversity on a regional, State or national scale is problematic.

In most forest jurisdictions and land tenures throughout Australia the environmental costs of pest plants have not been quantified and few data are available. Direct total economic costs for the public forestry sector are retrievable, based on annual expenditure on eradication or control measures. Estimates of lost economic productivity are also feasible for clearly defined examples but resolution on a broader scale presents considerable difficulties.

Table 62: Plant pests affecting ecosystem health and vitality in forest areas by State or Territory

Plant pests	ACT	NSW	NT	Qld	SA	Tas	Vic	WA
Bathurst burr (*Xanthium spinosum*)	0	1	1	1	0	2	1	1
Blackberry (*Rubus vulgaris*)	3/4	5	–	3	1	–	5	3
Blackberry (*Rubus fruticosus* agg.)	–	1	–	–	1	5	1	–
Blue morning glory (*Ipomoea indica*)	–	0	–	–	–	–	0	–
Blue-bell creeper (*Sollya heterophylla*)	–	0	–	–	1	0	0	–
Bone seed (*Chrysanthemoides monilifera*)	–	0	–	–	1	4	1	–
Boxthorn, African (*Lycium ferocissimum*)	–	1	–	–	3	2	0	–
Bracken fern (*Pteridium esculentum*)	1	–	–	3	5	4	3	–
Broadleaved weeds	–	0	–	–	–	2	0	–
Calliopsis/coreopsis (*Coreopsis lanceolata*)	–	0	–	–	–	–	0	–
Cape broom (*Teline monspessulana*)	–	0	–	–	1	2	–	–
Cape ivy (*Delairea odorata*)	–	–	–	–	–	–	1	–
Chess or cheat (*Bromus secalinus*)	–	0	–	–	–	–	–	–
Canadian fleabane (*Conza canadensis*)	–	1	–	–	0	–	0	–
Cotoneaster (*Cotoneaster* spp)	–	0	–	–	0	–	0	–
Crofton weed/mist-flower (*Ageratina* spp.)	–	1	–	–	0	–	0	–
Dodder laurel (*Cassytga melantha*)/ Australian dodder (*Cuscuta australis*)	–	1	–	–	0	–	1	–
Eucalypt (*Eucalyptus* spp.)	–	0	–	–	1	0	0	–
Galvanised burr (*Sclerolaena birchii*)	–	1	–	–	–	–	–	–
Gorse (*Ulex europaeus*)	–	1	–	–	1	3	1	–
Grasses, exotic (*Poaceae* spp.)	4	2	4	5	4	2	1	4
Great brome (*Bromus diandrus*), soft brome (*B. molliformis*)	–	0	–	–	–	–	–	–
Groundsel bush (*Baccharis halimofolia*)	–	1	–	–	0	–	0	–
Horehound (*Marrubium vulgare*)	–	1	–	–	0	1	1	–
Lantana (*Lantana camara*)	–	3	1	5	0	–	1	–
Madrid (*Bromus madritensis*), red brome (*B. rubens*)	–	0	–	–	–	–	–	–
Paperbark (*Melaleuca* spp.)	–	0	–	–	0	1	0	–
Mimosa (*Mimosa* spp.)	–	0	3	–	0	–	0	–
Mistletoe	–	0	–	–	0	–	1	–
Noogoora burr (*Xanthium occidentale*)	–	1	1	–	0	–	1	–
One-leaved cape tulip (*Homeria flaccida*)	–	0	–	–		–	0	–
Ox-eye daisy (*Leucanthemum vulgare*)	–	0	–	–	0	–	0	–
Paterson's curse/salvation Jane (*Echium plantagineum*)	–	1	–	–	1	2	1	–
Pines (*Pinus* spp.)	–	1	–	–	1	2	1	–
Prickly pear (*Opuntia* spp.)	–	1	–	–	–	–	0	–
Ragwort (*Senecio jacabaea*)	–	0	–	–	0	2	1	–
She-oak (*Allocasuarina* spp.)	–	0	–	–	0	–	0	–
St John's wort (*Hypericum perforatum*)	–	1	–	–	0	1	1	–

continued over page

Table 62: Plant pests affecting ecosystem health and vitality in forest areas by State or Territory

Plant pests	ACT	NSW	NT	Qld	SA	Tas	Vic	WA
continued from previous page								
Stinging nettle/dwarf nettle (*Urtica urens* or *U. dioica*)	–	0	–	–	0	1	0	–
Sweet briar (*Rosa rubiginosa*)	–	1	–	–	0	1	1	–
Sweet pittosporum (*Pittosporum undulatum*)	–	–	–	–	–	–	1	–
Tea tree (*Leptospermum* spp.)	–	0	–	–	0	1	0	–
Thistle	–	1	–	–	1	2	1	–
Tree of heaven (*Ailanthus altissima*)	–	1	–	–	0	–	0	–
Vines, creepers – bridal (*Asparagus asparagoides*)	–	1	–	–	1	–	1	–
Water hyacinth (*Eichhornia crassipes*)	–	0	–	–	–	–	0	–
Wattles (*Acacia* spp.)	–	0	–	–	1	3	1	–
Willows (*Salix* spp.)	–	1	–	–	0	2	1	–
Pasture legumes	–	–	4	–	–	–	–	–
Calopo (*Calopogonium mucunoides*)	–	–	3	–	–	–	–	–
Neem (*Azadirachta indica*)	–	–	3	–	–	–	–	–
Morning glory vines – various	–	–	3	–	–	–	–	–
Castor oil (*Ricinus communis*)	–	–	4	–	–	–	–	–
Candle bush (*Senna alata*)	–	–	3	–	–	–	–	–
Sicklepod (*Senna obtusifolia*)	–	–	3	–	–	–	–	–
Sida (*Sida* spp)	–	–	3	–	–	–	–	–
Snakeweeds (*Stachytarpheta* spp.)	–	–	3	–	–	–	–	–
Gambia pea (*Crotalaria goreensis*)	–	–	3	–	–	–	–	–
Mintweed (*Hyptis suaveolens*)	–	–	3	–	–	–	–	–

Source: National Forest Inventory, 2003.
Note: Some pests are perceived to have differing impacts between production forests and conservations forests.
When differing impacts are reported the production forest figure is reported first followed by the conservation forests figure
0 = Reported present but not problematic
1 = Occurs but is not widespread, has little impact, and requires little or no control
2 = Extent and impact are limited but control measures are intensive
3 = Widespread or having adverse impacts
4 = Widespread and having adverse impacts
5 = Very widespread and having severe adverse impact

Further reading

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Sawfly larvae on eucalypt sampling

Pathogens

Phytophthora species of fungi are a major concern in many forested areas and management plans are in place in most regions. Other fungi are a threat to some plantation species. There are no national figures on areas affected, although mapping has been carried out in Western Australia, Victoria and Tasmania.

Native forests and plantations are affected mainly by indigenous plant pathogens. In plantations of non-native species, however, pests and pathogens are primarily of overseas origin.

Table 63: Distribution of *Phytophthora* spp. in forest areas by State or Territory

	ACT	NSW	NT	Qld	SA	Tas	Vic	WA
Fungi (*Phytophthora* spp.)	4	3	3	5	–	5	5	5

Source: National Forest Inventory, 2003.

0 = Reported present but not problematic

1 = Occurs but is not widespread, has little impact, and requires little or no control

2 = Extent and impact are limited but control measures are intensive

3 = Widespread or having adverse impacts

4 = Widespread and having adverse impacts

5 = Very widespread and having severe adverse impact

The root-rotting fungus *Phytophthora cinnamomi* (and a number of other *Phytophthora* species) kill a wide range of plants in susceptible areas—predominantly regions with more than 600 mm annual rainfall. It has been associated with the death of commercially important eucalypt species, such as jarrah (*E. marginata*) in Western Australia, silvertop ash (*E. sieberi*) in south-eastern mainland Australia, and young plantation Gympie messmate (*E. cloeziana*) in Queensland. However, the most significant impacts are on biodiversity. Quantitative nationwide data are limited in their capacity to clearly distinguish the area and impacts in forests from those in vegetation types such as heathlands.

As many as 2 000 of the estimated 9 000 native plant species in the south-west of Western Australia are susceptible to *P. cinnamomi*. In Tasmania 181 species have been identified as hosts for *P. cinnamomi* and at least 39 threatened species are currently identified as being susceptible to the species. Tasmania further identifies areas for protection from *P. cinnamomi* incursion. *Phytophthora* is listed as a 'key threatening process' under the *Environment Protection and Biodiversity Conservation Act 1999* and a national Threat Abatement Plan for *P. cinnamomi* was released in 2001. Each State has their own approach to *Phytophthora* management under the national Threat Abatement Plan. *P. cinnamomi* spread is controlled through hygiene protocols and management zones for the protection of threatened flora. Forestry, nature conservation reserve and local agencies in many jurisdictions have implemented plans to restrict pathogen spread. In Western Australia intensive monitoring is undertaken to identify the distribution of the disease in commercial forests and conservation areas and to designate protectable areas that are free of the pathogen.

A wide range of chronic or periodic crown dieback syndromes, often with significant tree mortality and accompanying impacts on ecosystems occur to some degree in native forests in all States. Dieback is usually of complex origin—associated with combinations of factors such as climatic stresses, land management practices, severe insect attacks, and imbalance in insect predator levels. Pathogenic fungi are not generally the primary factors, but canker-causing fungi—including *Cryphonectria eucalypti* (formerly *Endothia gyrosa*) and *Botryosphaeria* spp.—often have a significant secondary role. Definition of the syndromes and causal agents is often difficult. It is also hard to clearly delineate the affected areas because a wide range of land tenures is involved.

Jarrah (*Eucalyptus marginata*) dieback, south west Western Australia

Rapid expansion of native hardwood plantations in Australia has seen defoliating diseases become more significant. Major outbreaks are infrequent and depend on factors such as local climatic conditions, age and genetic composition of plantations. Few fungal leaf diseases of eucalypts are economically damaging in commercial or environmental plantations, but significant exceptions include several native *Mycosphaerella* spp.—the most serious being *M. cryptica* and *M. nubilosa* in young blue and shining gum (*E. globulus* and *E. nitens*) plantations in southern Australia, *Cylindrocladium quinqueseptatum* in young eucalypt plantations in northern Queensland, and *Quambalaria pitereka* in young spotted gum (*Corymbia* spp.) plantations in humid areas of New South Wales and Queensland. Control measures include selection for genetic resistance to these foliar pathogens in plantations. Such diseases are less debilitating in natural forests and woodlands, where inoculum levels are usually low.

In cool temperate rainforest and mixed forest in Tasmania and Victoria, myrtle wilt disease—caused by the native pathogenic fungus *Chalara australis*—attacks myrtle (*Nothofagus cunninghamii*), through wounds in stems and branches. Although, myrtle wilt disease is widespread in undisturbed forest, damage to trees associated with road-building and harvesting can increase the activity of this disease.

Root and butt rots caused by *Armillaria* spp., most significantly *A. luteobubalina*, in eucalypt forest predominantly in southern Australia, cause small patch deaths of a range of plant species. *Ganoderma* spp., *Rigidoporus vinctus*, and *Phellinus noxius* in Queensland kill a low, but increasing, percentage of trees in a similar way. Species affected include young hoop pine (*Araucaria cunninghamii*), rainforest species, eucalypts and acacias—especially in regrowth forests or second rotation plantations.

Acacia species in a wide range of land tenures and forest ecosystems are affected by species of the native gall or phyllode rust fungi *Racospermyces* and *Uromycladium*. These can cause severe defoliation, affect tree form, and even cause death. Impacts in natural stands are usually small, whereas in plantations—for example of *Acacia mangium* in northern Australia—severe levels of phyllode rust have warranted investigations for disease resistance.

In areas where climatic, topographic and stand conditions are suitable, the exotic needle-cast fungus *Dothistroma septospora*, first recorded in Australia in 1975, is able to cause severe needle loss in *Pinus radiata* plantations up to 15 years of age. The northern tablelands of New South Wales and small areas in south-eastern Queensland are worst affected, but the disease is also sometimes significant in the tablelands of southern New South Wales and in north-eastern Victoria. Thinning of stands is used as an ameliorative measure, but aerial spraying with low concentrations of copper-based fungicide is occasionally undertaken. The disease is absent from South Australia and Western Australia and, although present, causes little damage in Tasmania. Relatively little significant needle blight has occurred during the past 5 years because of drought conditions over much of the *P. radiata* estate. Planting of disease-resistant stock is currently undertaken to reduce disease impacts in highly prone locations in northern New South Wales. The fungus *Sphaeropsis sapinea* is associated with top death and occasional mortality of *P. radiata*, usually on drought-prone sites and needle-cast associated with the fungi *Cyclaneusma minus* and *Lophodermium* spp. also occurs in many *P. radiata* growing regions.

Mundulla yellows have the potential to have significant impact on eucalypts, having been associated with the death of trees within several species. The disease occurs in both old and young vegetation. Research is underway to identify the cause of Mundulla yellows. It is unknown whether the cause is pathogenic.

River regulation

River regulation, usually by means of dams, is widespread in Australia. Rivers are regulated for irrigation, hydroelectric generation, urban and rural water supply, or diversion to other catchments. This can have dramatic impacts on water quality and quantity and hence the values of forests reliant on periodic flooding.


Michael F. Ryan

Case study: Murray-Darling River system

Australia's largest river system, encompassed by the Murray-Darling Basin, drains an area of more than one million square kilometers across five different states and territories in eastern Australia. The States and Territories are Queensland, New South Wales, the Australian Capital Territory, Victoria and South Australia. The Murray-Darling Basin accounts for 30–40 per cent of Australia's total primary production. Almost 2 million people live in the Basin and it supports more than 4 million people beyond its boundaries.

River regulation within the Basin can significantly affect water flow, natural inundation cycles and water quality. It has reduced the outflow of the Murray-Darling River system from a mean of 13 700 gigalitres per year to 4 900 gigalitres per year. About 90 per cent of the water is used for irrigation.

The Barmah and Millewa group of forests, in the floodplain of the River Murray, cover an area of approximately 70 000 hectares, forming the largest river red gum forest in Australia. Contained within these forests are 3 300 hectares of wetlands. When construction of the Hume Dam was completed in 1936, flooding patterns within the forest changed drastically and unseasonal and unnatural wetting and drying patterns significantly affected plant and animal communities.

As a result of this impact, a water management strategy has been developed for the forest with the aim to enhance forest, fish and wildlife values whilst limiting adverse effects on other areas. An annual Environmental Water Allocation of 100 gigalitres is used to supplement natural floods to encourage breeding of forest flora and fauna.

River red gum (*Eucalyptus camaldulensis*) regeneration at high flood level, Barmah State Forest, Victoria

Climatic events

Drought

Australia is the driest inhabited continent and also experiences extreme variability of rainfall over much of the country. Droughts somewhere in the country are frequent and many continue for several years. The most drought-prone regions are the marginal areas away from the coasts and ranges.

Drought stresses native forests directly and causes production losses in native and exotic timber plantations. It is also a frequent precursor to fires, dust-storms, and general land degradation. Additionally, drought-stressed flora are more susceptible to pests and diseases, and suffer increased browsing pressure as food sources become scarce for fauna in the affected regions.

During late 2002, drought stress was associated with a marked increase in the extent and severity of chronic eucalypt decline in coastal New South Wales. At the same time there was extensive 'drought scorch' of trees and stands, especially on skeletal soils over rock, on the south coast. Although there was some overlap, the accelerated decline was mostly on somewhat sheltered slopes, whereas drought scorch was mostly on exposed ridgetops. Drought scorched trees recovered rapidly. In central Queensland large areas of eucalypt-dominated forest experience extensive canopy die back and death associated with the periodic (30–50 years) occurrence of major periods of drought.

Wind damage

There is no formal means of collecting information on wind damage across Australia. However, damage in forest plantations is monitored through systematic forest health surveys and some areas in northern Australia collect data on cyclone damage to native forests. The Australian Government Bureau of Meteorology monitors and reports significant climatic events and may include information about wind damage to forested areas. Cyclones and tornados can cause catastrophic incidents of wind damage to forests. Less forceful winds may still blow out the young growing shoots of trees, causing bud loss, flattened crowns and unwanted forking. This is particularly prevalent at higher altitudes and in exposed areas.

Storm damage in manna gum (*Eucalyptus viminalis*) forest, Braidwood, New South Wales

Clearing

Forest clearance has direct and indirect impacts on landscape and ecosystem health. Clearance and associated habitat loss is the most significant threat to species and ecosystems in eastern Australia. In addition forest clearing impacts on a range of other values including run-off and infiltration rates, soil compaction and associated soil erosion, salinisation and soil acidification.

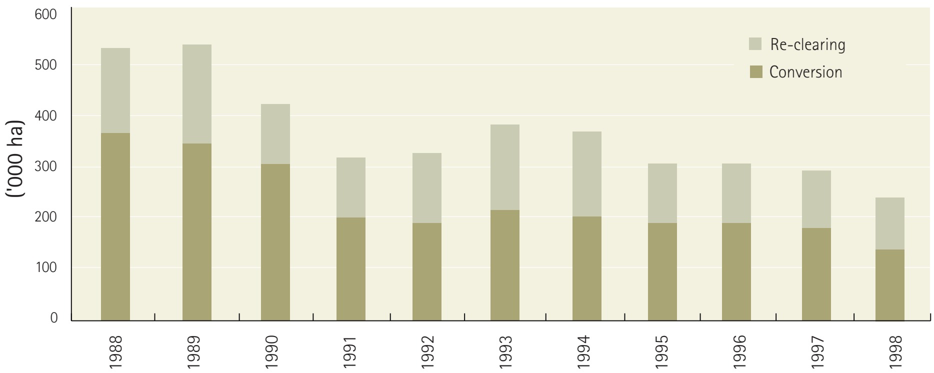
About 40 per cent of Australia's native forest has been cleared to make way for settlement, agriculture and grazing. Forest clearing records suggest that the annual rate of clearing has declined from 0.54 million hectares in 1988 to 0.24 million hectares in 1998 (Figure 35). Over the period 1991 to 1995, 77 per cent of the land cleared (irrespective of vegetation cover) was for pasture development, principally in Queensland, although smaller areas in other States and Territories were also cleared. The majority of this land clearance occurs on privately managed land—freehold and leasehold—and mostly within the more open woodland forest types. A recent survey by the Queensland government identified a significant increase in land clearing in Queensland in 1999–2000, which was then followed with a return to a near 10-year average rate of land clearing in the following year.

While State and Territories have constitutional responsibility for the management of natural resources, they are signatories with the Australian Government to a number of national statements on native vegetation clearance, including the National Framework for the Management and Monitoring of Australia's Native Vegetation, the Intergovernmental Agreement on a National Action Plan for Salinity and Water Quality, and the framework for the extension of the Natural Heritage Trust.

State government agencies are now establishing plantations on cleared agricultural lands in preference to areas covered by native forest. In Tasmania some plantations continue to be established on land cleared of native forest, in accordance with State undertakings in the Tasmanian Regional Forest Agreement. Australia-wide, the majority of the current plantation estate is on land previously used for agricultural purposes, 20 per cent is second rotation plantings on land previously under plantation and 21 per cent is on land that was converted from native forests for plantation establishment. These latter areas were planted prior to 1990. Reforestation of harvested areas for public multiple-use native forests is now a requirement in all State and Territory codes of forest practice.

All governments have agreed to reduce the national rate of land clearance to zero—meaning that the area of native communities cleared per year should not exceed the area being revegetated as native vegetation communities over the same period—to prevent land-clearing that might lead to unacceptable land and water degradation, and to prevent the clearing of endangered or vulnerable vegetation communities or critical habitat for threatened species. Most States and Territories now have legislation in place that regulates the clearing of native vegetation on all land tenures.

Figure 35: Annual clearing of forest cover by year



Source: Australian Greenhouse Office (2002)

Note: Conversion is the clearance of forested areas to clear land for farming activities; re-clearing is the clearance of regrowth from areas that have previously been cleared

Case study: Queensland land clearing moratorium—a landmark decision

In the period 1991 to 1995 over two-thirds of land clearance in Australia occurred in Queensland. The clearing of vegetation on freehold, leasehold and other State land in Queensland is regulated through a permit system that aims to conserve native remnant vegetation and ensure that clearing does not contribute to land degradation. In most cases a permit is required to undertake any clearing of remnant vegetation, however, a number of exemptions apply as to when a permit is not required, for example, to maintain existing fences and other infrastructure.

Persons caught clearing illegally without a permit may be prosecuted and if found guilty may be required to revegetate the illegally cleared areas and be disqualified from applying for a clearing permit for 5 years. Re-vegetation orders also attach to the land and bind successors in title.

In May 2003, the Queensland government announced a halt on the acceptance of new applications for clearing permits while they and the Australian Government negotiate with key stakeholders on a proposal to further reduce the current rate of clearing. The proposal involves phasing out broadscale clearing by 2006 and providing a financial assistance package for affected landholders.

The halt does not affect exemptions or existing permits. It also allows applications to continue to be accepted for certain activities, such as clearing for weed control or public safety.

Further reading

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Grazing

There were no hoofed animals in Australia before Europeans arrived, and the subsequent introduction of these animals at high stocking densities has caused land degradation in many parts of the country. The impact of domestic stock—mainly sheep and cattle—on forests includes changes in structure and composition, particularly in ground layers, loss of biodiversity and degradation of soil. Grazing also has considerable indirect impacts on ecosystem health, especially in drier areas, through the impact that grazing animals have on fuel loads and hence fire regime.

Grazing in multiple-use forests is managed in similar ways in all States and Territories. Queensland serves as an example. Grazing in nature conservation reserves is generally against the legislation and policies of conservation agencies. Grazing predominantly occurs on private or leasehold lands. In Queensland, cattle are currently grazed in the south-eastern part of the State, either under a Stock Grazing Permit (SGP) or a Term Lease. SGPs are issued by the Department of Primary Industries (DPI) Forestry on multiple-use forests for a period not exceeding seven years and provide greater management control than Term Leases. Most of the areas of forest on freehold and leasehold lands are grazed by domestic stock. State agencies have a variety of regulatory and non-regulatory programs to address the impacts of overgrazing and associated degradation. Grazing by domestic stock is generally prevented in nature conservation reserves by legislation and/or policy.


Michael F. Ryan

Sheep grazing in woodland

Salinisation

Dryland salinity is a widespread and rapidly growing problem in Australia. It occurs predominantly on cleared agricultural land but can also affect adjacent woodland forests. One contributing factor to salinisation is the widespread clearing of deep-rooted native tree species, which has resulted in rising water tables mobilising salt in the soil. The increased salt concentrations and waterlogged soils stresses or kills plants. An estimate of the area of land affected by induced salinity was conducted in 2000 during the National Land and Water Resources Audit (Table 64) but focussed predominately on agricultural land, as forested land was considered to be at minimal risk.

Biodiversity is under threat from salinisation in some areas. In Western Australia, an estimated 16 per cent of the south-western agricultural region is affected by salinity threatening 450 endemic plant species with extinction.

Reforestation in salinity-affected and salinity-prone areas is frequently cited as an appropriate means of addressing the salinity problem. Blue gum plantations in the south-west of Western Australia have had some success in this respect (see case study). At the same time, the impact of large-scale afforestation can vary widely. While reforestation may be effective against dryland salinity, in the same area it can potentially increase river salinity levels until the hydrological regime achieves a new equilibrium.

Table 64: Area of land ('000 ha) with a high potential to develop induced salinity in Australia

State/Territory	1998–2000	Predicted 2050
Australian Capital Territory	Minor	–
New South Wales	181	1 300
Northern Territory	–	–
Queensland	48	3 100
South Australia	390	600
Tasmania	54	90
Victoria	670	3 110
Western Australia	4 363	8 800
Total	5 658	17 000

Source: National Land and Water Resources Audit, 2000.

Case Study: Commercial reforestation to control salinity in Western Australia blue gum plantations

In Western Australia, induced salinity is the State's biggest environmental threat. It is estimated that 30 per cent of the 18 million hectares of cleared farmland in south-west Western Australia needs to be returned to perennial vegetation to control salinity. This push for revegetation has provided an opportunity for new industries in rural areas and has had a major impact on reversing land degradation.

The State's Forest Products Commission (FPC) has coordinated the blue gum program. Unlike earlier plantation programs that were developed on Government land to supply local industries, the blue gum program started with the combined objectives of meeting world demand for wood fibre, and helping to solve serious land degradation problems without the requirement of purchasing land for plantation establishment.

Blue gums (*Eucalyptus globulus*) are one of Australia's fastest-growing native trees, well suited to Western Australian conditions. An intensive breeding program by FPC scientists has developed the Western blue gum that produces premium wood fibre for the paper industry.

The FPC demonstrated the potential of blue gum crops to landowners and investors by planting 4 000 hectares on farms along the west and south coasts of Western Australia in 1988 and 1989. This generated significant interest and investment from private investors within Australia and internationally. Blue gum plantations in the Albany region provided $46 million directly and indirectly in wages and other income in 1997.

By the end of 1998, the Government and private investors had established 100 000 hectares of blue gums across hundreds of south-western properties. FPC predicts that by the year 2020, 800 000 hectares of tree crops will be established on Western Australian farms.

Trees affected by salinity on the shores of Lake Dumbleyung, Western Australia

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Soil acidification

Slow soil acidification is a natural process in some areas, but is largely balanced by deposition of plant material and organic matter in the soils. Australia's soils are old and highly weathered and can be naturally quite acidic on the surface as well as deep in the profile. Surface and subsoil acidity exists in all States and Territories and affects an area up to nine times that of dryland salinity. The largest areas of acid soils are in New South Wales, Western Australia, Victoria and Queensland.

Accelerated soil acidification is a serious soil degradation problem. When land is developed for agriculture or forestry the combination of disturbance and changes to the nitrogen and carbon cycles causes soil acidification rates to increase. When soils and sediments that contain iron sulfides are drained or disturbed, sulfuric acid is formed. The impact of forest plantations on soil acidity has yet to be examined.

There is a national strategy for the management of acid sulphate soils which involves risk mapping; avoiding disturbance of coastal acid sulphate soils; education of the agricultural sectors; policy, planning and development strategies; mitigating impacts when disturbance is unavoidable; remediation in the form of neutralisation of acid; revegetation of acid scald areas; and modification of drains and floodgates.

Mining

The extent of forest areas affected by mining exploration is exemplified by a case study for Victorian box-ironbark forests, while a Western Australian case study illustrates the requirements and controls that generally apply to mining exploration.

Case study: Box-ironbark forests in Victoria

A draft report on gold mining in the box-ironbark ecosystems of Victoria assessed the level of disturbance in forested areas contributed by mining operations. The survey was based on a sample of 185 mining tenements active sometime during the period from 1976–1996, covering an area of approximately 11 900 hectares.

The study identified disturbance on 108 tenements (58 per cent). The area disturbed by mining was estimated to be about 1 000 hectares, or 0.4 per cent of the total box-ironbark ecosystems on public land (about 254 300 hectares). Of the disturbed area, 140 hectares was classified as highly disturbed or un-recoverable to the original condition of the Ecological Vegetation Class, mainly due to tailing dams (60 hectares) and open cut voids (70 hectares).

Source: Environment Conservation Council (2000).

Case study: Mining exploration in Western Australia

In Western Australia, the *Mining Act 1978* requires the agreement of the Minister for the Environment and Heritage before access is given to multiple-use forest and timber reserves, nature conservation reserves or A class nature reserves. In A class parks and reserves the approval of both houses of Parliament is required before Mining Leases and General Purpose Leases are granted and mining can occur.

All proposals for operations that may potentially cause a significant environmental impact must be referred for the consideration of the Environmental Protection Agency (EPA) under section 38 of the Western Australian *Environmental Protection Act 1982*.

Mineral exploration is conducted on exploration licences or prospecting licences. These are granted with rigorous conditions to protect the environment, specific to the nature of the land, and are designed to ensure that the activities do not cause unacceptable impacts.

Currently, major developments are usually facilitated through State Agreements that are ratified by Parliament as State Agreement Acts. These Acts relate to bauxite and coal extraction. While these Acts are not subject to the *Conservation and Land Management Act 1984*, they include requirements to protect forest values and facilitate recovery of harvestable timber before mining. The projects are subject to environmental assessment by the EPA and ongoing activities are reviewed by inter-agency environmental review committees. Rehabilitation of forest values after mining and the re-establishment of sustainable productive timber harvesting is a key goal of these committees. It has been usual for companies to pay compensation to the EPA based on areas affected. This is intended to pay for the loss of productive timber from affected areas and to cover the costs incurred in supervisory or inspection activities by EPA officers.

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Climate change

An assessment by the CSIRO in 2001 estimated that most of Australia will warm 0.4º to 2.0ºC by 2030, and 1º to 6ºC by 2070 (Figure 36), with slightly less warming near the coast. This is expected to result in:

- more evaporation, more hot days and fewer cold days
- rainfall decreasing in the south and east (mainly winter/spring)
- some inland and eastern coastal areas experiencing wetter summers
- some inland areas becoming wetter in autumn
- extreme rainfall and tropical cyclones becoming more intense.

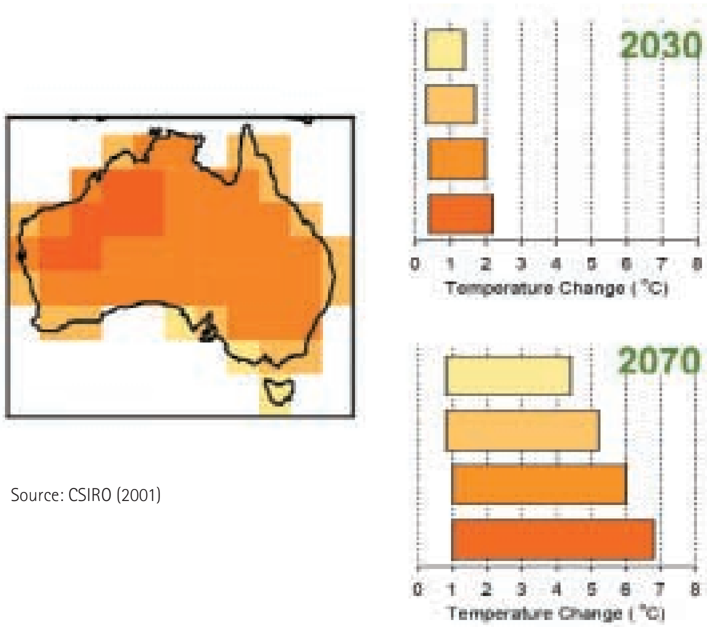
Overall this means that less water will be available.

Future forest productivity will depend on the balance between the benefits of increased carbon dioxide and the patterns of change in rainfall and temperature. A doubling of carbon dioxide with a warming of 3°C and no rainfall change, possible by 2070, would increase tree growth across much of southern Australia, particularly in the wheat belt and semi-arid regions. Increases are likely to be more marked (25–50 per cent) in southern Australia near the more marginal wheat-growing areas and the fringes of the pastoral zone.

However, a reduction in winter and spring rainfall in southern Australia (Figure 37), and increased fire frequency, would offset some of these benefits. The benefits will also be affected by changes in pests and in the longer term by limited nutrient supply. Modest increases (0–25 per cent) in tree growth are likely to occur in parts of the semi-arid tropics. However, in the monsoon tropics of far north Queensland, the Northern Territory and the north of Western Australia, the adverse effect of warming on tree growth will more than offset the gains from a doubling of carbon dioxide, leading to declines of 25–50 per cent in tree growth. Anticipating the changes up to several decades ahead might assist Australia's forest planners and managers to establish plantations in areas where the climate conditions will be suitable for the life of the trees.

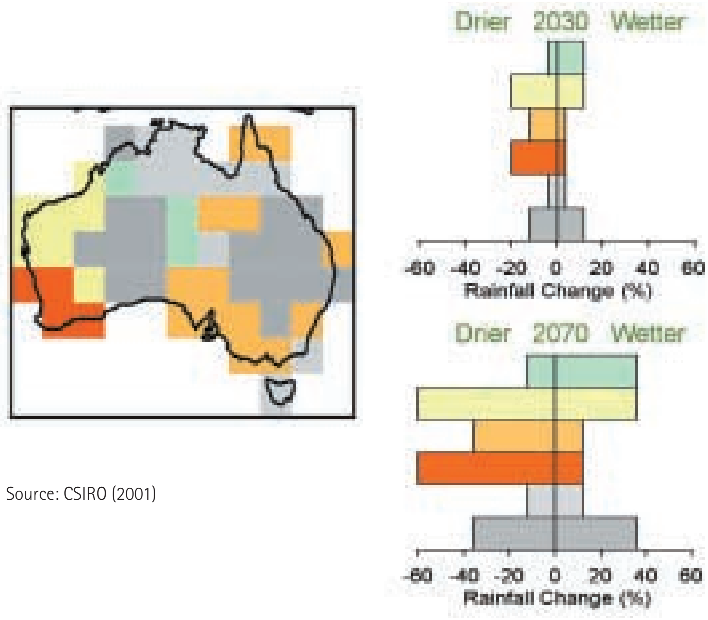
Changes in climate will be associated with changes in fire region. Future climates are expected to affect the components of forest ecosystems differently. A landscape study of refugia and future climate in the tall, wet forests of the Central Highlands of Victoria provides a model for the integrated investigations that are needed for other regions.

Figure 36: Projected changes in annual temperature



Source: CSIRO (2001)

Figure 37: Projected changes in annual average rainfall



Source: CSIRO (2001)

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Air pollution

Indicator 3.1b

Area and per cent of forest land subjected to levels of specific air pollutants (e.g. sulphates, nitrate, ozone) or ultraviolet-B radiation that may cause negative impacts on forest ecosystem health and vitality

Rationale

Changing atmospheric constituents have the potential to affect forest ecosystem health, particularly where forests occur in high risk areas, such as downwind from certain industries.

Compared to much of the northern hemisphere, air quality is good across most of Australia most of the time. The global phenomenon of increased ultraviolet irradiation due to stratospheric ozone depletion is likely to affect all vegetation to a certain extent. Acid rain is not a problem in Australian forests. Risks to ecosystem health and vitality are greater near major metropolitan areas, and around particular industrial plants in more remote areas.

Changing atmospheric constituents have the potential to affect forest ecosystem health, particularly where forests occur in high risk areas, such as downwind from certain industries or cities.

Air pollutants occur on a range of temporal and spatial scales. Assessing the impacts on forests of pollutants from a point source requires intensive monitoring of both emissions and forest health not currently undertaken in Australia. The National Pollutant Inventory (NPI) requires industries generating more than specified amounts of polluting substances to report on their emissions, however, there are no long-term data for the impact of these emissions on Australian forests. The major pollutants that could have an impact on parts of Australia's forests are photochemical smog, sulphur dioxide, fluorides and increased amounts of ultraviolet-B radiation resulting from ozone depletion in the stratosphere.

Photochemical smog has the potential to impact on local and regional scales depending on climatic conditions, such as prevailing winds, and the topography of the land. Photochemical smog is formed when emissions of nitrogen oxides and hydrocarbons (mainly from vehicle emissions) react with sunlight to form ozone (O_3). Fine particulates—less than 10 micrometres in diameter—and other noxious chemical emissions are also of concern and may become trapped in smog layers or caught in naturally occurring inversion layers forming in valleys. The constituents of most concern in smog are ozone, which is highly reactive with all biological materials, causing disruption of cell membranes and oxidisation of nitrogen. At low levels plants are able to assimilate nitrogen oxides and growth may be enhanced, but at higher concentrations, growth is inhibited.

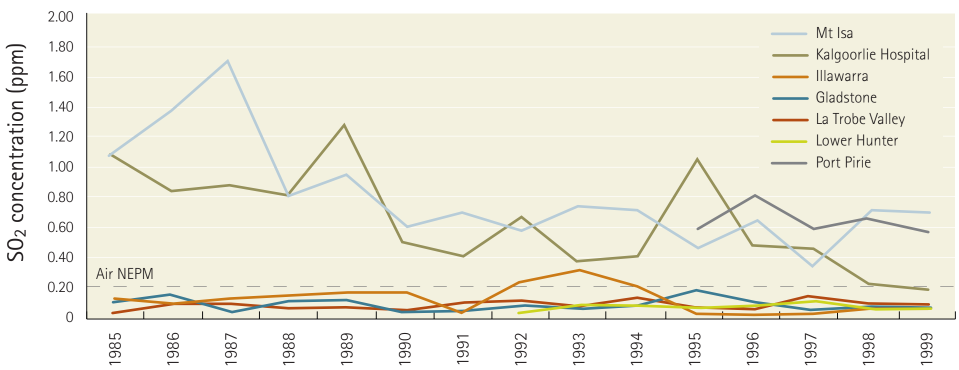
Fine particulates may also affect plants through deposition on leaves and possible blockage of stomata. In addition, metropolitan air contains so-called 'air toxics', which are organic compounds that are known or suspected to damage animal, and possibly ecosystem, health if present in sufficient quantity.

Sulphur dioxide (SO_2) is another emitted pollutant of concern. This can come from coal-fired power stations (if the coal being used has a high sulphur content), from desulphurisation of metals and from vegetation burning. It reacts with water in the atmosphere to form sulphuric acid (H_2SO_4), which is the chief constituent of acid rain. The gas can also be absorbed by leaves and reacts with moist surfaces within foliage to form sulphurous acids. These compounds dissociate to toxic ions which damage the photosynthetic apparatus resulting in yellowing, necrosis and leaf drop. Acid rain can reduce pH in soil and water bodies, and affect the function of plant roots and, in severe cases, leaves. In general, Australia's urban areas are free of this problem, but certain operations in other locations—such as ore-roasting—may release sulphur dioxide. Acidic rain can also fall naturally at times, for example, after bushfires and because of the release of formic acid from vegetation in northern Australia.

Air emissions from an industrial processing plant

Industrial processing facilities are the main sources of airborne fluoride, especially aluminium smelters and steel plants. There are six aluminium smelters located in eastern Australia, one of the largest and most modern being at Tomago in the Hunter Valley, New South Wales. Eucalypts growing in the vicinity of aluminium smelters can be susceptible to damage and there are significant differences in susceptibility between individual species. Excess fluoride inhibits photosynthesis and respiration, causing yellowing and in some species, reddening of leaves. At Tomago approximately 99 per cent of emissions are removed before release of residual fumes into the atmosphere and monitoring of native vegetation for fluoride levels is carried over a radius of 20 kilometres from the point source. However, not all industrial activities meet such high standards, and air pollution exceeding national environmental protection measures (NEPMs) occurs in the vicinities of mining towns, for example, Mount Isa, Kalgoorlie and Port Pirie (Figure 38).

Figure 38: Highest one-hour averages of sulphur dioxide since 1985 in regional centres of Australia



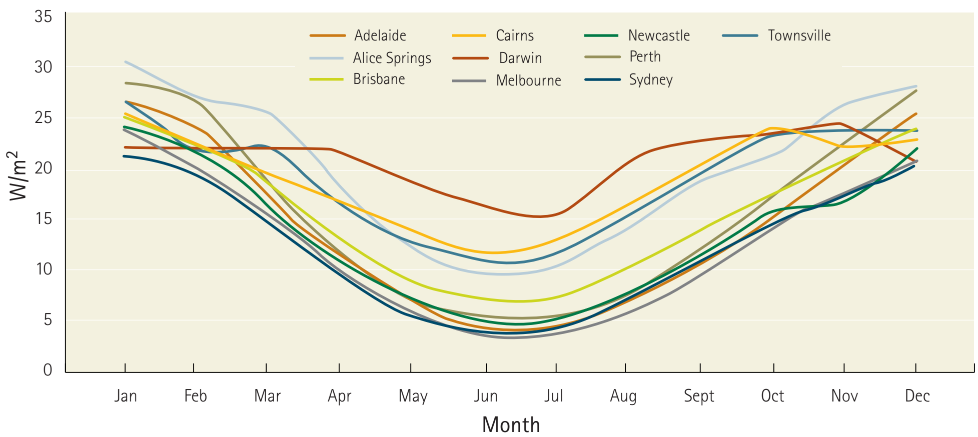
Source: Manins *et al* (2001)

Ultraviolet-B (UV-B) radiation

Reduced concentrations of ozone in the stratosphere have allowed increased penetration of UV-B radiation to ground level. The intensity of irradiation varies with latitude and cloud cover, being greater closer to the equator and in areas with reduced cloud cover. The change in UV irradiation following stratospheric ozone depletion is greatest for temperate latitudes, while the absolute amount of UV received remains greatest in equatorial latitudes.

Irradiation with UV-B can cause cellular damage in plants, thereby reducing productivity. As species can be expected to vary in their sensitivity to irradiation, there could be secondary effects on forest ecosystems as inter-species competition may be altered. Although UV-B exposure in Australia is known to have increased in the last decade (Figure 39), there have been no reports of significant impacts of UV-B radiation on forest species and ecosystems.

Figure 39: Total daily average biologically effective UV radiation in major Australian centres weighted to UV-B 1996–2002



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Changes in forest ecology as indicated by changed biophysical and chemical components

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Indicator 3.1c

Area and percentage of forest land with diminished or improved biological, physical and chemical components indicative of changes in fundamental ecological processes

Rationale

This indicator is useful because it provides a measure of the status of fundamental ecological processes that underpin the maintenance of ecosystem health and vitality.

Little information is available on changes in areas and percentages of biophysical components. However, research is underway on ways of assessing conditions such as eucalypt crown dieback and on possible causes.

This indicator provides a measure of the status of fundamental ecological processes that underpin the maintenance of ecosystem health and vitality. Compared to most of the ecosystems that characterise Australian landscapes, forests rarely display the chronic degrading processes such as salinisation, acidification or water erosion on a large scale. By comparison, agricultural woodlands and retained trees in paddocks in many rural regions—especially the wheat–sheep belt of southern and south-western Australia and irrigated areas of the Murray-Darling Basin—are often in poor health. Tree planting in these areas is an integral part of catchment management initiatives.

Forested lands have been subjected to widespread and selective clearing and have changed substantially in area and composition over the past 200 years. In terms of the condition of the tree layer and with some notable exceptions, the remaining native forests and the expanding plantation estate are generally in a healthy condition. Fires, storms, drought, diseases and pests cause intermittent and sometimes severe damage—however, native vegetation is well adapted to respond to such events, and affected forest sites usually regrow or are recolonised. Unless particularly frequent, these events generally have little effect on the longer term vitality of native forests and are reported on under indicator 3.1a. However, other factors such as harvesting and agricultural practices, grazing and fire regimes have had a broad impact on floristic and structural characteristics of forests and associated habitat values and ecological processes. These latter issues are also reported on under indicator 3.1a.

Information on deterioration in the health and vitality of Australia's forests is almost entirely based on changes in tree health, usually canopy condition. At a workshop held in Canberra in 1980, all States with the exception of the Northern Territory reported localised declines in the health and vigour of their forests and woodlands, characterised by symptoms of eucalypt crown dieback and eventually widespread tree death. Some of these conditions have been related to drought, disease or insect attacks, others remain unexplained or of complex causes. Some attempts have been made to map the occurrence of eucalyptus dieback on a continental scale, but the heterogeneity of data, the variety of causes and lack of spatial information limit the usefulness of this information for national reporting.

Changes in the forest ecosystem, to the extent that deterioration occurs in fundamental ecological processes, are likely to be long-term and require indicators that can be monitored at appropriate temporal and spatial scales. The area requiring such monitoring is very large, more than 16 million hectares, often encompassing some of the most rugged terrain of our continent. Considering the predominance of eucalypts in Australian forest communities, indicators based on eucalypt crown condition appear to offer the best opportunity for reporting on forest health and vitality. Indicators derived from additional components of the ecosystem, for example responses of functional groups of the forest biota, could be built in at some future date. Currently no State has the capacity to monitor the health and vitality of forest ecosystems on this scale and suitable indicators are still being developed for future reporting.

Australia is in the process of developing remote assessment capabilities for data collection on this indicator (3.1c). Changes in tree crown condition integrate responses of vegetation communities to a wide range of environmental influences—physical, biological and anthropogenic—and are quite generic across eucalypt species and forest types. Assessments of degrees of crown dieback in plantations and some high value native stands have been used to assess impacts of drought and disease, but they require intensive observation by trained staff and are not suited to broad-scale native forest monitoring. Also, national standards for reporting on levels of damage sustained by tree crowns in plantations affected by pests and diseases are only now under development.

Advances in acquisition and processing of remotely assessed data from airborne or space platforms appear to offer solutions appropriate to the scale and diversity of the native forest resource. A research program, initiated by State Forests New South Wales and CSIRO Forestry and Forest Products, with additional funding from the Australian Government, has developed an indicator designed to meet the needs of State of the Forests reporting. The indicator does not identify cause and effect relationships, but aims to assess crown condition efficiently and objectively so that deterioration or recovery of forest health can be detected over time.

The Eucalypt Crown Condition Indicator

Canopy of Karri (*Eucalyptus diversicolor*) and Jarrah (*Eucalyptus marginata*) forest, south west Western Australia

The Eucalypt Crown Condition Indicator incorporates physiological and structural changes in eucalypt canopies and was developed at a research site in coastal tall, mixed species eucalypt forest at Olney State Forest south of Newcastle, New South Wales, a portion of which is severely affected by so-called 'bellbird dieback' (see case study). Eucalypt forest decline, often with bell miner 'invasion', occurs in patches of eastern coastal forests from Victoria to southern Queensland. It is estimated that there are now 10 000 hectares of native forest affected by the syndrome and the problem is spreading. The chosen area of forest was traversed at low altitude by a fixed wing aircraft bearing a high resolution spectrometer, which collected digitised reflectance images in selected narrow wavebands of the visible and infra-red spectra. An existing comprehensive dossier of information on the crown condition of individual trees made it possible to relate the reflectance of tree crowns to canopy health. Spectral indices were derived which could be correlated with leaf, shoot and branch characteristics of individual tree crowns. Methods were then developed to aggregate information from trees across several hectares of diseased and healthy forest to provide an accurate picture of the extent of dieback.

A derivative of this approach has been used successfully to assess impacts of a long established psyllid outbreak on mountain ash (*Eucalyptus regnans*) in the Central Highlands of Victoria. Research in progress seeks to reduce the costs of acquisition of remotely-sensed data and to enable this form of spatial information to be integrated into GIS-based forest management. Research has also been extended to include remote assessment of the health of pine plantations in southern New South Wales. Acceptance of the approach and its incorporation into future State of the Forests reporting will depend on further proving its application to a range of forest types with significant health problems, and the availability of suitable spectrographic equipment and air- or space-borne platforms and cost–benefit factors.

Case study: Bellbird dieback—an example of forests in decline

One of the pleasures of visiting Australia's coastal forests from southern Queensland to East Gippsland, Victoria, is hearing distinctive call of native bell miners (*Manorina melanophrys*) (also known as bellbirds), often near a creek where rainforest elements mix with eucalyptus overstorey. These native, insectivorous birds seem to prosper where forests are opened up by walking or logging tracks, especially if dams or creeks are nearby. The patches of forest in such valleys often contain some of our fastest growing and valuable timber species, like Sydney blue gum (*Eucalyptus saligna*), black butt (*E. pilularis*), flooded gum (*E. grandis*), angophoras or turpentine (*Syncarpia glomulifera*).

Unfortunately considerable areas of these forests are affected by severe crown dieback, which appears to signify a fundamental change in the vitality and sustainability of the vegetation community. Some dominant tree species, such as Sydney blue gum which occurs from the south-east forests of New South Wales to Queensland, suffer extreme insect defoliation, leading eventually to crown decline and tree death.

The common feature of such dieback patches is a large increase in the population of the native bell miner. They live in colonies of up to 200 individuals and occupy patches of forest extending to several hectares. Bell miners are very aggressive individuals and chase other insectivorous birds from the area. Research has suggested that the loss of most bird species from these areas triggers very high populations of leaf-attacking insects to establish. Foremost among these are psyllids, a family of sap-sucking species endemic in native forests. Sydney blue gum appears to be particularly attractive to psyllids, and 16 different psyllid species have been found on this tree in only two study sites in New South Wales.

Several other factors may contribute to this problem—for example, climate variation, site quality, burning practices, harvesting history and other forms of site disturbance. Indeed, the bell miner 'invasion' is likely to prove a symptom rather than a cause of the dieback. Further research is needed.

Nevertheless, the association of bell miners with this form of dieback and the undoubted contribution of insect damage to the disease seem to be two critical factors. At present no control measure has been developed that is consistent with the multiple-use objectives of these highly valuable mixed eucalypt forests. Remotely assessed methods of data acquisition as described here provide the opportunity for accurate mapping of diseased forests and monitoring changes in forest health—prerequisites for the development of options for management of this complex problem.

Source: Stone (1999)

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Timber trestle bridge