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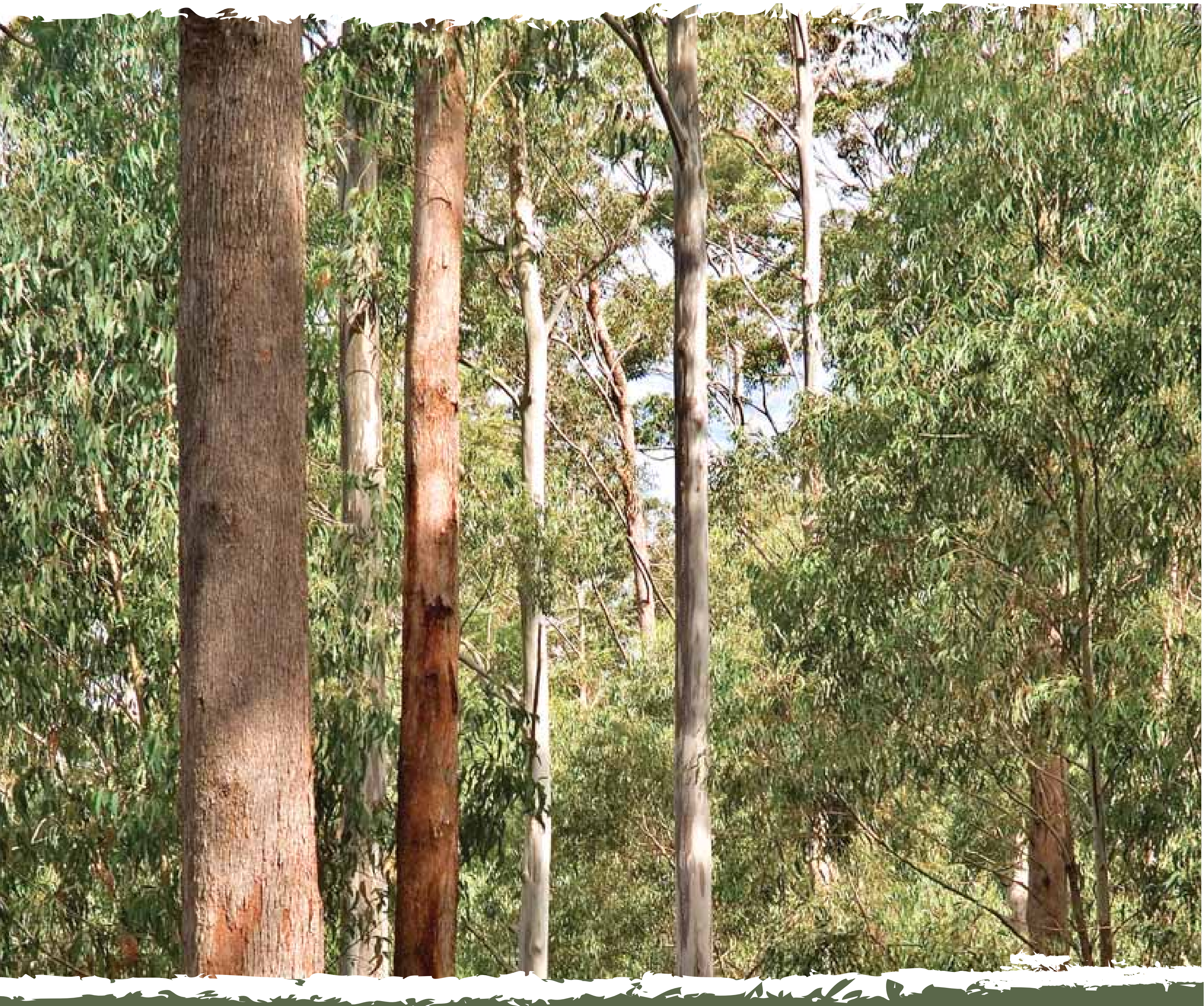

Silvicultural guidelines

Private Native Forestry Code of Practice

Acknowledgements

These guidelines draw heavily from Florence, R.G. 2004, *Ecology and silviculture of eucalypt forests,* CSIRO Publishing, Melbourne which was prepared for use with the *Native Vegetation Conservation Act 1997*.

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1 Introduction

1.1 Silviculture

Silviculture is the art and science of forest management. It encompasses the management of forests for economic benefit (such as sawlogs, veneer logs, honey), environmental benefit (such as flora, fauna, water) and social benefit (such as visual landscape, recreation, heritage). Often these benefits are not compatible. For example, the highest economic return may be gained by clearfelling a forest, but this can have detrimental effects on environmental and social values. Silviculture is a science because there is much known about the processes that occur naturally in native forests, and the impact of these processes on the activities of people. However, forests are extremely complex natural systems. Determining the best management regime within the context of this complexity and the competing benefits that can be derived from the forest is the art of silviculture.

1.1.1 Why not one silvicultural regime?

There is great diversity in the composition, structure, productive condition and environmental values of the private native forests of New South Wales. This is due to the range of natural environments in NSW, and the response of the forests to past use (including grazing, logging and other clearing) and fire. Because of this diversity there is no single silvicultural prescription that can be applied uniformly to all forests.

1.1.2 Regulation of private native forestry in NSW

From 1 August 2007, the harvesting of native forest on private land in NSW has been regulated by the requirements of the *Native Vegetation Act 2003* (NV Act) and the Native Vegetation Regulation 2005, incorporating the Private Native Forestry Code of Practice (PNF Code).

The PNF Code sets standards for forest operations in private native forests. It is based on the principles of ecologically sustainable forest management (ESFM) which requires the maintenance of the full suite of forest values. These values include both biodiversity and timber production. As a component of this, the PNF Code requires the long term maintenance of a forest structure.

The Department of Environment, Climate Change and Water (DECCW) is responsible for administering the logging of native forests. A private native forest manager will, in the first instance, need to contact DECCW to obtain an approved PNF property vegetation plan (PVP).

Note: These guidelines should be used in conjunction with the PNF Code. It is critical that all forest management planning is undertaken in consideration of the relevant PNF Code.

1.2 How to use these guidelines

These guidelines provide essential information for owners and managers of native forests on private land. An appreciation of silvicultural principles and the differences between species and forest types is essential in the observation, interpretation and understanding of any forest.

The guidelines aim to give forest managers an understanding of:

- the forest types found in NSW (section 2)
- the ecological basis of silvicultural practice (section 3)
- important silvicultural procedures (section 4)
- social and economic factors that influence silvicultural practice (section 5)
- silvicultural practice (section 6)
- silvicultural attributes of the major forest types (section 7).

The use of these guidelines and the optimum silvicultural regime for any given forest depend on many factors, including management intent, nature of the local industry, economic considerations, forest type and species present, and the condition and structure of the forest.

2 Forest types

There are many ways to describe or classify forests; they can range from very broad to very discrete classifications. These guidelines separate the forests of NSW into three categories: rainforest, eucalypt forest and cypress forest; eucalypt forests can be described as either wet or dry.

Because of the complexity of species and communities in eucalypt forests, it is helpful to classify them in more detail into forest types, based on factors including similarity of growing conditions, common species associations, productivity and similarity of silvicultural and management practices. Forest types can been described to a finer level of species associations (Baur 1965).

Note: The PNF Code is based on the concept of broad forest types, and these are consistent with the traditional forest types classification. To assist identifying the relevant broad forest type at any location, Appendix A groups the discrete, and easily recognised, forest types from Baur (1965) into one of the broad forest types listed in section 3.1 or 3.2 of the PNF Code.

2.1 Rainforests and eucalypt and cypress pine forests

The historical commercial forests of NSW are made up of rainforests and eucalypt and cypress pine forests. An appreciation of what constitutes a rainforest is required to understand the relationship between forest types, particularly the progression from eucalypt forests to rainforests in high rainfall areas.

2.1.1 Rainforests

Rainforests are generally restricted to coastal lowlands and mountains, where their occurrence is influenced by soil fertility and protection from fire. The best development of rainforests is on soils that are fertile, such as those derived from basalt, or where nutrients have accumulated on lower slopes. Rainforests are both homogeneous and in complex patterns with eucalypt communities.

Note: The harvesting of rainforest is prohibited under the PNF Code.

2.1.2 Eucalypt forests

There are more than 700 eucalypt species in Australia. Temperature and rainfall at the regional level largely influence species patterns. At the local level the influence of a number of other environmental factors come into play, including soil fertility, soil physical conditions, soil moisture status, aspect and position on slope. Past wildfire and logging have also influenced the species pattern.

The eucalypt forests of NSW are more diverse than those of any other state. A rich pattern of forest communities reflects temperate and subtropical zones, the elevation range from the coast to the mountains, variation from arid inland areas to the high rainfall coastal areas, and the diversity of soil types.

2.1.3 Cypress pine forests

Cypress pine is widely distributed, especially in inland NSW. White cypress pine is the most extensive and productive species, and it provides a valuable timber resource. Black cypress pine is also common but grows usually on poor quality, steep country and, though it has very limited timber value, is a source of cypress oil which is used in termite control. White cypress pine originates predominantly from two eras: regeneration in the 1890s and after 1950. There was little regeneration between 1890 and 1950 due to the rabbit plague. White cypress pine is tolerant of a range of soil types and climates, and occurs as almost pure forests or in association with a variety of dry climate eucalypts.

Note: In the PNF Code some of the mixed eucalypt and cypress pine forests fall into the western hardwoods broad forest type; these include forest types 124, 176, 177, 180 to 185, 204 to 207, 209 and 210.

2.2 Characterising eucalypt forests

Eucalypt forests grow on a wide range of sites and vary greatly in productivity. Eucalypt forests can be described in terms of their location along a vegetation gradient, from relatively low productivity dry sclerophyll forest to higher productivity wet sclerophyll forest. This gradient is broadly associated with increasing access to soil nutrients and water. It is common to differentiate eucalypt forests along this gradient in terms of the height of the tallest trees and the type of understorey.

2.2.1 Dry sclerophyll eucalypt forest

Dry sclerophyll eucalypt forest is the most extensive type of eucalypt forest in NSW and an important timber resource. It has the following characteristics.

- The dominant trees are eucalypts, although some acacias, casuarinas and banksias may be present.
- Trees are 10–30 m in height.
- The understorey may either be shrubby or grassy.
- Understorey shrubs usually have small, tough leaves.

2.2.2 Wet sclerophyll eucalypt forest

Wet sclerophyll forest is more productive than dry sclerophyll eucalypt forest and has the following characteristics:

- The overstorey of tall trees includes eucalypts and a number of other species.
- Dominant trees are 30–60 m in height.
- The understorey consists of ferns, soft-leaved shrubs and small trees of mainly rainforest origin.

Well-developed wet sclerophyll forest eventually merges with rainforest.

2.3 Forest types

The generic forest types used for these guidelines are summarised in Table 1. A description of the composition and ecological attributes of each forest type is given in Appendix A.

The coastal and tablelands eucalypt types can be characterised in terms of their range on the rainforest – wet sclerophyll forest – dry sclerophyll forest vegetation gradient (Figure 1). Cypress pine, river red gum and western hardwoods cannot realistically be placed on this gradient, as they have a greater affinity to woodlands.

Note: The PNF Code broad forest types are matched with the forest types in Table 1. To assist identification of the broad forest types in the field, they have been formulated from groupings of the more discrete forest types described in the Forestry Commission of NSW Research Note 17. The various forest types (from Research Note 17) incorporated in each PNF Code broad forest type are listed in Appendix B.

The forest will need to be classified into broad forest types, and marked on the Forest Operations Plan, in order to comply with the PNF Code.

Table 1: Forest types and their location

Generic forest type *	PNF Code broad forest type	Location
Blackbutt Mixed hardwoods Spotted gum Moist coastal hardwoods Flooded gum	North coast blackbutt North coast dry mixed hardwood Spotted gum North coast moist mixed hardwood North coast flooded gum	North and central coasts, extending into the escarpment and mountain forests
Silvertop ash–stringybark Spotted gum	South coast ash–stringybark Spotted gum	South coast and extending into the escarpment and mountain forests
Tablelands hardwoods Alpine ash	Tablelands hardwood Tablelands ash	Tablelands
River red gum Cypress pine Western hardwoods	River red gum forests Cypress forests or western hardwoods Western hardwoods	Western zone

* As described in Appendix A.

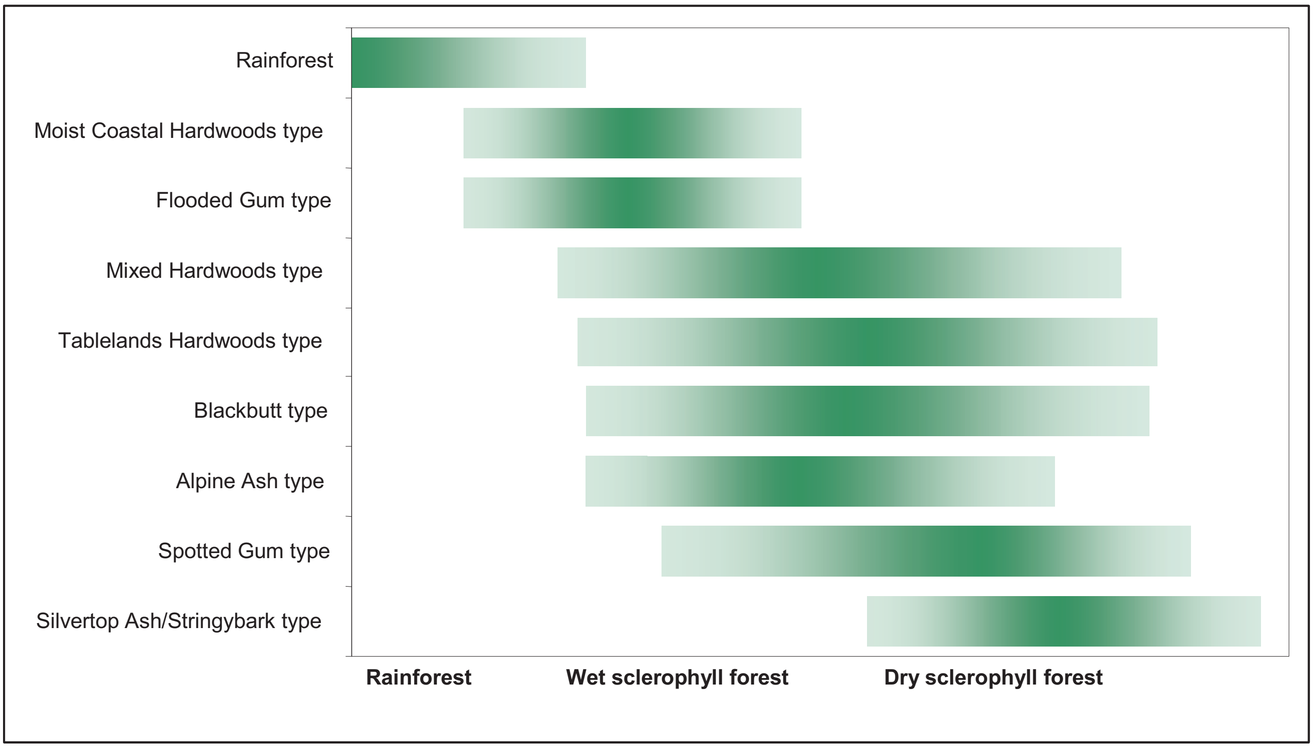


Figure 1: Dry sclerophyll – wet sclerophyll – rainforest vegetation gradient

3 Ecological basis of silvicultural practice

It is important to have a good understanding of the natural processes in forest ecosystems to develop ecologically appropriate silvicultural strategies. The most critical processes are discussed below.

3.1 Maintaining natural species patterns

The evolution of eucalypt species may reflect their progressive adaptation to changing environmental stresses over millions of years, stresses associated with continental drift, climate change and other changing conditions. The present eucalypt forests vary widely in species composition and productivity, reflecting the sensitive response of species and communities to small variations in the environment, including:

- texture and structure of the soil, which affect the capacity of soil to hold water and the movement of water and roots
- aspect and slope, which affect the moisture relations (and fire history) of the site
- fertility of the soil
- the presence of detrimental or beneficial soil microflora, such as fungi.

An appreciation of the way forest composition is controlled by site factors is important in formulating silvicultural practice. This is because the species naturally present are well adapted to the prevailing conditions, and different species make varying demands on site resources (Box 1).

It follows that it will not be ecologically appropriate to alter natural species patterns significantly, particularly if increasing the numbers of a preferred but more site-demanding species. This could create environmental stresses associated with nutrient and water deficits, and affect the health and vitality of the forest. This is an important guiding principle in the management of any eucalypt forest.

Box 1: Blackbutt grading to mixed eucalypt, an example of natural species distribution

To develop rapidly to maturity, blackbutt will use more water than slower growing species, such as white mahogany or tallowwood, which grow in similar environments. Hence, where soil physical conditions and water supply are near optimum for blackbutt it will outcompete the slower growing species and form nearly pure forests.

Alternatively, where the availability of water limits blackbutt growth, there may be mixtures of blackbutt, white mahogany, tallowwood and other species. In this case the mixed community represents a sensitive ecological balance between the species composition of the forest and the availability of site resources.

3.2 Regeneration

After harvesting, or where the forest canopy has opened through natural processes (wind throw, senescence, death or fire), regeneration will come from:

- new seedlings developing where there has been disturbance to the soil surface and seeds are present
- advance growth, including lignotubers (dependent on species) at different development stages
- coppice shoots developing on stumps.

3.2.1 Seedling regeneration

3.2.1.1 Seed production

The following seed production principles are important when considering how a forest will regenerate after harvesting.

1 It may take anything from two to five years for a new flower bud to develop into a mature capsule ready to release seed, depending on the species and environmental conditions.
2 Capsules that are ready to release seed are normally located at the base of tufts of leaves at the extremity of the branch. Figure 2 shows the location of floral parts through the development sequence on a typical branch.
3 Usually only part of the seed crop is shed when the capsule first reaches maturity. Seed continues to be shed during following years.
4 Seeds are released as the capsule dries out, so more tend to be shed at a seasonally dry time of the year. If fire scorches part of the crown, most seeds are shed within a few weeks.
5 All species have good and light seed years. Eucalypts vary greatly in the frequency of good seed years. There may be a reasonable crop every two to four years, and a bumper crop at wide and irregular intervals. Nevertheless, because most eucalypts will set some seed each year and seed from any single crop is shed over two or more years, some seed will be available in most years.
6 Most of the seed produced by a forest will be found in larger, more dominant trees. Suppressed and small trees contribute little to total seed supply.
7 Eucalypt seed does not have wings, is not carried by birds, and does not float on the wind. The distance it is dispersed from a parent tree generally depends on the species, the size of the crop, and wind strength and direction. Eucalypt seed is effectively dispersed to around 1–1.5 times the height of the parent tree. River red gum seed can be dispersed by flood waters.
8 Unlike wattle seed, eucalypt seed will not accumulate and survive in the soil for long periods. Once shed from the capsules, eucalypt seed will usually only remain viable for a few months and, in most situations, seed will be rapidly consumed by insects, although occasionally insects will disperse seed further from the tree without destroying it.

3.2.1.2 Seedling establishment

Only a small proportion of the seed reaching the forest floor will germinate and survive to become established seedlings. Much of the seed is eaten by insects (particularly ants) before it germinates. Other seed falls onto the litter layer and may germinate after rain, and a continuation of moist conditions is required for seedlings to establish. Seedlings are also susceptible to damage from fungi, or may not grow due to a lack of nutrients. The roots of eucalypts form close connections with some fungi (mycorrhizae) which improve their performance, especially the acquisition of nutrients. Seedlings may have a reduced chance of survival if they fail to establish these associations (for example, if suitable fungi are not present on previously treeless sites).

Seedling establishment may be greatly enhanced where there is a suitable seedbed which may be created in one of three ways.

1 Fire creates a good seedbed because it removes the litter layer and exposes soil, destroys unfavourable soil fungi, and releases soil and litter nutrients.
2 Mechanical disturbance, which is intentional or a consequence of harvesting, reduces competition by understorey species and exposes soil. While regeneration after mechanical disturbance is often less spectacular than regeneration after fire, it can be significant in eucalypt forests.
3 Prolonged flooding can kill off herbaceous vegetation and create a moist seedbed to enable regeneration of trees such as river red gum.

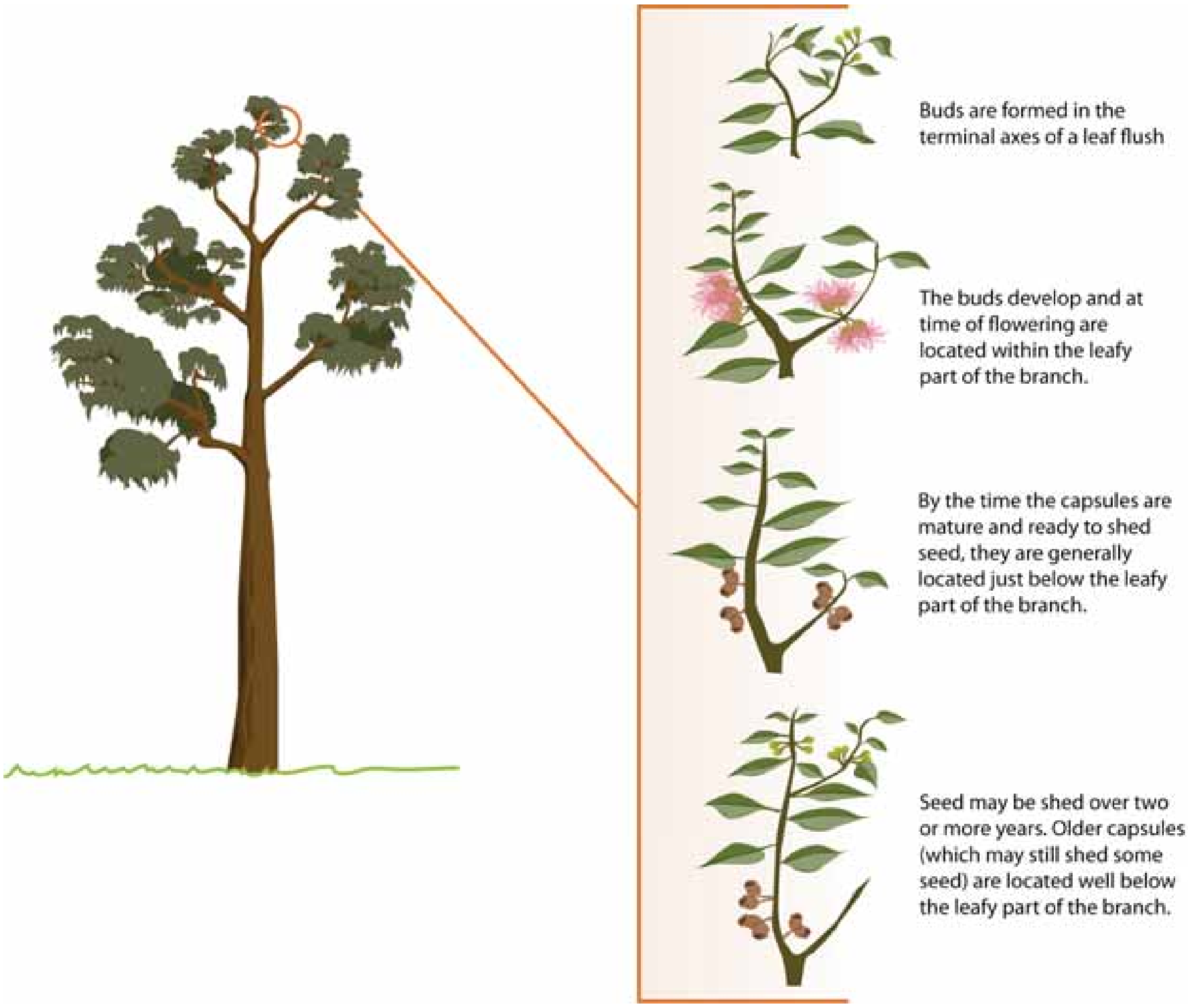


Figure 2: Typical development of seed capsules in the branch of a eucalypt

3.2.2 Advance growth

The term advance growth refers to established seedlings and saplings that have resulted from disturbance.

Where they are impeded by overstorey competition, or because of dry or infertile soils, seedlings of most species of eucalypt form a lignotuber, which is a woody swelling or bulbous mass at the base of the stem. The lignotuber contains nutrient and starch reserves, and has buds that can form new shoots if the aerial parts of the seedling are damaged or destroyed. Seedlings from lignotubers are very hardy and may survive for many decades. They are particularly significant in dry sclerophyll forests where new seedlings may become established and survive infrequently.

Lignotuber seedlings do not survive well in wet sclerophyll forest, especially where there is a well-developed understorey of non-eucalypt species; forest management must rely on new seedling regeneration to maintain stocking and productivity.

Advance growth also includes saplings and small pole-size trees, many of which may be in a suppressed condition.

Note: Some high site quality forest species do not form lignotubers (they are non-lignotuberous). These species include blackbutt, flooded gum, river red gum, brown barrel and shining gum.

3.2.3 Coppicing

Most eucalypts have dormant buds around their stem. When the stem is cut or the tree is burnt, vigorous new shoots can develop from these buds – this is called coppicing. Like advance growth, coppicing is a source of regeneration which is more important in dry sclerophyll forests than in wet sclerophyll forests.

3.3 Growth and development

3.3.1 Growth stages

There are four recognised growth stages in the normal development sequence: sapling, pole, mature and over-mature (Figure 3).

Sapling: Once the seedling has become established, vigorous development of a main stem occurs. During this phase of rapid height growth, the lower branches will be continually shed, and the crown will remain small and compact.

Pole: Once height growth starts to slow down, the young eucalypt enters the pole stage when growth continues at a slower pace than in the sapling stage. The lower branches stop shedding and grow longer, and this deepens and broadens the crown. The tree starts to increase rapidly in diameter.

Mature: The tree enters the mature stage when height growth is nearly complete. The crown structure becomes more complex, with smaller lateral branches developing on the existing branches, which serves to expand and fill in the crown. Diameter growth continues, but hollows have not yet formed.

Over-mature: After 80–100 years or more, depending on the species, the larger branches begin to fail as fungal attack weakens the inside of the trunk and branches. This is the beginning of the over-mature stage. While new branches develop close to the trunk, they are never as efficient as the branches of the crown. Branch breakage and branch regeneration may be repeated several times, as the tree becomes old and decrepit. Trees well advanced in this process are referred to as 'senescent' and may live to be 250–500 years old. Over-mature trees include most of the trees that contain hollows that are habitat for many wildlife species.

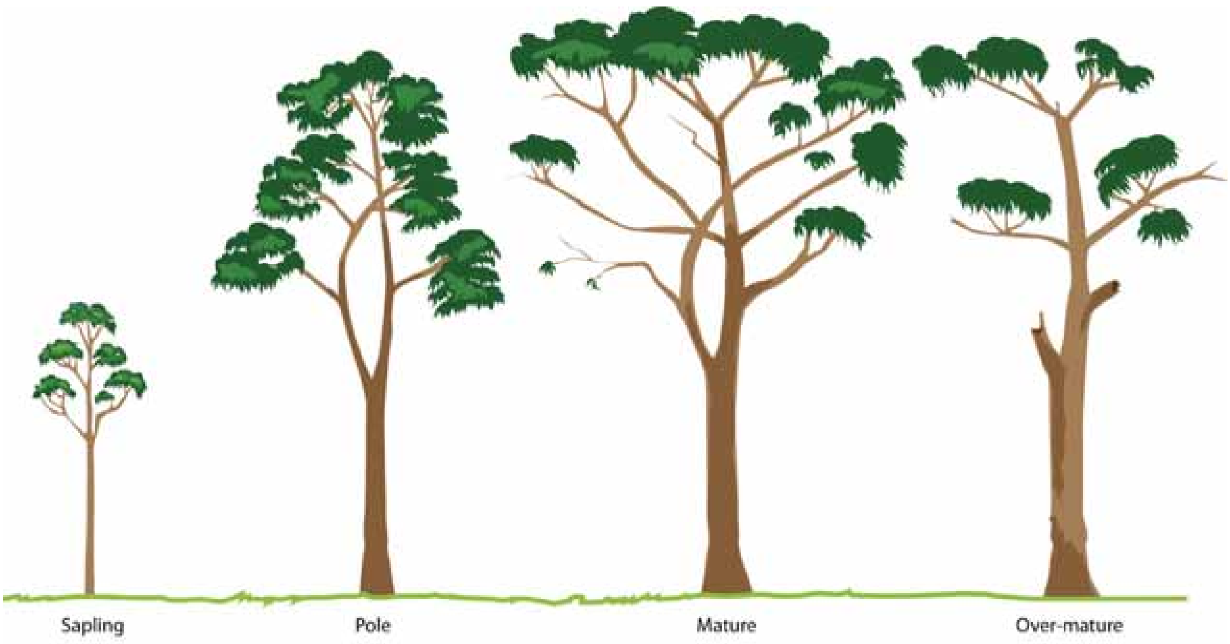


Figure 3: Four growth stages in the normal development sequence

3.3.2 The concept of tolerance

Some species of rainforest trees may grow slowly under a near-closed canopy where they receive direct sunlight through small openings in the canopy for part of the day. These trees must also compete with the large trees of the rainforest for root-growing space, nutrients and water. Because they can withstand this pressure for resources, they are referred to as 'tolerant', that is, tolerant of competition. No species of eucalypt is tolerant in this sense. They are notably intolerant, particularly when they compete for light. However, there is some range in the tolerance rating of eucalypts. While no eucalypt is truly tolerant, intolerant and less intolerant species can be differentiated. The latter are commonly referred to as tolerant eucalypts.

Table 2 indicates the tolerance of eucalypts and other important species, as well as their general growth characteristics and implications for management. Non-eucalypt species in wet sclerophyll forests are usually very tolerant, as is cypress pine.

Table 2: Tolerance of forest trees and implications for management

Tolerance	**Species**	**Growth characteristics**	**Silvicultural considerations**
Very intolerant	Flooded gum	Rapid height growth when given access to a high level of light – can't develop in the shade of other trees.	Requires large canopy openings.
Intolerant	Blackbutt, alpine ash, silvertop ash, stringybark	Fast-growing species, poor development under other trees.	Requires medium to large canopy openings.
Intermediate	Spotted gum, river red gum, brown barrel	Moderate growth rate where part of the overstorey may exist in growth-restricted form under other trees.	Requires medium-sized canopy openings.
Tolerant	Tallowwood, white mahogany, red mahogany, grey gum, ironbarks	Slow to medium growing species, can exist in growth-restricted form under other trees.	Requires small canopy openings, or can develop in small gaps in mixed species forest.
Very tolerant	Turpentine, brush box, cypress pine	Slow growing species, often exist in growth-restricted form under other trees.	Able to respond to very small openings in the canopy after the death or removal of individual trees.

The tolerance of the species in a forest influences silvicultural practice. For example, in a forest of very intolerant and intolerant species, substantial canopy openings are necessary to ensure good seedling generation and unimpeded progression of the trees through the development stages. Moreover, the individual trees will respond well to a large growing space, and will grow fastest where canopy openings are extensive.

3.3.3 Crown shyness

A characteristic of eucalypts which contributes to their intolerance is their 'crown-shy' nature. This reflects the sensitivity of the delicate growing tips of eucalypts to any sort of damage, such as where crowns touch each other due to wind sway. Crown shyness is exhibited where:

- overlapping or interlocking crowns in eucalypt forests is uncommon
- small trees bend away from large trees
- eucalypts developed under other trees may quickly lose the capacity for height growth.

3.3.4 Growth restriction

Not all trees in a forest will develop uniformly through the growth stages. The growth of individual trees will be suppressed if they are out-competed for light, water or nutrients, or if there is contact between crowns of adjacent trees. Trees may either die (more intolerant eucalypts) or persist at different stages of development, but as more or less suppressed stems (more tolerant eucalypts and tolerant non-eucalypt species). These suppressed trees are referred to as growth restricted (Figure 4).

Growth-restricted trees often have only a small amount of foliage relative to their height and diameter, their trunks may be poorly formed, and they may be unable to respond if released from competition. *Thus it is possible for a small tree to be relatively old. When formulating silvicultural practice, it is extremely important to appreciate that trees of the same size are not necessarily the same age or have the same growth potential.*

Figure 4: Growth-restricted saplings under mature trees

3.3.5 The structure of forests

Structure' is a term that describes the way the tree components of a forest are related spatially. The structure of forests can range from simple to complex. An even-aged forest has a simple structure, with tree crowns all at about the same height. However, where even-aged forests are developing rapidly, the trees segregate into a number of crown classes, from those that become dominant within the canopy, to those that are becoming suppressed and will eventually die (self-thinning).

Where there is a number of age classes, the forest will have a more complex structure. An old-growth forest may have a complex structure in which there are over-mature and mature trees overtopping regrowth saplings, and perhaps a rainforest understorey. From a wood production and carbon sequestration perspective, the ideal structure for an uneven-aged forest would be where trees within each age class are aggregated in patches or groups, permitting individuals within each group to achieve dominance and develop rapidly through the growth stages.

Alternatively, where several age or size classes are present, but without any clearly defined spatial pattern, it is likely that many of the sapling and pole-size trees will be subject to competition and will be growth restricted and suppressed.

3.3.6 Consequences of inappropriate forest structure

When harvesting a forest, canopy openings may need to be created to allow regrowth of appropriate species to develop, more or less unimpeded, through the normal growth stages. The examples in Box 2 illustrate the consequences for forest productivity where openings are of insufficient size.

If either of the problems caused by inappropriate forest structure as described in Box 2 are to be resolved, markets will be needed for smaller diameter trees and more intensive forest harvesting practised, including the creation of canopy openings of sufficient size to encourage and maintain dynamic growth.

Box 2: Examples of the consequences of inappropriate structure

Example 1: In Queensland, trees are selected for harvesting based on their size, without any provisions for canopy openings. In the late 1990s the condition of the forests was characterised by a low percentage of trees of sawlog quality or smaller trees with the potential to become sawlogs. Between two-thirds and four-fifths of the stems growing on potentially productive public forest in south-east Queensland were not of sawlog standard and these forests will be increasingly dominated by low quality stems.

The decline in the quality of these forests will have a negative impact on both the wood production potential and the forest's value as wildlife habitat. There will be less structural diversity and, as tree crowns weaken, a decline in the quality and quantity of the food resources and hollow-bearing trees available for arboreal animals.

Example 2: Tree condition in mixed species forest that have been subject to periodic selection harvesting for almost a century shows the consequences of inappropriate forest structure.

An assessment of the tree condition on part of Pine Creek State Forest near Coffs Harbour showed that of 3200 trees assessed, only 40% were in fair to good condition. Most of these were blackbutt and flooded gum in mature and pole classes. The other 60% were weak older trees and growth-restricted trees. Most of these were tolerant species (white mahogany, tallowwood, grey ironbark, grey gum, brush box and turpentine). A similar assessment of spotted gum forest in Bodalla State Forest on the south coast showed only 30% of the trees had good trunks and crowns.

Note: The PNF Code contains restrictions on the creation of canopy openings.

3.4 Environmental values of forests

Silvicultural practices need not only manage forests for wood production but also maintain environmental values. Environmental values most directly related to silvicultural practice include:

1. conservation of biodiversity
2. productive capacity and sustainability of ecosystems
3. forest health and vitality.

The second and third values may be maintained through silvicultural practices that seek to maintain natural species patterns, to improve the productive condition of the existing growing stock and to ensure that adequate regeneration establishes and can continue to develop.

Conservation of biodiversity should be seen as an integral part of silviculture. Where a forest is to be harvested, the basic step of tree marking should address, in the one operation, both wood production and wildlife conservation. Harvesting and tree marking should be conducted to ensure regeneration and to allow healthy trees to grow. Wood production objectives include which trees are to be harvested and which trees are to be retained. Wildlife conservation objectives include which trees are to be retained as habitat and food trees and which trees are to be retained to maintain or develop structural diversity.

Forest managers should be aware of the regulatory processes and obligations relating to conservation of native plants and wildlife, particularly conservation of threatened species. To assist forest managers to gain an appreciation of wildlife habitat, some wildlife and planning principles to conserve wildlife as part of an integrated silvicultural operation are outlined below.

3.4.1 Wildlife principles

There is much information on the distribution and habitat requirements of native forest wildlife. Forest managers need to know what wildlife inhabits their forests and the habitat requirements of each species, in particular rare or threatened species.

Land managers' knowledge of the flora and fauna on their property is variable – from broadscale knowledge of the larger and common fauna to detailed knowledge due to their own interests, such as bird watching or amateur botany. DECCW has lists of threatened species likely to be found in each locality. Some broad wildlife principles are listed below.

3.4.1.1 Forest fauna

Forest fauna are crucial to forest health. All native forest fauna have a role in maintaining healthy and productive forests. They may play a direct role as pollinators or predators of pest species, or an indirect role by turning over soil and leaf litter in the search of food (thus improving soil friability and nutrient cycling) or transporting fungal spores beneficial and crucial to the growth and development some forest tree species.

Terrestrial animals

- The distribution of terrestrial animals will be influenced by site factors, such as vegetation type, soil type, moisture levels, presence of old stumps, logs or rocks, and condition of the understorey and the ground cover layer. Certain plant species may be important food sources, as are populations of invertebrate species on which some of the animals feed.
- A structurally complex canopy cover with dense, heath-type understoreys constitutes preferred habitat for many terrestrial animals. These animals may not be disadvantaged by harvesting and slash burning operations that can generate dense understoreys, particularly where there is a mosaic pattern of cut and uncut forest.
- Fuel reduction burning and grazing can affect the habitat value for terrestrial animals. Where fuel reduction burning is carried out at low intensity over a wide area, a reduction in the complexity of the forest understorey may disadvantage many terrestrial species, but favour predatory species such as the dingo and fox. Grazing (especially when accompanying high frequency, low intensity burning) also reduces structural complexity. Burning removes stumps and fallen logs that provide habitat and food resources for ground-dwelling animals. Alternatively, planned moderately intense fire has been successfully used to generate a patchwork of dense understorey thickets needed for shelter and food in Western Australia.

Arboreal animals

Many arboreal (tree-dwelling) mammals and birds depend on the availability of nesting sites in tree hollows, and an array of tree and shrub foliage (and related insects) for food for their existence. Hollows which are of critical importance to wildlife generally occur in over-mature trees and may take more than 100 years to reach a size that is useful for large wildlife species. Hollows in standing dead trees also comprise critical habitat. Some animals, which generally include those species that are most threatened, will not survive where their habitat is critically altered; others have wider environmental tolerances and can adapt to highly altered habitats. Many hollow-dependant fauna require a number of hollow-bearing trees within their home ranges in order to respond to changed weather conditions, parasites and breeding circumstances.

Arboreal mammals and birds tend to be concentrated in patches or mosaics where environmental conditions are favourable; for example, within the dry sclerophyll forests of the Eden region, 60% of the arboreal mammals are found in only 9% of the forest. The tree species, moisture and nutrient status of the soil, tree and understorey species richness, and cover abundance determine the quality of food resources for some animals.

Greater numbers of wildlife species, and populations of species, are likely to occur where floristic and structural diversity is greater. Floristic diversity, including mixtures of overstorey eucalypt and other canopy species, in addition to floristically diverse understorey and shrub-layer species, may be critical in maintaining a year-round supply of food resources for sedentary animals. These same resources may be crucial at certain times of year for migratory species as they transit the landscape between their life stages (such as winter-flowering trees and shrubs for honeyeaters).

Arboreal mammals tend to be associated with different growth stages. For example, south coast populations of the common brushtail possum and squirrel glider build up to a peak in pole and early-mature forests. Populations of yellow-bellied glider and greater glider peak in mature and over-mature forests, and populations of the common ringtail possum, mountain brushtail possum and eastern pygmy possum peak in declining old-growth forests with a rainforest understorey. Because of these growth stage preferences, there are animals whose populations may be maintained at high levels in mixed species, multi-aged forests with a history of selective logging; these include the sugar glider, yellow-bellied glider, greater glider, feathertail glider and squirrel glider. It also applies to the koala in some east coast forests.

In summary, wildlife values may be enhanced by working towards a multi-aged mixed species forest with a wide range of components, from saplings and poles to mature and over-mature trees, and a diverse understorey.

3.4.2 Planning for wildlife

Habitat for wildlife needs to be maintained at many scales in the landscape to accommodate as many species as possible. The following principles are important in maintaining habitat.

1 Connectivity of habitat

The key issue is to enable populations of each wildlife species to persist and move about the landscape. Key habitat elements for both terrestrial and arboreal species need to be retained and distributed appropriately. A network of corridors to connect habitat patches is beneficial for many wildlife species; examples of buffers include streams and rivers that contain undisturbed forests with over-mature trees and other habitat features. However, in many cases habitat features are best distributed throughout the landscape. Conservation of wildlife can be improved by planning for the needs of wildlife at a farm or broader scale.

2 Landscape heterogeneity

The diversity, size, and spatial arrangement of habitat patches across the landscape is important for some wildlife species. Maintaining such heterogeneity is implicit in the philosophy behind these silvicultural guidelines.

3 Stand structural complexity

Features that add to structural complexity of tree stands include the retention and maintenance of:

- multiple ages of trees within each stand
- large living trees and stags
- large logs on the forest floor
- multiple canopies
- canopy gaps and areas of relatively dense canopy
- thickets of understorey vegetation.

Though it may not be possible to retain all of these features in all situations (for example, highly intolerant eucalypts do not grow well in multiple-aged stands), in general practices that increase structural diversity beyond what is desirable in a forest managed solely for timber production are encouraged.

4 Integrity of aquatic ecosystems

Streams, rivers and wetlands are highly sensitive to disturbance, and are important for the conservation of biodiversity. It is therefore important to manage forestry operations adjacent to these areas to protect biodiversity and maintain water quality and aquatic habitat.

3.4.3 Managing wildlife during harvesting

In accordance with the principles of ecologically sustainable forest management across both the public and private forest estate, the management of forests for timber production, wildlife, and other biodiversity values is highly integrated. Conserving wildlife in harvested forests, or ensuring rapid recolonisation after harvesting, is an important principle, and depends on the extent to which key elements of wildlife habitat are retained and managed.

This means protecting the many elements of primary habitat, such as old logs, rocks, ground cover, hollow trees and feed trees, during harvesting and, where fire is used, promoting and maintaining an understorey mosaic, including areas of dense understorey vegetation.

Note: The PNF Code contains provisions for the protection of habitat and biodiversity, including the retention of a number of key habitat components for wildlife. Retention of habitat in other areas of a property also contributes to wildlife conservation.

There are also specific requirements in the PNF Code for specified individual threatened species.

In addition, there may be specific requirements for individual species, particularly species designated as rare or threatened, or for endangered ecological communities under the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth).

4 Important silvicultural procedures

The PNF Code refers to, and contains provisions relating to, the silvicultural practices of single tree selection, thinning, and Australian group selection (AGS). These practices will be referred to in the following sections of these guidelines.

Creating canopy openings is associated with AGS.

4.1 Tree marking

Tree marking traditionally has been done by either marking trees which are to be removed or by marking trees that are to be retained. The following describes tree marking for retention. If trees are marked for removal then these concepts and principles still need to be considered but the trees marked are only those that are permitted to be removed. .

Trees that are to be retained for wildlife should be physically marked. Tree marking is also highly recommended for all trees with good productive capacity that should be retained for future harvest and a seed source with good genetics, and for those trees that should be harvested in the current operation.

There will be circumstances where an experienced faller might make effective judgements without prior marking of trees to be felled, for example, where the forest is in good productive condition and near fully stocked. However, *pre-logging physical marking of trees to be felled is preferred* because the tree marker is likely to have a better spatial appreciation of the layout of the forest and, if necessary, can adjust the marking to satisfy the requirements of the PNF Code and incorporate and ensure the forest owners' long-term management objectives for the forest.

There are four steps in implementing a tree-marking regime:

1. marking trees for wildlife
2. marking trees with good productive potential to be retained for future harvest and seed source (optional and recommended)
3. marking trees for harvesting (optional and recommended)
4. adjusting tree marking in order to satisfy the PNF Code requirements and achieve an appropriate balance between wood production and biodiversity.

Step 1: Marking trees for wildlife

The maintenance of habitat for arboreal mammals and birds is governed by the PNF Code standards for tree retention. Additional considerations when marking for wildlife purposes are:

- Where over-mature trees that are retained for wildlife habitat are senescent, they may have little impact on regrowth, but where still relatively vigorous they can limit wood production significantly due to the size of their crowns.
- Wildlife values are enhanced in areas that are structurally diverse and contain a variety of food sources. A management option is to leave some patches that include habitat trees, dense understorey and a variety of tree species and size classes undisturbed.
- If the number of large over-mature trees is considerably greater than is required to meet the wildlife standards, one option is to ringbark, poison or fell some of them as waste to release advance growth. However, if this is undertaken, it is important to ensure that the number of retained hollow-bearing trees and trees approaching hollow-bearing age remains adequate throughout the managed area.

Step 2: Marking trees with good productive potential to be retained for future harvest (optional but recommended)

Tree marking should seek to retain all trees judged capable of good productive potential for future harvest. Trees that are retained should have defect-free trunks and vigorous, well-balanced crowns. The size of trees that should be retained will vary depending on the forest type and quality of the site. In addition, some species (such as grey gum and grey box) develop defects such as internal ‘pipe’ at an early stage so it may not be appropriate to retain them beyond a certain size. Forest managers should seek local advice on the wood-growing characteristics of different tree species.

Step 3: Marking trees for harvesting (optional but recommended)

Trees not marked for retention are potentially available for harvest. The harvest should aim to both provide an economic benefit to the forest manager and improve the average productivity of the forest. In addition to thinning within patches of pole and mature trees, harvesting should focus on older trees that have reached commercial maturity and are starting to slow down in growth, trees that are already in decline, or trees that are in a growth-restricted condition. As many trees as possible of marginal commercial quality should be harvested, unless they need to be retained to satisfy PNF Code basal area requirements or for wildlife purposes. Marking trees for felling should include preferred direction to minimise risk of damage to trees marked for wildlife purposes and trees with future growth potential.

Step 4: Adjusting tree marking to satisfy PNF Code requirements and achieve an appropriate balance between wood production and biodiversity

These tree marking guidelines represent a ‘single tree selection’ approach to silviculture, that is, each tree is considered on its own merits. However, it is necessary to take account of the impact that tree marking will have in terms of the basal area and canopy opening limits of the PNF Code, the structure of the forest, and the balance between biodiversity, conservation and wood production. There will be circumstances where little or no adjustment is needed and others where much thought must be given to ways of achieving PNF Code requirements and other management objectives. This can be a very challenging part of silvicultural management.

4.2 Creating canopy openings

Canopy openings should be planned and not created incidentally. These openings may release advance growth (from lignotuber type seedlings to stems up to half canopy height) or ensure that new seedling regeneration can establish and grow to maturity. Prospective canopy openings may be located:

1. where, after harvesting, there are natural canopy openings of sufficient size to ensure advance growth, or new seedling regeneration can develop through the size classes; if sapling-size advance growth in these openings has been weakened by competition, they may be coppiced to enable new, more vigorous stems to develop
2. where one or more additional trees (preferably those of marginal productivity) can be harvested in order to create an effective canopy opening, but without compromising the requirements of the PNF Code or environmental objectives.

An effective canopy opening will vary with site factors and the tolerance of the species, but for most forest types will be 50–60 m in diameter.

Note: The size and extent of canopy openings must at all times conform to the requirements of the PNF Code.

4.3 Encouraging regeneration on difficult sites

Treatment of the soil surface to encourage new seedling regeneration is recommended within wet sclerophyll forests, or forests that have grassy rather than shrubby understoreys.

4.3.1 Wet sclerophyll forest

There should be adequate seedling regeneration in canopy openings where at least 60–70% of the site is mechanically disturbed. This means removing competition (such as ferns and shrubs) and exposing the mineral soil surface using the blade on a harvesting machine or tractor. The blade should be lifted every few metres to avoid pushing topsoil too far and to reduce the potential for erosion. If weeds such as lantana are present, it may be necessary to take appropriate action to prevent the weeds from taking over the site. Seek advice from the local weed authority.

Alternatively (or additionally), harvesting debris might be allowed to dry out and burned when weather conditions are suitable. Fire intensity should be as high as possible, consistent with the natural regeneration processes of the eucalypts and the protection of retained trees. Problems associated with burning of debris include:

- destruction of established seedlings
- loss of seed within the crowns of felled trees
- infrequency of weather conditions needed to sustain a fire that will create a good seedbed, but with minimal risk that the fire will spread to the surrounding forest
- need for specialised fire fighting equipment and experience
- possible stimulation of dense, competitive vegetation, such as wattles or lantana, that also responds to fire.

4.3.2 Forest with a grassy floor

There are eucalypt forests, particularly at higher elevations, with a distinctly grassy rather than a shrubby forest ground layer. Eucalypts do not regenerate as consistently or uniformly on these sites. In nature, regeneration may have developed primarily on localised seedbeds created where trees have fallen and burnt intensively. It is recommended that seedbeds be created through mechanical disturbance (blading off the grass and disturbing the mineral soil), rather than through a post-harvest burn of only moderate intensity (which may only serve to stimulate grass growth).

4.4 Direct seeding and planting

Natural regeneration is the preferred means of regeneration because it helps ensure that natural species patterns are maintained (see section 3.1). However, if canopy openings are unlikely to be successfully regenerated by natural means (due to invasion by weeds or a poor natural seed crop) or natural regeneration is unsuccessful, regeneration can be enhanced by direct seeding or planting. To conserve genetic diversity, it is best to use locally collected seed for direct seeding, or for growing seedlings for planting. While the basics of direct seeding and planting, as described below, are simple, there are many potential pitfalls (for example weeds, rabbits, browsing animals, frosts or use of nursery stock that is not compatible with the site) and it is advisable to seek advice from people who have successfully established trees on similar sites.

4.4.1 Direct seeding guidelines

- Collect capsules with mature seed from the crowns of felled trees of all species.
- Extract seed from the capsules by drying it in the sun.
- Seed can be sown by hand or by machine.
- Sow seed onto burnt or mechanically disturbed ground, preferably just before rain and at the wetter time of the year.
- Use seed from a mixture of species that are appropriate to the site.

4.4.2 Planting guidelines

- Seedlings can be grown at home or are available from commercial nurseries.
- Seedlings should be about 20–30 cm tall and hardened-off prior to planting.
- Prepare the site for planting by burning or mechanical disturbance, and use of herbicides where necessary, to ensure a weed-free seedbed.
- Plant seedlings at around 1100 stems/hectare (ha) (3 m x 3 m spacing).
- Plant seedlings during the wetter time of the year.

- Fertilise seedlings after planting with around 100 g of a complete NPK (nitrogen, phosphate and potassium) fertiliser per tree.

4.5 Thinning principles for even-aged forests

Eucalypt forests may be even-aged, or substantially even-aged, where in the past:

- a wildfire killed or weakened the overstorey trees, resulting in vigorous regeneration
- much of the overstorey was harvested in a single operation (or several operations over a short period of time)
- land had been cleared for agricultural purposes, but subsequently regenerated to forest.

In all cases there may be some large remnant trees within the forest, which may have a negative impact on the condition of the regrowth, but may also provide habitat for wildlife.

Even-aged forests, or substantial patches of even-aged regrowth within uneven-aged forest, can be highly productive. That productivity can be enhanced further if the forests are thinned from time to time. Thinning may be carried out at two stages: before regrowth has reached a commercial size (preferably at the sapling stage and before too much of the green crown has been lost through competition), and when commercial products are harvested (pole and early mature stages).

Thinning is particularly justified in highly stocked forests of fast-growing eucalypts, such as blackbutt. These forests can build up rapidly to a peak in volume production. If thinned (non-commercially) during the rapid early growth phase, much of the total volume production can be directed to a smaller number of trees, greatly accelerating their diameter growth and reducing the time taken to reach commercial size. The benefits of thinning have been convincingly demonstrated in regrowth mountain ash in Victoria. A forest thinned at five years (non-commercially) and at 20 years (for pulpwood) would produce, at 50 years, almost as much sawlog volume as that produced by an unthinned forest at 80 years.

Of course, not all eucalypts respond to thinning in this way. Some species, particularly those associated with poorer sites, are inherently slow growing and hence less responsive to thinning. Moreover, fast-growing species may respond only slowly where thinning has been unduly delayed and all crowns (even those of the dominant trees) have been weakened by competition. Nevertheless, unless an even-aged forest is seriously affected in this way, thinning can help revive the dynamic growth process, improve future biodiversity and prospects for future harvests.

5 Social and economic factors

5.1 Conflicting objectives of management

Historically private forests have been managed primarily for wood production as a supplementary source of income. Due to public pressure and increasing concern for the environment, management today focuses on both conservation of environmental values of the forests and on wood production. This is consistent with the principles of ecologically sustainable forest management.

The objectives of private native forest management can be broadly stated as follows:

1 To appreciate and conserve all environmental values of the forest. This may mean:

- maintaining natural species patterns within forests (in all structural layers including the understorey)
- maintaining or improving structural diversity (that is, a range of tree sizes and understorey life-forms)
- protecting from harvesting any patch of forest with significant environmental values
- ensuring there are sufficient habitat components available to conserve wildlife populations or ensure their rapid recovery after harvesting.

2 To maintain or improve the condition of the forest growing stock; this may mean:

- harvesting the forest in such a way that the more productive elements of the growing stock are retained for future harvest
- ensuring that, where the forest does not have enough trees or advance growth to be considered adequately stocked, regeneration following harvesting will both establish and have room to develop through to maturity.

Some of these objectives are in direct conflict. For example, improving the productivity of a forest usually means reducing its structural diversity, as the more uniform it is the faster the trees are likely to move through the growth stages. Conversely, reducing structural diversity may impact on the wildlife values of a forest. *The silviculturist needs to achieve a suitable balance between these objectives.*

An example is given in Box 3.

Box 3: Example of the conflicting objectives of management

Figure 5 illustrates adjacent areas of a spotted gum – blackbutt – white stringybark forest on the south coast. The uneven-aged forest on the left has good structural diversity and wildlife habitat potential and is aesthetically pleasing. However, from a wood production perspective, it is understocked and many of the trees have limited growth potential. The even-aged forest on the right has resulted from regeneration following clearfelling and, although it is a highly productive forest, it lacks many of the environmental attributes of the selectively harvested forest. Optimum forest management might be achieved by a mosaic of these two systems so that areas of suitable habitat for wildlife, such as hollow-bearing trees, remain connected and are present throughout the landscape.

Uneven-aged forest

Even-aged forest

Figure 5: Adjacent forests on the south coast

5.2 Economic considerations

Until recently, the forest processing industry generally only accepted large logs that had very little defect; this meant that many poorer quality trees were left in the forest. Industry now accepts logs of a wider range of size and quality. This can facilitate better silviculture by enabling the harvest of trees with limited potential for continued growth.

In regard to the marketing of forest products, the questions a forest manager will need to consider are:

- What range of log products will I be able to sell?
- What volume of wood is available, and in what grades?
- Will the wood volume justify the costs of road construction, harvesting and log transport?
- Will the environmental constraints affect the viability of the operation?

These factors will influence both harvesting and silvicultural decisions. The forest manager can seek advice from Department of Industry and Investment, the local timber processing industries and other relevant parties on the prospects for harvesting.

The efficiency with which harvesting can be carried out is another economic factor influencing silvicultural practice. Clearfelling, burning of debris and direct seeding over a large area can be a highly efficient operation, carried out at minimal cost. However, it fails to satisfy other objectives of management. Modern multiple-purpose silvicultural practice is more costly, particularly where it involves tree-marking and relatively low-impact harvesting. However, this is a trade-off needed to balance the competing objectives of management.

5.3 PNF Code conditions relating to silviculture

The PNF Code sets the standards for forestry operations in private forests across NSW. This includes prescriptions relating to various silvicultural practices.

Some native forests in private ownership may not be in a suitable condition to support economic harvesting and meet PNF Code requirements. Examples include forests with a history of unregulated exploitive logging that have poor biodiversity values and contain few merchantable trees, and understocked forests requiring more intensive forms of site manipulation in order to reach the regeneration standards of the PNF Code. These forests will present significant challenges to the native-forest manager.

5.4 Using basal area to limit harvesting intensity

The PNF Code uses the concept of basal area to set tree retention levels, or disturbance thresholds, for single tree selection and thinning operations. Basal area is widely used to regulate the level of growing stock in fully stocked even-aged forests and plantations. However, its use in uneven-aged forests can be problematic due to variations in the size and spatial arrangement of trees.

It is important to note that the minimum stand basal areas for single tree selection and thinning operations set by the PNF Code for the various broad forest types are not necessarily optimum for maximum timber yield. Rather, they are minimum disturbance thresholds that have been developed by taking all forest values into account. When developing silvicultural prescriptions (section 6) the emphasis should be on keeping all quality trees that are judged capable of further growth. However, while it is unrealistic to set specific silvicultural basal area targets for native forests, it is useful to have some appreciation of the range of what may be optimum (Table 3).

Table 3: Optimum post-harvesting basal areas by forest type with a stand height greater than 25 metres

Forest type	Optimum post-harvest basal area range (m^2/ha)
Blackbutt, 'wet' spotted gum, moist coastal hardwoods, flooded gum, alpine ash	15–20
'Dry' spotted gum, mixed hardwoods, silvertop ash/stringybark, tablelands hardwoods	8–15
River red gum	12–15
Cypress pine and western hardwoods	6–8

6 Silvicultural practice

6.1 Determining the most appropriate silvicultural approach

Prior to harvesting, the forest condition should be evaluated to help formulate silvicultural practice consistent with the objectives of management.

Note: Adequate planning at this stage will help to determine how best to carry out operations in accordance with the PNF Code.

Forest condition may be evaluated by systematically observing the forest, as follows.

Forest type – Note the individual tree species, their relative frequency and the characteristics of the understorey. What is the forest type: dry sclerophyll or wet sclerophyll? Is the area of forest to be harvested more or less uniform in composition, or are there changes with aspect or terrain?

Forest components and their condition – Identify growth stages present in the forest (saplings, pole-size trees, mature and over-mature trees). What is the productive condition of trees in each of these stages, what proportion of trees would you describe as growth-restricted, and what proportion has good quality, straight, defect-free trunks with good growth potential (healthy crowns, access to light, limited competition)?

Forest structure – Observe the way trees in different size classes are arranged. Is the forest even-aged? If there are a number of growth stages, how are they arranged spatially – in even-aged patches, or in a less structured pattern? Does unsatisfactory tree condition reflect an unsatisfactory forest structure and silvicultural history?

Wildlife habitat – Observe the presence of components required to conserve wildlife, such as trees with hollows, recruitment trees, food trees, nest and roost sites and condition of the forest floor. Will it be possible to satisfy the criteria relating to wildlife conservation?

Forest regeneration – Will the existing forest simply be thinned, or will the canopy be opened up in patches? If canopy openings are to be created, is there a useful quantity of lignotubers and other advance growth? If not, is seedling regeneration likely to develop in response to soil disturbance, or will it be necessary to apply a regeneration treatment (further soil disturbance, burning of debris)? Does the need for site preparation vary within the block, for example, in different terrains? Can seed trees be retained close to the canopy openings?

Historical influences – Note evidence of past disturbances (fire, logging), which might have influenced the growing stock condition. For example, the height and condition of tree stumps will tell you something about past logging; the frequency and depth of fire scars on older trees, and carbon blackening of fibrous-barked trees may tell something of fire history.

By drawing together all these observations it should be possible to:

- appreciate the composition, components, structure and condition of the growing stock
- determine what prospects there are for a commercial harvesting operation
- formulate practice consistent with the objectives of management and the PNF Code .

Armed with a description of the forest condition, Figure 6 and associated category descriptions may be used to determine the most appropriate silvicultural approach.

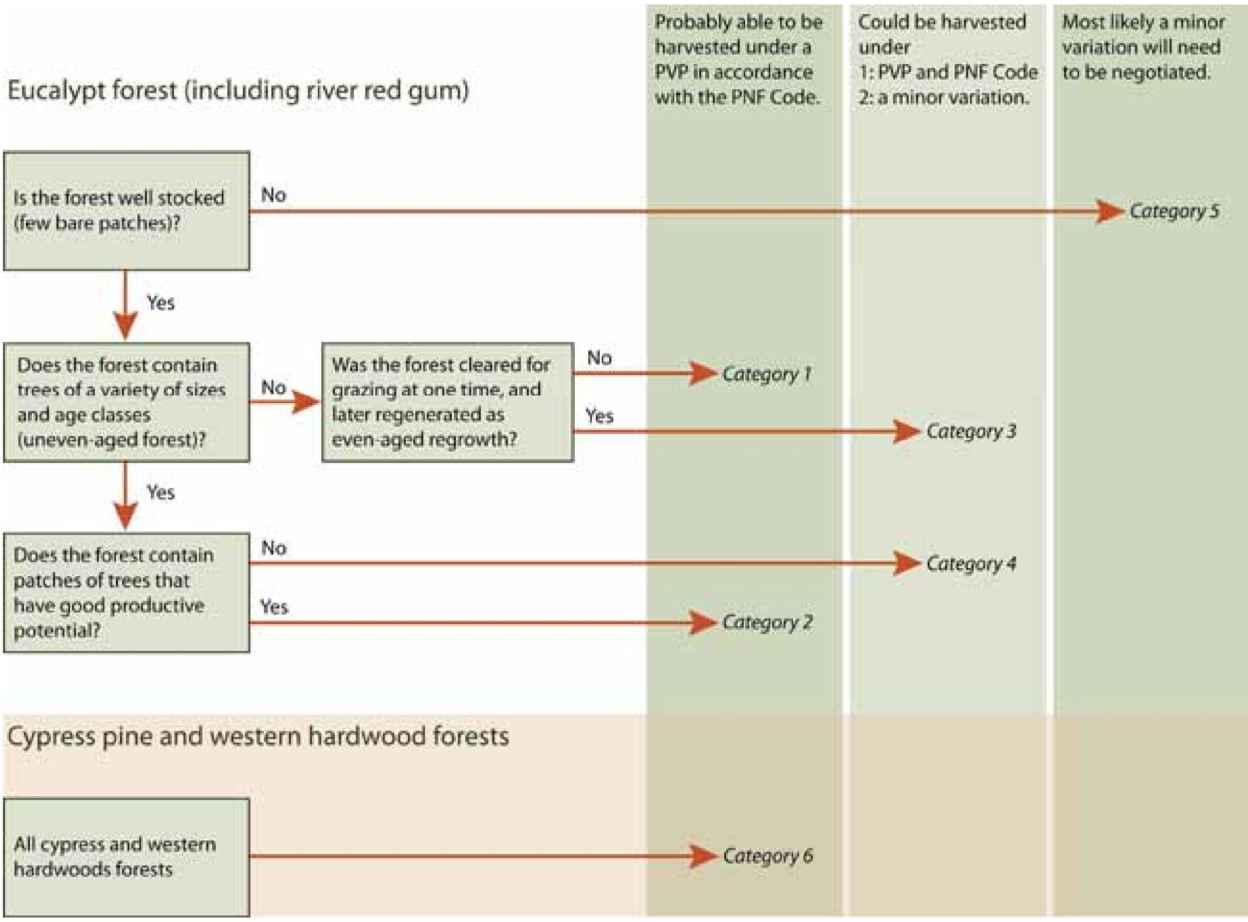


Figure 6: Flow chart to determine broad silvicultural categories

Category 1: Essentially even-aged eucalypt forest that has regenerated following intense wildfire, intensive logging or clearing for agriculture.

It is usually associated with the more intolerant eucalypt species capable of rapid response to harvesting and fire. Examples include blackbutt and flooded gum forest on the north coast, and alpine ash forest on the southern tablelands. Even-aged forests can be thinned in accordance with the PNF Code.

Category 2: Eucalypt forest that is uneven-aged but is well stocked and in good productive condition. There are usually defined patches that contain trees of the same size.

An example is a well-stocked forest with patches of mature trees resulting from logging around 1910–1930, and patches of pole regrowth from logging around 1980–1990. Ideally, there would be several over-mature trees scattered throughout. The silvicultural prescriptions for uneven-aged forests in good productive condition would be appropriate to this forest.

Category 3: Eucalypt forest that is essentially, though not completely, even-aged, the result of early clearing for grazing and subsequent forest regeneration. The forest may also contain some over-mature and growth-restricted remnants of the original forest.

A great deal of private forest has developed in this way, with the regrowth forest now up to 100 years old or more. It may have been selectively harvested on several occasions, mainly for poles and sawlogs. As the forest started from a near clearfelled base, parts of the growing stock may be in moderate to good condition and capable of being harvested under the PNF Code. Alternatively, where there are a greater number of residual over-mature or growth-restricted trees, it may be more advantageous to harvest at a greater intensity, for which minor variation will be required.

Category 4: Eucalypt forest with a good stocking of trees, but few trees in good productive condition.

This is likely to be a common condition where forest was selectively logged in the past, but without any post-harvest improvement treatment such as ringbarking of non-economic trees. Where the forest was logged only lightly in the past, it may now consist of a mixture of large over-mature trees, some stagnant trees without any growth potential, and relatively few patches of effective regrowth. In other cases there may have been a succession of selective loggings that have resulted in an accumulation of growth-restricted trees. In either case the forest owner has three options. The first is to harvest under a PVP in accordance with the PNF Code and accept that in some situations the conditions relating to residual basal area and canopy openings will limit the opportunity to improve the forest productivity in the one harvest. The second is to apply for minor variation which could be based on removal of trees with little growth or economic potential. This may include reducing the residual basal area below the minimum stand basal areas for single tree selection and thinning operations set down in the PNF Code. The third is to manage the forest for conservation, perhaps applying for any government-funded incentives that may be available.

Category 5: Eucalypt forest that is notably understocked.

Understocking is most likely to apply to wet sclerophyll or higher elevation grassy forests where no post-harvest regeneration treatment has been carried out. Minor variation may be necessary for any single tree selection or thinning harvesting operation, and special consideration may need to be given to treatments designed to regenerate the forest.

Category 6: Cypress pine and western hardwoods forest.

Cypress pine and western hardwoods forests are generally well stocked and can usually be harvested under the PNF Code.

6.2 Silvicultural practice for forests satisfying PNF Code conditions

This section details silvicultural practice for forests that can be harvested under the PNF Code. These prescriptions should be read in conjunction with the silvicultural attributes of the relevant forest type, described in section 7.

6.2.1 Uneven-aged eucalypt forest in good productive condition

Uneven-aged eucalypt forest in good productive condition contains trees of various size classes, including patches of pole and young mature regrowth trees. In this situation it is appropriate to follow the four tree marking steps set out in section 4, and how these steps would be applied is described in Box 4.

Box 4: Four-step tree marking of uneven-aged eucalypt forest in good productive condition

Step 1 – Mark trees to be retained as wildlife habitat following the guidelines in section 3.

Step 2 – Mark trees to be retained for future production; the aim should be to retain most trees judged capable of growing to a more valuable size during the next cutting cycle, namely:

Trees >80 cm diameter at breast height over bark (dbhob). Only trees required for wildlife purposes will normally be retained. However, the forest owner might elect to retain additional trees of commercial quality in order to enhance structural diversity and wildlife habitat. Note that in river red gum forests all trees of 125-cm dbhob are to be retained.

Trees 60–80 cm dbhob. Where trees reach 60 cm dbhob they are often seen to have reached commercial maturity and are harvested as sawlogs, veneer logs and for girders. However, the forest owner might consider retaining trees over 60 cm dbhob with defect-free trunks and vigorous well-balanced crowns. These can make high value products at later harvests, and will enhance structural diversity and wildlife habitat. Where there is a patch of mature trees, they might be thinned to an average spacing of around 12 m.

Trees 40–60 cm dbhob. Trees may be accepted as conventional saw or veneer logs when they reach 40-cm dbhob. There may be a tendency to harvest them at this time. However, they are also the prospective high value crop, and those capable of reaching 60-cm dbhob in a reasonable time should be retained to accrue further value. Such trees will have well-formed crowns of reasonable vigour and defect-free trunks at least 6 m in length. Where trees of this size occur in patches, they should be spaced around 10 m apart.

Trees 20–40 cm dbhob. Trees in this size range should be retained if they have future product potential. Over-stocked patches should be thinned and weak or poorly formed trees harvested. Trees in this size range can supply small sawlogs, poles and pulpwood. A typical operation might thin a group of even-aged trees to a stocking of around 300 stems/ha (6 m x 6 m), which should stimulate the growth of retained trees. Moreover, there may be little point in retaining a tree where it is within 10 m of a retained larger, productive tree.

Step 3 – Mark trees to be harvested; the aim should be to remove commercially as many trees as possible which have reached commercial maturity but are in decline, and trees which have weak crowns and poor trunks, or have an unacceptable level of defect and are not required for wildlife purposes.

Step 4 – Observe the spatial patterns of retained trees and, where necessary, adjust the tree marking to satisfy the PNF Code, and achieve a suitable forest structure and conservation-wood production balance.

Adjusting tree marking to reflect the management objective of an acceptable balance between biodiversity values and wood production is a critical part of the process and the most difficult. An example of why it is necessary is given in Box 5 and a suggested approach in Figure 7.

Box 5: Example of adjusting tree marking to balance conservation and wood production objectives

A mature/over-mature blackbutt forest had been selectively logged in the past, creating some areas of good blackbutt pole regrowth, but retaining areas of substantially intact mature and over-mature trees. There are also some areas that failed to regenerate in the past, along with a general distribution of the more tolerant species (tallowwood, red mahogany and bloodwood) in a growth-restricted condition.

Under the requirements of the PNF Code, a significant number of the large over-mature trees would be retained as wildlife habitat. However, most of the mature trees would probably be available for harvest. After harvesting this would leave a forest dominated by over-mature trees, some non-commercial mature trees and a lower storey of tolerant species that may or may not have the capacity for continued growth. The only future productive areas of the forest may be the areas of pole regrowth. This pattern would not satisfy any reasonable production–conservation balance. Thus, some adjustment to the tree marking is essential. The following may be an appropriate option:

- Identify patches of mature and over-mature trees to be retained more or less indefinitely as a contribution to biodiversity.
- Identify and protect small units of the forest with a more complex uneven-aged structure, based on mature trees, a lower stratum of growth-restricted trees, and any regrowth that may subsequently develop in small gaps. Such floristically and structurally diverse units can have important habitat values, for example, for the koala.
- Identify prospective canopy openings and ensure adequate retention of strips of mature and over-mature trees that will separate canopy openings. Create canopy openings based on patches of mature trees, and areas that failed to regenerate in the past.
- Identify individual mature trees to be thinned from between canopy openings, or from within patches of regrowth, being careful not to reduce minimum stand basal areas in between canopy openings below the limits specified in the PNF Code.

6.2.2 Uneven-aged eucalypt forest that is well stocked but in relatively poor condition

This is likely where the forest has been logged in the past to maximise sawlog yield, without providing for future cutting cycles. Examples include:

- forest that has only been lightly logged in the past and now has many large over-mature trees, some growth-restricted remnants of the original forest, and only a few patches of effective regrowth
- forest that has been selectively harvested on a number of occasions, resulting in an accumulation of growth-restricted trees; this is typical of spotted gum forests.

This type of forest may be harvested under a PVP subject to PNF Code conditions as shown in Box 6. However, the forest owner must accept that there will be only limited improvement in the forest condition if it is harvested in this manner. It would be preferable to harvest such a forest at a greater intensity, which would stimulate a more productive forest in the long term and might generate a higher economic return in the short term. To do this the forest owner would have to seek a minor variation and/or utilise Australian Group Selection.

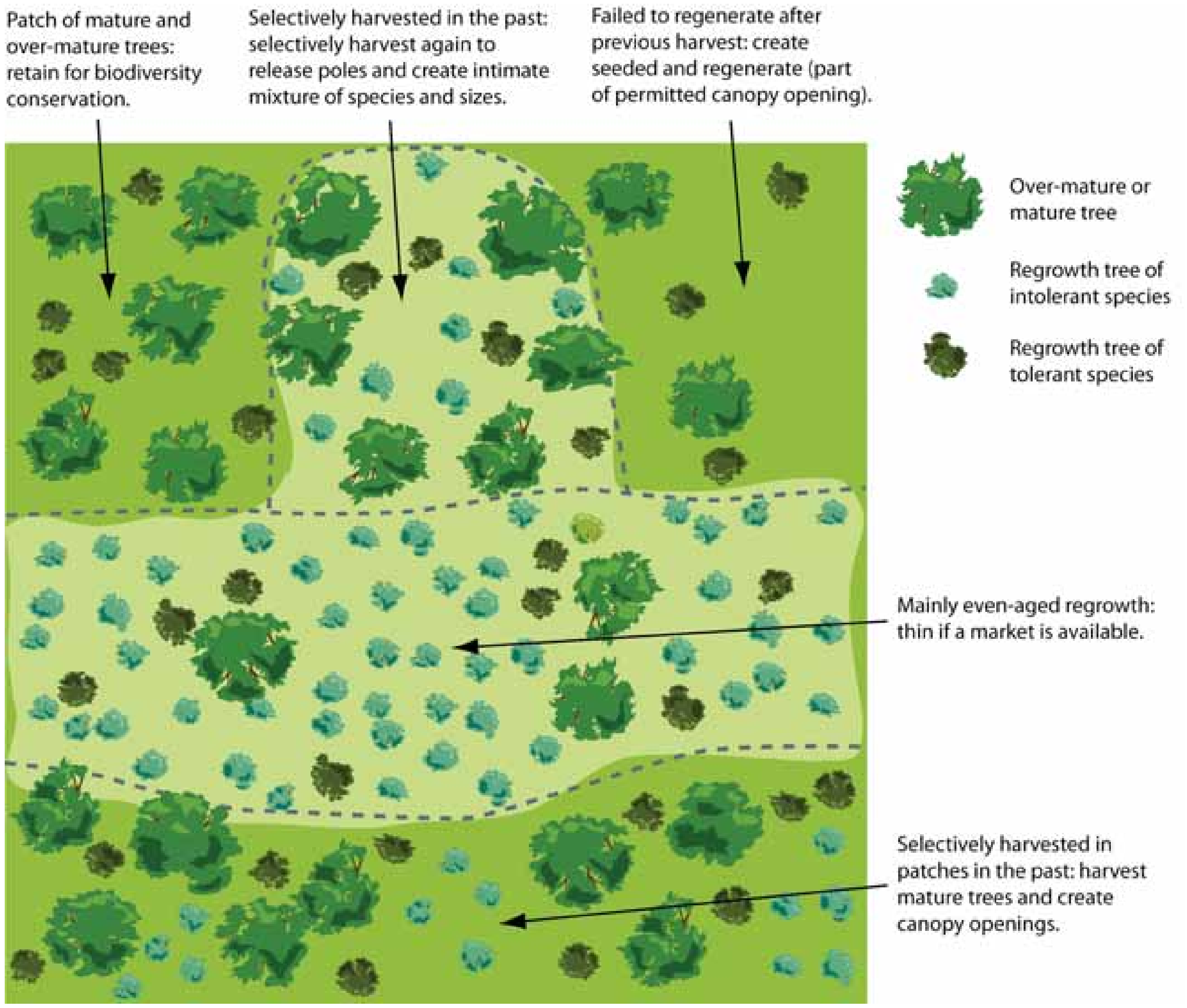


Figure 7: A silvicultural regime for an area of uneven-aged eucalypt forest in good productive condition

6.2.3 Even-aged forest

Silvicultural prescriptions for even-aged forest are illustrated in examples given below, ranging from two of the most productive forests in the state (blackbutt and flooded gum) to near-stagnant dry sclerophyll scribbly gum – brittle gum forest. It is important to recognise that wildlife principles relating to native forest still apply to thinning operations. Wildlife tree retention should follow the general standard for all broad forest types (section 3.4), with particular emphasis on retaining any older trees with hollows, or the potential to develop hollows, within even-aged regrowth.

Box 6: Example of silvicultural guidelines for well-stocked forest in relatively poor condition

A mixed species forest (white stringybark – blackbutt – red bloodwood – spotted gum) was selectively harvested in the 1970s. There was no post-harvest improvement treatment, and there are now few trees with reasonable growth potential. The components of the forest include:

- large diameter over-mature trees of all species
- stagnant stringybark and bloodwood, some in the 40–60 dbhob range, which may have been within the secondary stratum of the original forest
- pole-sized trees that had responded to the harvest but are now in a growth-restricted condition
- some patches of pole blackbutt and stringybark, the only components in reasonable productive condition
- a heavy litter layer indicating the forest has not been burnt for some time.

The following approach might be used in this forest:

1. Mark all habitat trees and trees worth retaining as productive elements of the forest.
2. Identify 20% of the net harvestable area where canopy openings will be created; canopies can be up to twice the stand height, preferably focusing on patches of forest in poor condition.
3. Mark trees for harvesting outside of the canopy openings, and trees that will release or stimulate the growth of the more productive elements identified in 1 above. Any other trees might be harvested where consistent with the PNF Code conditions, but avoid creating additional openings in the forest greater than 0.1 hectare in area.
4. Carry out site preparation for regeneration within the canopy openings. A general fuel reduction burn might be considered, with complementary site disturbance within the openings. (Ensure that all necessary fire permits have been obtained.)

Ensure consistency with the PNF Code.

6.2.3.1 Thinning even-aged blackbutt forest

Blackbutt is a fast-growing eucalypt with a capacity for rapid site occupancy from an early age, and for individual trees to respond to large amounts of growing space, particularly on high quality sites. A thinning operation will normally attempt to retain the larger (dominant or emergent) trees of the forest, and free up the better ‘co-dominants’, that is, trees which make up the general upper canopy level but are becoming crowded on the sides. During the sapling or pole stages, blackbutt can be thinned as heavily as practicable, but in a way that is consistent with existing and perceived future markets. This is described in Box 7.

A forest owner might elect to retain more stems to insure against damage (particularly storms), and to ensure that residual tree quality following each thinning is maximised. Sometimes, too wide an early spacing might lead to heavy branching and poor form, particularly on sites where trees are not growing rapidly in height and their expression of dominance is not strong.

Box 7: Thinning young even-aged blackbutt forest

Thin blackbutt based on market characteristics as follows:

- If there is a pulpwood market (for example, for trees around 20 cm dbhob), thin the forest to around 600 stems/ha (average spacing 4 m x 4 m).
- If there is no pulpwood market but small sawlogs can be sold (from trees as small as around 30 cm dbhob), a stocking of around 280 stems/ha (6 m x 6 m) would be optimal.
- Where only large sawlogs can be marketed (from trees >40 cm dbhob), maximum volume production might be achieved with a stocking as low as 100 to 150 stems/ha (8–10 m spacing).
- Ensure consistency with the PNF Code.

6.2.3.2 Thinning even-aged flooded gum forest

Flooded gum is a 'very intolerant' eucalypt, and for this reason usually forms an even-aged forest. Because there can be a rapid increase in green crown area as stems compete for site resources, early non-commercial thinning is highly desirable. While flooded gum is highly responsive to increased growing space, the first thinning should not be too heavy – widely spaced flooded gum might form excessively large branches and this will seriously affect wood quality. Flooded gum is usually managed on a shorter rotation than blackbutt, for example, 25 years on good quality sites. Thinning is described in Box 8.

Heavy thinning will not be so appropriate on a low or moderate quality site where the dominant trees might not be as responsive to a large increase in growing space. Here, the commercial thinning might reduce the stocking to around 250 stems/ha (6.5 m x 6.5 m).

Box 8: Thinning even-aged flooded gum forest

The following schedule is appropriate on a high quality site:

- Early (<5 years of age) non-commercial thinning to around 400 stems/ha (5 m x 5 m).
- Thin to 100–200 stems/ha (around 8 m x 8 m) as soon as commercially feasible, usually around 12 to 15 years.
- Fell around 25–35 years of age for veneer logs and sawlogs to create canopy openings. Canopy openings should be large, at least 40–50 m in diameter. Note that under the PNF Code canopies can be up to twice the stand height.
- Ensure consistency with the PNF Code.

6.2.3.3 Thinning even-aged messmate stringybark and brown barrel forest

Messmate stringybark and brown barrel are among the most tolerant or persistent eucalypts. They lack the rapid early growth phase of faster growing and more intolerant species, and self-thin more slowly. Where a forest remains unthinned for a long time, persistent but relatively weak-crowned trees might accumulate, particularly on lower quality sites (see Box 9).

Box 9: Thinning even-aged messmate stringybark and brown barrel forest

While messmate stringybark responds to thinning, early heavy thinning regimes (both commercial and non-commercial) as recommended for blackbutt and flooded gum may result in a sharp decline in volume production. Nevertheless, where there is a market for small-sized material, thinning should be carried out as soon as commercially feasible. A first thinning to around 500 stems/ha (5 m x 5 m) will stimulate diameter growth of the dominant and co-dominant trees and help maintain a good green crown. Later thinning might reduce the stocking progressively to 200 stems/ha (about 7 m x 7 m).

Brown barrel is more responsive to thinning than messmate stringybark but, again, not to the same extent as fast-growing intolerant species. It is necessary to ensure that brown barrel is not thinned too early or too heavily as it may develop strong persistent branching, particularly on lower quality sites, which will seriously affect wood quality. It is suggested that brown barrel up to 20 years of age is thinned to around 300 stems/ha (6 m x 6 m), and older forests are progressively thinned to 150 stems/ha (8 m x 8 m).

Ensure consistency with the PNF Code.

6.2.3.4 Thinning even-aged spotted gum regrowth

Significant areas of even-aged spotted gum regrowth have developed primarily on previously cleared grazing land. Because of site factors and management history, crowns may be thin and expression of dominance weak. Where some of these trees have reached the small sawlog stage, a commercial thinning can be carried out, which should stimulate growth of the residual trees. However, before this stage is reached, non-commercial thinning may be worthwhile (Box 10).

Box 10: Non-commercial thinning of even-aged spotted gum

- Stem injection of herbicide is the most cost-effective method of non-commercial thinning of spotted gum.
- Alternatively, unwanted trees may be cut down using a chainsaw or brush-cutter and herbicide applied to the stump. Applying herbicide to the surface of cut stumps will prevent the development of coppice shoots.
- Thinning must be done to favour the best trees (that is, those with larger diameter straight stems and healthy crowns) by removing the poorer-formed trees.
- An average stocking of around 400 stems/ha (5 m x 5 m) might be sought. If there are only a limited number of good quality trees, it is more important to retain the better trees than to obtain even spacing of residual trees. So spacing may vary between 3 m and 7 m.
- Ensure consistency with the PNF Code.

6.2.3.5 Thinning even-aged river red gum forest

River red gum forest is usually even-aged due to its regeneration processes. River red gums in southern NSW do not form lignotubers and therefore depend on seedlings for regeneration. After flooding there can be prolific germination of seedlings. These seedlings usually only survive and develop into saplings if their taproot can reach groundwater. During the time between germination and the taproot reaching groundwater there needs to be follow-up rain otherwise the seedlings will die.

Many of the forests on the Murray and Murrumbidgee River flood plains have resulted from flooding and periods of good follow-up rain in the early 1900s. Unfortunately, river red gum regeneration since the 1950s has been sporadic due to regulation of rivers and the lack of widespread flooding. The following guidelines (Box 11) are suggested for thinning of even-aged river red gum forests.

Box 11: Thinning of even-aged river red gum forest

- Young regrowth should be maintained at a high stocking level until dominant trees are well established.
- Where the average diameter of better quality trees is 20 to 30 cm dbhob, the forest might be thinned to an average spacing of 7 m x 7 m to free-up crowns and stimulate diameter growth. This can be done commercially where there is a market for small sizes. It is best to retain smaller suppressed stems, in preference to thinning them by cutting, to avoid active coppice growth on the cut stumps.
- Progressive thinning within uniform even-aged forests should be based on residual basal area. Successive thinnings could be applied when there is a commercially feasible harvest volume available. However, to comply with the PNF Code minimum stand basal area should not be reduced below 12 m^2/ha.
- Alternatively, trees can be thinned to a spacing equal to a quarter of the diameter multiplied by 100 expressed in metres. For example, a tree with a 40-cm diameter would have a 10-m spacing.

6.2.3.6 Thinning low quality dry sclerophyll forest

Low quality dry sclerophyll forest is not normally seen as a commercial resource. However, it can be thinned for firewood and, in the future, well-managed forests might provide a number of other products, including sawlogs (Box 12).

Box 12: Thinning of dry sclerophyll forest

There are considerable areas of apparently even-aged scribbly gum – brittle gum – peppermint forest on the southern tablelands. This forest can be thinned to a stocking of around 280 stems/ha (6 m x 6 m) by injecting unwanted trees with herbicide or felling with a chainsaw. Once dried, the trees can be harvested for firewood.

Ensure consistency with the PNF Code.

6.2.4 White cypress pine forest

As discussed in section 2, there are two main categories of white cypress pine forests:

1. those that regenerated in the late 1800s (referred to as the 1890s forests) with an understorey of more recent post-1950s regeneration
2. near stagnant (or ‘locked-up’) areas of post-1950s cypress pine regrowth.

6.2.4.1 Harvesting of the 1890s forests

Current commercial harvesting applies primarily to the 1890s forests. Silviculture should involve a combination of commercial harvesting of the older overstorey trees, followed several years later by non-commercial thinning of the lower storey (Box 13).

Box 13: Harvesting of the 1890s white cypress pine forests

- Only areas with adequate white cypress pine in the lower storey (2–6 m in height) should be harvested.
- Keep all old grey gums, roost, nest or food resource trees as required to satisfy the PNF Code wildlife habitat and biodiversity prescriptions.
- Wait at least three to five years after harvesting of the overstorey trees so that the lower storey trees with the best growth potential become evident and then thin the lower storey (to waste) to a stocking of around 280 stems/ha (6 m x 6 m). Retain the largest and straightest trees.
- Keep all stumps as low to the ground as possible in order to facilitate movement of harvesting machinery in later years.
- Ensure consistency with the PNF Code.

6.2.4.2 Commercial thinning of white cypress pine regrowth

White cypress pine may be commercially thinned when the trees are 15–25 cm dbhob. At this size the trees might be 75 to 85 years old. White cypress pine differs from eucalypts in that even if it has been suppressed for decades, individual trees can resume growing once the forest is opened up after thinning. Guidelines for thinning are given in Box 14.

Box 14: Commercial thinning of white cypress pine regrowth

- Harvest the forest to a residual basal area of around 6–8 m^2/ha.
- Retain the largest and straightest trees.
- Thin to waste any trees unlikely to ever be commercial.
- Keep stumps as low to the ground as possible in order to facilitate movement of harvesting machinery in later years.
- Ensure consistency with the PNF Code.

6.2.5 Western hardwoods forest

Western hardwoods forest is a forest type in its own right, but also merges with the cypress pine forests (see Appendix A for species and pine–eucalypt environmental relationships). Western hardwoods forest is not particularly productive, and is subject to management of low intensity (Box 15).

Box 15: Silvicultural guidelines for western hardwoods forest

- Mark trees for retention to satisfy the PNF Code wildlife habitat and biodiversity prescriptions.
- Mark trees to be retained for future harvests focusing on:
  1. selection of stems with good production potential, and already of commercial size
  2. sub-merchantable stems and advance growth with good growth potential.
- Mark trees for harvest that will release other trees with good growth potential from competition. These are likely to be trees that have reached commercial maturity and are in decline, have low potential for continued growth, or have poor stem form.
- As the productivity and optimum basal area for semi-arid western region hardwoods will be less than that for hardwoods in coastal regions, it is recommended that western hardwoods forests be reduced as much as permitted by the PNF Code (for example, 8 m^2/ha where stand height is less than 25 m), particularly where there is little advance growth or seedling regeneration. Coppicing can also contribute to post-harvest regrowth.
- Ensure consistency with the PNF Code.

6.3 Silvicultural practice where a variation to the PNF Code could be considered

A harvesting proposal that does not comply with the minimum stand basal area requirements of the PNF Code can be considered in certain circumstances. This will generally apply in two cases:

1. where the forest owner seeks to enhance future productivity of a forest that is in poor condition, for example, with a large number of trees with limited growth potential (or poor form) and relatively few areas of vigorous regrowth, and possibly improve some wildlife values that are presently missing or under represented in the forest
2. where the forest is notably understocked. In this case an economically viable harvest may reduce the basal area for a given broad forest type below the minimum stand basal area threshold for single tree selection and thinning operations specified in the PNF Code. Widespread site disturbance may be needed to regenerate the forest.

If harvesting is proposed in these situations it will be necessary to formulate a silvicultural strategy based on the condition of each area of forest proposed for harvesting. This is because the diversity of forest types, and wide variation in the condition of individual forests within forest types, make it impossible to specify standard silvicultural regimes. It should be noted that large, old trees are relatively rare in many parts of NSW and are a valuable wildlife resource, so proposals to remove them may not be granted. Silvicultural guidelines are presented in a series of examples below, but some of these apply to degraded forest that will not provide an economic harvest in the short or medium term.

These prescriptions should be read in conjunction with the silvicultural attributes of the relevant forest type, described in section 7.

6.3.1 Growing stock in poor productive condition

6.3.1.1 Eucalypt forest with a substantial component of trees with no economic value

This could be a forest that has not been harvested recently but has a history of recurrent wildfire that has rendered most standing timber unmarketable. Harvesting according to the Code may do little to improve its productive condition. However, harvesting at a greater intensity could create a more dynamic forest. This will also enhance structural diversity and improve environmental values in the long term. The following silvicultural practice should be used as a guide for this type of forest (Box 16).

Box 16: Example of silvicultural treatment of forests with a substantial component of unmarketable trees

1 Select and protect patches of forest of environmental interest, for example gully heads, patches of lower slope communities, or any patch of forest that attracts interest because of structural and/or vegetational attributes. Some of these patches may contain significant wildlife habitat species, for example where mountain grey gum occurs on lower slopes within silvertop ash – stringybark forest. The patches might constitute around 20% of the forest and make a permanent contribution to conservation of biodiversity.
2 Designate any additional wildlife habitat trees and retain patches of undisturbed forest around them, for example patches 25 m in diameter. These patches may constitute a further 20% of the net forest area. This means that some 40% of the forest is directed to habitat conservation, and 60% will contribute to both wood production and biodiversity.
3 Harvest the remainder of the forest in a single operation, or preferably over two harvests separated by at least 10 years. Advance growth, poles and trees with future commercial potential should be retained within the harvested area. It is critical that damage is minimised to these trees during tree felling and extraction.
4 Assess regeneration. This should not be a problem within dry sclerophyll forest; however, appropriate site treatments should be applied elsewhere. The pattern of tree retention may need to be modified for higher elevation messmate – brown barrel forest where regeneration difficulties may be encountered. In this case, overstorey trees might be removed in two operations, the second after regeneration has established.

6.3.1.2 Previously harvested eucalypt forest with a residual stocking of over-mature trees and little productive regrowth

Where a forest has been harvested in the past, but without post-harvest improvement treatment, it may still contain an unduly large stocking of dominant, over-mature and stagnant secondary overstorey trees. Given the competitive effect of large trees on regrowth, particularly on sites subject to environmental stress, much of the regrowth is likely to be in a weak condition (such as trees with small or narrow crowns, or relatively old trees, that are incapable of good growth following release from competition).

This forest can be harvested under the PNF Code (see section 6), although there will be limited possibilities for improving its productive condition. Alternatively, minor variation might be sought using a different silvicultural prescription (Box 17).

Box 17: Silvicultural guidelines for previously harvested forest with a residual stocking of over-mature trees and little productive regrowth

1 Mark trees with hollows and habitat recruitment trees. Where there are aggregations of these trees, patches of forest may be retained, more or less indefinitely, for biological and structural diversity.
2 Mark for retention any good-quality, dominant regrowth trees that have the potential to grow into crop trees of the future. These may be released from competition later by non-commercially thinning around them.
3 Mark all trees that are likely to yield logs of current commercial specifications. Changing utilisation standards has probably permitted commercial utilisation of trees that were left during previous harvesting.
4 Based on the distribution of trees for retention and harvesting, determine a pattern of canopy openings. Canopy openings cannot be larger, or cover a higher proportion of the harvested area, than allowed under the PNF Code. Where possible, canopy openings should be based on groups of harvested trees.

If relatively few trees are available for commercial harvest, little can be done to improve the forest condition unless the forest owner is prepared to invest in tree felling or ringbarking without any immediate financial return.

6.3.1.3 Regrowth eucalypt forest with a large component of trees with limited growth potential

There will be situations, mostly within spotted gum forest, where most of the original overstorey has been removed progressively over many decades in successive harvests. In this case there might be substantial regrowth stocking, but only a small proportion of stems may have straight trunks, strong crowns and good growth rates (Box 18).

6.3.1.4 Dry sclerophyll eucalypt forest where only larger sawlogs have been harvested

Many dry sclerophyll forests, particularly on the northern and southern tablelands, have been harvested in the past for large diameter sawlogs only. Generally these forests have a reasonable level of growing stock, but much of it is in an unsatisfactory condition. A further harvesting of trees with limited growth potential could improve the average productivity of these forests and free up trees of smaller sizes. However, after retention of trees for wildlife habitat and biodiversity and other environmental objectives, the volume available for harvest might be economically marginal, and it might be some time before a further improvement harvest is justified.

6.3.2 Understocked eucalypt forest

6.3.2.1 Mixed hardwood forests in variable condition

Most of the mixed coastal hardwood forests (such as tallowwood, white mahogany, grey gum and grey ironbark) have been cut on a number of occasions for sawlogs and, in particular, for durable poles and piles. Some of these forests might be in excellent condition, being well stocked with a high proportion of trees with straight trunks and vigorous crowns. However, there are some forests (usually wetter types) in a somewhat run-down condition with low stocking rates and poor quality trees. In this case, silvicultural practice must focus on retention of any trees with reasonable growth potential, site preparation for regeneration and, if necessary, planting or direct seeding (Box 19).

6.3.2.2 Moist coastal hardwood forest in a variable but frequently degraded condition

Extensive areas of moist coastal hardwood forest have been intensively harvested in the past. In good quality forest this resulted in near-complete removal of all trees. Other areas were logged less intensively, with some smaller and lower-quality trees retained, probably because they did not contain marketable logs. In either case, some of these forests did not regenerate well due to the difficulties of effectively regenerating wet sclerophyll forest. Appropriate silvicultural practices for these forests are described in Box 20.

Box 18: Silvicultural guidelines for regrowth forest with a large component of trees with limited growth potential

In a previously harvested spotted gum forest, the larger trees (>50 cm dbhob) had the highest average rate of diameter growth (0.5 cm/year). Trees in the intermediate size class (30–50 cm) were growing at only a very weak 0.25 cm/year. Many of these were probably 'old' trees that had developed slowly under the restricting influence of the original canopy. The average growth rate of trees in the 10–30 cm dbhob range was also well below that of the larger trees in the forest. Finally, there was stagnant but persistent advance growth in trees <10 cm dbhob.

This may be typical of much spotted gum forest where little effort has been directed to creating adequate canopy openings. This is a forest that could be harvested under the PNF Code conditions but there would be only limited, if any, improvement in productivity. Alternatively, silvicultural practice might be directed to creating more dynamic forests while retaining a reasonable level of structural diversity.

1 Retain some of the larger trees for wildlife purposes and to enhance structural diversity.
2 Mark for retention all trees, in all size classes with reasonable trunks and crowns.
3 Utilise (harvest) as many trees as possible with marginal growth potential. There will be a residual stocking of trees with little growth or commercial potential.
4 Create canopy openings (around 40–50 m in diameter) in areas where there are few residual trees with commercial potential. Remove trees within the canopy openings that have little growth potential, including small suppressed stems that can produce vigorous coppice shoots.

The stocking and structure of the post-harvest forest will depend on its initial condition. However, the aim should be to retain as many trees as possible consistent with the objective of improving the forest productivity. It may take several cutting cycles to revive a forest in this condition.

Box 19: Silvicultural guidelines for mixed hardwood forests in variable condition

1 Forests that are, to an extent, understocked though not degraded

There may be some residual over-mature trees, some reasonably vigorous pole or early mature trees, and an accumulation of growth-restricted trees (both secondary storey remnants of the original forest and regrowth which are now suppressed).

Large over-mature trees may be retained, though perhaps not beyond the stocking needed to meet habitat requirements. As many trees as possible with little growth potential might be harvested, and trees with good potential retained (apart from those that might be harvested as thinnings). This will create a mosaic pattern of canopy openings, which will need to be regenerated. Advance growth should be carefully assessed. There is sometimes a useful stocking of small, often spindly stems in these tolerant species forests, even in wet sclerophyll forest. These stems may be coppiced to generate dynamic growth. Where there is no advance growth, site treatment and a seed source will be essential. Canopy openings might be planted with seedling stock of species occurring naturally on the site.

2 Degraded mixed hardwood forest

Where wet sclerophyll mixed hardwood forest has been harvested on several occasions, the remaining trees may be in a growth-restricted condition. These may be remnants of the original forest, or trees that had developed following a harvest but succumbed to competition.

It may be uneconomical to treat this forest in the absence of a market for small-diameter logs, and much effort will need to be directed to regenerating the forest.

Box 20: Silvicultural practice for moist coastal hardwood forest in a variable but frequently degraded condition

1 Forests subject to near-complete harvest of commercial products

This case study refers to a Sydney blue gum – tallowwood forest where all commercial products had been removed during previous harvesting. Later assessment showed there were originally 45 stems/ha (all >30 cm dbhob), 25 of which were >80 cm dbhob. Of the 21 stems/ha present at the time of assessment, only two were of commercial quality. The absence of stocking of trees in the 0–30 cm dbhob range suggests a failure of regeneration after harvesting.

There is little prospect of another commercial harvest in these forests in the short to medium term, and hence little prospect for improving the forest condition through a regeneration program. A forest owner with this type of forest may wish to disturb patches of forest from time to time and sow seed or plant seedlings.

2 Forests subject to less intensive harvesting with retention of some management potential

This relates to areas of forest with relatively intact forest ecosystems, for example with patches containing over-mature trees, some pole and early mature trees of the tolerant species, and a rainforest element understorey. While clearly understocked, the forest may be visually attractive and have structural diversity.

The forest owner might elect to protect this forest, or harvest some of the commercial trees and regenerate it in patches, preferably by the planting of seedling stock.

7 Silvicultural attributes of forest types

The following notes describe the silvicultural attributes of each forest type, focusing on forest regeneration and development processes. They are to be read in conjunction with the silvicultural prescriptions presented in section 6.

7.1 Blackbutt forest

Blackbutt forest is one of the NSW forest types more amenable to wood production management. Where appropriately managed, the forest is capable of high levels of wood production and can supply a range of markets (poles, small sawlogs, girders, veneer logs and conventional sawlogs).

7.1.1 Regeneration

Blackbutt is one of the few non-lignotuberous eucalypts, and reproduces largely through new seedling regeneration. Given a seed source, sufficient seedlings will normally establish within more open forests in response to site disturbance and/or a fire of low intensity. However, intensive site preparation, involving extended mechanical disturbance or intense fire, is usually needed towards the wet sclerophyll end of blackbutt's vegetation range.

7.1.2 Silvicultural management

Blackbutt is an intolerant eucalypt. A patch of blackbutt regeneration may maintain vigorous development only where it is substantially free of overstorey competition. On a high quality site where mature forest can be up to 40 m in height, canopy openings at least 50 m in diameter, and preferably wider, will be required. Blackbutt can self-thin rapidly, helping maintain vigorous development of the dominant trees within the patch. One of the great attributes of blackbutt is its capacity to maintain fast diameter growth well into the prime sawlog range. Thus the time taken to produce a quality sawlog can be surprisingly short (40 to 50 years on a good site and with adequate growing space).

The blackbutt forest can be managed as either uneven-aged or even-aged forests. Periodic harvests over many decades have often resulted in the formation of productive forests with three or more age classes. Where the forest structure and condition permits, it is appropriate to take advantage of blackbutt's vigour by creating canopy openings to the extent permitted by the PNF Code.

Even-aged regrowth forests have become established where a combination of logging and post-harvest treatment has approached clearfelling in intensity. The thinning of even-aged blackbutt forests is described in section 6.

Some difficulties may arise where blackbutt occurs mixed with more tolerant lignotuberous species (for example with mixed hardwood forest). In this case there may have been a secondary stratum of tolerant species beneath the original canopy. Few of these trees were harvested or ringbarked in early operations and some persist to this day, despite improved timber utilisation standards.

Moreover, blackbutt seedlings must establish and compete with an already established pool of lignotuberous seedlings. Where site preparation is inadequate or the canopy opening too small, blackbutt may succumb to excessive competition, which will result in more tolerant species of the forest becoming dominant. Thus it will be essential to pay particular attention to the competitive ability of blackbutt when harvesting mixed species forests (Box 1).

7.2 Mixed hardwood forest

Mixed hardwood forests are very extensive in NSW and have an important role in providing strong durable timbers, particularly as poles and piles.

7.2.1 Regeneration

There are few regeneration problems in the more open dry sclerophyll forest. All species are lignotuberous and coppice strongly. However, new seedlings may not develop profusely. They may establish readily but only continue to develop under the most favourable site conditions. In particular, continued growth of eucalypts may be impeded where an expanding wet sclerophyll understorey dominates the pool of lignotuberous seedlings.

7.2.2 Silvicultural management

Species of the mixed hardwood forest are amongst the most tolerant of the eucalypts and seedlings may develop well in smaller canopy openings. However, they are still sensitive to competition, and if canopy openings are too small the crowns may weaken and become uneven, resulting in reduced growth rates. Forests with a long history of selective logging may be well stocked, but many trees will have limited growth potential, especially where trees with better quality trunks have been harvested periodically as poles and piles.

The more tolerant species in mixed hardwood forest may develop long straight trunks in relatively small canopy openings (15–20 m diameter); however; they must be released by further harvesting before crowns are unduly weakened.

7.2.3 Coppice management

Both the mixed hardwood and spotted gum forest have been managed as coppice forests supplying small-diameter mining timber and timber for hardboard manufacture. Coppice forests can be either uneven-aged or even-aged. More details are given for spotted gum forest type.

7.3 Spotted gum forest

Spotted gum is one of the most widely occurring forest types in coastal NSW. It occurs as dry sclerophyll forest on the north and central coasts, and as dry and wet sclerophyll forest on the south coast.

7.3.1 Regeneration

Spotted gum in dry sclerophyll forest is relatively easy to manage from a regeneration perspective. There is usually a good pool of lignotuberous seedlings and the species coppices well. New seedling regeneration will establish when conditions are favourable, but then persist at the restricted lignotuber stage for an extended period.

However, lignotuberous seedlings will not persist within wet sclerophyll forests. In these forests new seedlings may establish following harvesting and bypass the extended lignotuber stage but develop only slowly, particularly when in competition with the understorey. It may be useful to try to build up a lignotuber pool by treating the wet sclerophyll forest some years before harvesting, for example through fire or mechanical site disturbance.

7.3.2 Silvicultural management

Spotted gum is best described as an intolerant but persistent species that is particularly sensitive to overstorey competition. Seedlings may remain in their lignotuberous form even where the overstorey stocking is only light or where they are some distance from an edge of trees. Hence canopy openings of a reasonable size (at least 40–50 m diameter) will be needed to trigger vigorous sapling growth and ensure development through the growth stages.

If spotted gum forest has been selectively harvested several times, there may be an accumulation of growing stock that has responded to partial release. Growth will depend on the size of canopy openings and location of trees within them. Unless a large part of the canopy was removed, much of this advance growth will be affected in time by competition from residual canopy trees and trees within the lower strata. Thus a wide range of sizes may be present in the forest, but it is likely that only a small proportion will have vigorous crowns and good growth rates. This is illustrated in Box 18and highlights the need to open up the forests to generate more dynamic growth.

7.3.3 Coppice management

Lower quality spotted gum forests (along with those of the mixed hardwoods) have been used as a source of mining timber, hardboard raw material and small logs. They have been managed as short rotation coppice forests, either even-aged or uneven-aged with two to three age classes. As might be expected, coppice production is more efficient where forests have been selectively harvested on a short cutting cycle than in forests that are periodically re-established from seedlings. Growth can be severely influenced by high basal areas (>20 m^2/ha) and the build-up of poor quality stems.

7.4 Moist coastal hardwood forest

Moist coastal hardwood forest merges with rainforest. It can be a difficult forest to manage for continued wood production due to the difficulty of achieving adequate regeneration.

7.4.1 Regeneration

Tallowwood – Sydney blue gum – brush box forest may not regenerate profusely even where subject to clearfelling with retention of seed trees, felling of the understorey and slash burning. In the experience of Forests NSW, regeneration stocking rates have been highly variable. There may be problems in obtaining a suitable burn, it may be difficult to guarantee a good seed crop at the time of the burn, and development of weeds responsive to fire may affect the early growth or survival of tallowwood and brush box. These are both species that grow slowly in the early stages. For this reason the faster-growing Sydney blue gum may regenerate more favourably following a regeneration burn.

For private native forests, a partial harvesting within moist coastal forest may be more appropriate, with the harvesting machinery used to open up disturbed patches. These patches might regenerate naturally or can be planted with seedling stock.

7.4.2 Silvicultural management

The growth rates of even-aged Sydney blue gum – tallowwood forests may not match those of blackbutt or flooded gum, but it is a quite productive forest type. For example, some research has shown average growth rates up to 1 cm dbhob per year over the time it takes a sawlog forest to mature (40–70 years).

7.5 Flooded gum forest

Flooded gum is undoubtedly a more common component of coastal forests now than it was at the time of settlement. This is because it is the species of moist coastal forests that responds well to disturbance (logging or fire).

7.5.1 Regeneration

Flooded gum is one of the most intolerant of the eucalypts. It is a non-lignotuberous species with regeneration after harvesting of mature forests coming almost exclusively from seedlings. Canopy openings should be prepared by mechanical disturbance or fire and care taken that unwanted plants that also respond to fire do not develop. Natural regeneration may be supplemented by direct seeding or planting.

7.5.2 Silvicultural management

Within private native forests natural stands of flooded gum (pure flooded gum or patches of flooded gum in mixed species forest) can be maintained by felling patches at commercial maturity, disturbing the immediate sites, and either planting or, where seed trees are available, relying on natural regeneration. Canopy openings should be large, at least 40–50 m in diameter.

Because flooded gum satisfies a number of markets (pulp, small logs, veneer logs), developing forests should be thinned where possible. The growth attributes of flooded gum and its response to thinning are described in section 6.

7.6 Silvertop ash – stringybark forest

The dry sclerophyll forests dominated by silvertop ash, stringybark and other species represent the major forest resource in the Eden region, and have underpinned the integrated sawlog–pulpwood industries there since the late 1960s.

7.6.1 Regeneration

These forests regenerate well following harvesting, through a mixture of seedlings that develop on disturbed sites, lignotuberous advance growth (but not including silvertop ash), and coppice development on cut stumps. All species are good seed producers, particularly silvertop ash, and can at times carry prolific seed crops. Seed fall is rapid after fire.

Regrowth can develop rapidly on high quality sites, particularly after fire. For example, at one study site a 38-year-old forest accumulated 29 m^2/ha basal area. However, the mean tree diameter (27 cm) was disadvantaged by a relatively slow rate of self-thinning. Regrowth development can be much poorer on lower quality sites where highly stocked forests may stagnate and lock up. This has been particularly evident where dense regrowth has developed following fire.

7.6.2 Silvicultural management

Usually only a small number of trees in older forests are of sawlog quality, a result of these forests being typically found on poor quality sites and burnt by wildfire on many occasions. Because of the low volume of sawlogs in these forests clearfelling was widely practised in the early stages of the integrated operations, as it was often the only economically viable silvicultural system. This system was later modified by the retention of patches of forest that had good growth potential (patches of saplings and poles that were usually a result of past fires), individual trees with future sawlog potential and wildlife habitat trees. Current practice is even more conservative and could be described as selective harvesting. Silvertop ash – stringybark forest is usually well stocked and can usually be harvested under the PNF Code. Silvicultural systems must take account of the intolerance of silvertop ash, and the considerable restrictive effect retained trees can have on regrowth for some distance beyond the tree crowns.

7.7 Tablelands forests

The tablelands forests represent a particularly diverse grouping of forest types. Most are amenable to management; for example, the New England blackbutt type will normally regenerate well following harvesting, with or without subsequent burning. It is appropriate to focus here on problem forests, notably the higher quality brown barrel – messmate forests with a heavy shrubby understorey or strong grass ground cover.

7.7.1 Regeneration

Regeneration has not developed consistently in some higher elevation forests. There may be a number of reasons for this:

- Seed production is an important consideration for non-lignotuberous species such as brown barrel, white ash and shining gum. Some species may produce heavy seed crops, but at irregular intervals (for example brown barrel). However, because a seed crop may be shed over four years, there will usually be some seed available at most times.
- Mechanically disturbed soil may be a more effective seedbed in some high elevation forests. In a Victorian study there were three times as many seedlings on disturbed mineral soil as on burnt sites. Similarly, regeneration developed profusely on disturbed soil following a wildfire in the Brindabella Ranges, ACT, but not on adjacent areas burnt in a wildfire but with the soil undisturbed. Conversely, fire has created successful seedbeds in other circumstances.

- Three years may not be sufficient time in which to assess the success of regeneration following logging. Brown barrel regeneration often appears over a lengthy period. For example, in one high quality forest no regeneration was observed for five years after logging, but then substantial regrowth began to develop.
- Eucalypt regeneration does not develop consistently or uniformly on grassy sites. Competition between grass and seedlings may be greater where fire has stimulated the grass sward and a large part of the canopy has been removed. Under these circumstances, frost may kill many seedlings that do become established.

It is recommended that unless regeneration is to depend on a visible and maturing seed crop, the use of fire to create a seedbed should be avoided. Some form of partial cutting should be used to optimise chances of regeneration developing and surviving, and the sites should be mechanically disturbed.

7.7.2 Silvicultural management

The more open forests of commercial quality may be uneven-aged, for example New England blackbutt forest. This may reflect a high incidence of fire. However, higher quality brown barrel forest, and forest with a grassy understorey, may not be so obviously uneven-aged. In this case, silvicultural practice might be based on operations that partially open the canopy and permit regeneration to develop. Once regeneration is well established, further overstorey can be removed to release it.

Where patches of even-aged regrowth are present (a result of past selective logging and/or fire) and a market is available, thinning should be carried out. However, thinning should not be heavy (as in blackbutt forest), as brown barrel can develop heavy persistent branching where it has too much growing space (section 6).

7.8 Alpine ash forest

Alpine ash only has a localised presence on the southern highlands, with a limited area of the forest on private lands. Alpine ash forest is, like blackbutt, a highly productive resource and very amenable to management.

7.8.1 Regeneration

Alpine ash is a non-lignotuberous species and coppices only weakly. Moreover, it is an intolerant species and accumulates little advance growth. Fortunately, it is a good seed producer, and substantial reserves of seed are usually present in the crowns of mature trees. It can regenerate adequately on soil disturbed in a harvesting operation (though it may take time to establish), and can respond prolifically on a burnt seedbed. Regeneration is inhibited where a grass sward has developed.

7.8.2 Silvicultural management

Alpine ash seedlings can develop vigorously, particularly on ash bed (burnt seedbed) sites, and sustain growth in dense forests where the tree self-thins efficiently and sorts well into dominance classes. Like blackbutt, alpine ash maintains a high rate of diameter growth well into the prime sawlog range. For example, trees can grow to 90 cm dbhob and produce large volumes of timber in 80 years.

Alpine ash forest has been managed effectively as uneven-aged forests, based on a mosaic pattern of even-aged patches. Where trees have reached commercial size, larger patches of even-aged forests can be thinned, for example to around 250–350 stems/ha at age 30 years, followed by a second thinning around 15–20 years later.

7.9 River red gum forest

The floodplain forests of the Murray and Murrumbidgee rivers have serviced the demand for strong durable timbers since early settlement. Some of the earliest silvicultural improvement treatments were carried out in these forests, that is, ringbarking of overstorey trees to release the advance growth that had followed a sequence of good regeneration (flood) years in the late 1800s.

7.9.1 Regeneration

Southern forms of river red gum (in contrast to northern forms) are non-lignotuberous, possibly because of priority the plant must give to the development of the taproot needed to reach water at depth. Hence regeneration depends on seedling establishment. The species coppices strongly but coppice is not a significant regrowth component, although it can have a restrictive effect on residual stems after thinning.

Natural regeneration can develop in the wake of floods, with seedlings establishing best where floodwaters have inundated the land for a limited period, and the newly established seedlings can survive. As the river red gum sapling does not have a vigorous, erect leading shoot, and poor stem form may result, it is an advantage if regeneration develops in clumps. Early non-commercial thinning is not recommended; however, the trees might be spaced when they have reached 20–30 cm dbhob in order to help maintain vigorous height growth.

7.9.2 Silvicultural management

Many present day regrowth forests on the Murray River floodplain are of late 1800s origin resulting from many decades of ringbarking and non-commercial thinning and, more recently, commercial thinning. Diameter growth rates of around 0.75 cm per year were recorded in the mid-1950s, but river regulation and the decline in regular flooding have markedly reduced growth rates since then.

Multiple use roles are now paramount in forest management, and the role of timber production is declining. Harvesting focuses on removal of less productive stems to create even spacing in the pole to early mature regrowth forests. Creating openings for new seedling regeneration will have to be addressed in the future.

7.10 White cypress pine forest

The origins and history of the white cypress pine forests have been described in section 2, with a history dominated by waves of cypress pine regeneration around the 1890s, and again from the 1950s. Eucalypts are present in most cypress pine forests, with the species and stocking levels varying with site conditions (Appendix A).

7.10.1 Regeneration

Since the 1950s cypress pine regeneration has often occurred in wheat field proportions. Cypress pine can establish after a sequence of good rainfall years, including a summer season with cooler than average temperatures and regular falls of rain. Regeneration of associated eucalypts is more infrequent, requiring some form of site disturbance and more exceptional climatic conditions. Cypress pine forests which are dense grow fairly quickly until the site is fully occupied. The initial burst of growth then slows and the forest will stagnate. This is referred to as lock-up and occurs at around 30 to 40 years of age. Regeneration may not establish under a dense tree canopy until the basal area is reduced below 14 m^2/ha. More uniform and dynamic regeneration will develop where the basal area is 7–9 m^2/ha, and without the problem of excessive stocking found in more open areas.

Cypress pine seedlings are highly susceptible to browsing by rabbits and sheep. Cattle are less destructive but should be excluded until the seedlings are large enough to not be at risk.

7.10.2 Silvicultural management

Commercial thinning of the 1890s regrowth has been important in stimulating growth of the residual trees and opening up the forests to encourage development of regeneration. A commercial thinning is possible when the forest is 75 to 85 years old. On public land, thinning regimes have been designed to extend sawlog supply until the post-1950s regrowth matures.

Control is achieved through basal area management, with forests typically maintained within the range 6–13 m^2/ha.

A striking feature of cypress pine is its capacity to survive in dense locked-up forests and yet respond to release when thinned. Hence regeneration should be thinned soon after the overstorey has been harvested. It is necessary to avoid excessive branching and poor stem form associated with very wide spacing. Spacing at about 6 m x 6 m (280 stems/ha) is normally recommended.

7.11 Western hardwoods forests

Western hardwood forests are composed of a variety of dry climate eucalypts. They occur as pure stands or mixed with cypress pine.

7.11.1 Regeneration

All the dry climate eucalypts are lignotuberous, and rely significantly on lignotuberous growth and coppice for regeneration. Western eucalypts generally regenerate in infrequent events such as site disturbance (typically by fire) followed by favourable climatic conditions over a number of years. Successful establishment is usually best in micro-sites with favourable moisture retention and protection from the sun, such as small hollows in the ground or in the shade of fallen branches. Western hardwoods can also regenerate after fire through epicormic shoots that resprout on the trunk. Cypress pine, with which the western hardwood is often associated, is less demanding for resources and can regenerate more readily. The nature of the disturbance (harvesting, fire), condition of crops and climatic conditions following the disturbance therefore greatly influences the balance of cypress pine and hardwood in mixed forests.

As with cypress pine, seedlings of western hardwoods are highly susceptible to browsing by rabbits and sheep. Cattle are less destructive but should be excluded until the seedlings are large enough to not be at risk.

7.11.2 Silvicultural management

As with all eucalypts, western hardwoods are intolerant to low levels of light, and are unable to grow even in the light shade of the woodlands. Therefore, if seedling regeneration is to be relied on, some sort of canopy openings will be required. Western hardwoods are low productivity forests, and in nature have low basal areas. The PNF Code minimum basal area for single tree selection and thinning operations for western hardwoods is 8 m^2/ha where stand height is less than 25 m and 12 m^2/ha where stand height is greater than or equal to 25 m.

New seedlings of western hardwoods are very slow growing. Measurement work in Queensland recorded average seedling heights of only 17 cm after two years, although it is thought that during this time the seedlings put quite some effort into establishing their root systems to ensure their survival. Casual observations suggest that ironbark regeneration may stagnate for at least 10 to 15 years while it forms a lignotuber, and will then start vertical growth at about 30 cm/year.

In contrast to the growth of new seedlings, coppice growth on western hardwoods can be quite rapid. Data from Queensland recorded growth rates of about 60 cm/year over the first four years after coppicing trees that were 5 cm in diameter and about 75 cm/year after coppicing trees around 10 cm in diameter. After four years the average annual height growth reduced to about 30 cm/year.

Western hardwoods in mixed forests with cypress pine have been seen as an increasingly attractive commercial resource, particularly for railway sleepers, poles, landscape materials and other durable products. Tree marking should aim to retain trees with pole and small sawlog potential, and to keep at least four large trees per hectare to maintain forest structure and composition. However, a problem in some forests is the continuing large number of badly formed and defective stems and a scarcity of sound large-diameter trees.

Abbreviations

dbhob	Diameter at breast height over bark
DECCW	Department of Environment, Climate Change and Water
NV Act	*Native Vegetation Act 2003*
PNF	Private native forestry
PNF Code	Private Native Forestry Code of Practice
PVP	Property vegetation plan

Glossary

Advance growth
Regeneration stems that develop beneath the canopy before ('in advance of') any substantial opening of the canopy. Advance growth may include lignotuberous seedlings in a static condition, saplings and small poles. The latter may be in a weak condition, but can respond when coppiced after a canopy opening is created. Advance growth may have developed following fires that created partial canopy openings or weakened the competitive capacity of canopy trees.

Basal area
The cross-sectional area of a tree measured at breast height over bark expressed in metres squared (m^2). Stand basal area is the sum of the basal area of all trees within a stand expressed in square metres per hectare (m^2/ha).

Biodiversity
The total of life forms within an area – including species of plants, animals and microorganisms, the genes they contain and the ecosystems they form. Modern objectives of forest management seek to maintain a high level of biodiversity through the development or maintenance of complex community structures, maintaining a range of stand components (sapling to over-mature trees), and conservation of the full range of plant (both overstorey and understorey) and animal species natural to the site.

Canopy opening
An area of the forest where there is a gap in the overstorey. Canopy openings may be created by removal of parts of the overstorey to release advance growth or stimulate the regeneration of new seedlings (in combination with burning or mechanical site disturbance).

Coppice
Shoots or growth which grow from the stump or roots following damage or logging..

Cutting cycle
The number of years between successive selection harvests, usually in reference to uneven-aged forest. The cutting cycle can depend on many factors, most critically the time it takes to achieve a commercially viable harvest without reducing the growing stock below an accepted threshold level. Depending on the condition of the growing stock, this might be anything between 10 and 60 years.

Diameter at breast height over bark	The diameter of a tree measured at 1.3 metres above the ground on the uphill side. Diameter is usually expressed in centimetres, rounded down to the nearest whole centimetre. Its measurement is described in Appendix C.
Dry sclerophyll forest	Forest in which the dominant trees are tall eucalypts with a grassy or shrubby understorey.
Ecologically sustainable forest management (ESFM)	Forest management which can be regarded as ecologically sustainable – long-term social and economic benefits are derived from wood production while: • conserving naturally occurring plants and animals (forest biodiversity) • maintaining the productivity, health and vitality of the forest • protecting the forest soil and its role in water supply • restoring parts of the forest which may be degraded in any way. Ecologically sustainable forest management requires a good appreciation of the nature of community patterns and processes and a precautionary and adaptive approach to forest management.
Environmental values of the forest	Conservation of biodiversity, the productive capacity and sustainable ecosystems and forest health and vitality, among other values.
Forest products	Large and small sawlogs, veneer logs, poles, piles and girders, among other products.
Fuel reduction burning	See prescribed burning.
Girders	Used in round or flat-faced form to support decking in bridges or wharves, or as sawn timber suitable for heavy construction. Girder logs must be from trees of durable species (tallowwood, grey box, grey gum, ironbarks) or species suitable for preservative treatment (blackbutt, spotted gum). They usually must have a small end diameter of 30–40 cm for bridge or wharf decking, or up to 60 cm for large dimension heavy construction sawn timber.
Lignotubers	A woody swelling or bulbous mass at the bases of the stem of a tree. The lignotuber contains nutrient and starch reserves and has buds that can form new shoots. Lignotuber seedlings are very hardy and may survive for many decades.
Mechanical disturbance	The removal of competing plants and exposure of bare mineral soil by machinery.
Minimum effective canopy opening	The minimum size of a canopy opening in which a species will regenerate and grow unrestricted through the growth stages. Generally, the more intolerant a species the larger will be the minimum effective canopy opening.

Net harvest area The area of forest able to be harvested after the removal of exclusion zones from the total forest area. Exclusion zones may be established to protect water quality (streamside reserves), cultural heritage sites, significant flora (rainforest, old-growth forest) and fauna (threatened species habitat), or wildlife corridors.

The PNF Code defines net harvest area as the area under the private native forestry PVP where harvesting is permitted in accordance with the Code.

The net harvest area does not include any land where trees may not be felled under the provisions of the PNF Code.

Old-growth forest Ecologically mature forest where the effects of disturbance are now negligible.

This includes an area of forest greater than 5 ha where:

- the overstorey is in late to over-mature growth stage with the presence of relatively large old trees (many containing hollows and often with the presence of dieback or dead branches in the crown);
- the age (growth) structure of the stand measured as relative crown cover consists of less than 10% regeneration and advance growth, and greater than 10% in the late to over-mature (senescent) growth;
- the effects of unnatural disturbance are now negligible.

Old growth woodlands west of the Great Dividing Range, while comprising characteristic canopy of late to over-mature trees – many with hollows – may comprise a woodland structure with less diverse or often shrubby understorey and a groundcover of grasses and herbs.

Piles Similar to poles, but usually of larger diameter. Turpentine is used as piles in a marine situation.

Poles Timber smaller than sawlogs. Hardwood poles must be of durable species (tallowwood, grey box, grey gum, ironbarks), unless suitable for preservative treatment (blackbutt, spotted gum). The tree bole needs to meet specifications for size and straightness and generally be defect free.

Rainforest Tree-dominated vegetation where the tree stratum (over 3 m in height) which has the greatest crown cover has rainforest species making up 50% or more of the crown cover except where non rainforest emergent species (including brush box and turpentine) occur and exceed 30% or more of the upper stratum crown cover.

Rainforest includes all areas of rainforest mappable at a 1:25000 scale. Rainforest also includes areas exceeding 0.5 hectares occurring as isolated clumps or lineal strips of rainforest trees.

Recruitment trees Mature trees that are close to developing hollows (where large branches that are dead or broken) that in time will become wildlife habitat trees.

Sawlog

A high quality eucalypt log with a centre diameter under bark of at least 40 cm. There can be a reasonable amount of defect but at least 10 cm of clear wood is needed outside a defective central zone ('pipe'). The minimum clear-wood thickness increases with the diameter of the log. Sawmills are increasingly capable of handling smaller diameter sawlogs. Local advice should be sought on the minimum dimensions for sawlogs, and the amount of defect a sawmill will accept.

Self-thinning

Tree mortality from the effect of competition between trees. Only a small proportion of stems in a patch of highly stocked regeneration will survive. As the stems compete for site resources (water, nutrients, root growing space), they will sort into dominance or crown classes (dominant, co-dominant, sub-dominant, suppressed), and reduce in number as the suppressed stems die. The rate of self-thinning (or natural thinning) varies widely. It is greatest for inherently vigorous species (blackbutt, flooded gum) on high quality sites, and lowest for slower-growing species on poor sites (silvertop ash). In the latter circumstances, the segregation into crown classes may cease, and the rate of self-thinning decline and the stand become stagnant or locked-up.

Silvicultural systems

In most silvicultural texts, silvicultural practices are described in terms of a number of silvicultural systems. These are designs for harvesting and regenerating forests resulting in a desired forest structure and adequate regeneration, among other objectives. The various systems can be thought of as gradational series in terms of the proportion of the canopy that is removed at any one harvest, as follows:

1 **Clearfelling** involves the removal of the entire stand. Subsequent regeneration might develop from advance growth, coppice or new seedlings. Seed supply may come from adjacent forests, the heads of felled trees, or seed that has accumulated with time as a soil seed store (the latter applies to wattle, but not to eucalypts). Alternatively, the site may be planted with seedling stock or seed may be directly sown onto the site by hand or from an aircraft.

2 **Clearfelling with seed trees** may be modified to the extent that a small number of mature trees are retained on the site for the specific purpose of supplying seed. It is usual practice to leave seed trees uniformly distributed through the area at a stocking of around 7–10 per hectare.

3 **The shelterwood method** is normally applied to even-aged forests of mature trees at higher elevation. The mature trees are removed in a series of cuttings in a relative short space of time. The aim is to regenerate relatively even-aged regrowth under the partial shelter of the overstorey. The intensity, number, and timing of successive harvests are dependent on the tolerance of the component species and the climatic conditions of the site (especially the risk of frost and snow).

4 **The selection method** involves the removal of only some trees. Harvesting is normally repeated at relatively short intervals (10–30 years), depending on the intensity of previous harvesting and the forest type. Under this method it is possible to be flexible in determining which components of the forest will be harvested, and which retained, to achieve a specified set of management objectives. Selection harvests can be light or heavy, or can involve the removal of trees in patches large enough to produce small even-aged stands

(referred to as group selection). The structure of the forest should be carefully considered when undertaking single tree selection harvesting.

5 **Australian Group Selection** is a selection system devised for eucalypt forests predominately in NSW and Queensland. The objective is to select for removal a group of trees to form a canopy opening. Ideally this opening should allow the seedlings in the middle to have no shading from the trees around the canopy opening. Thus the prescription for the width of the canopy opening is twice the stand height.

6 **Thinning** is the selection of a single tree for removal in order to provide more growing space for those trees retained. Thinning prescriptions often have an espacement requirement, for example a spacing of 10 m between trees of 20 cm diameter.

Veneer logs High quality logs that are rotary peeled or sliced to produce sheets of veneer. Veneer logs must be large (>40 cm diameter), round, straight, defect free and have a solid heart.

Wet sclerophyll forest An overstorey of tall eucalypts and a number of other species with an understorey of ferns, soft leaved shrubs, and small rainforest trees. Wet sclerophyll forest is more productive than dry sclerophyll forest.

Wildlife habitat trees Large, over-mature trees that contain hollows in broken branches or the trunk which provide important nesting sites for arboreal animals and tree-nesting birds.

Appendix A – Description of forest types

Rainforest types

There are two main types of rainforest in the coastal and mountain zones – the more complex subtropical rainforest and the vegetatively and structurally simpler warm temperate rainforest. Other types of less commercial importance are the cool temperate rainforest and the dry and depauperate rainforest. Note that under the PNF Code forest operations must not occur in rainforest.

Blackbutt types

From a commercial perspective blackbutt forest is the most productive in NSW. Blackbutt types are characterised by the occurrence, and usually by the dominance, of blackbutt species. Blackbutt species has a markedly discontinuous distribution in its narrow coastal range from the NSW–Victoria border to Fraser Island in Queensland. That distribution may be related to suitable (high) rainfall regimes and soil conditions able to service a relatively high soil moisture requirement.

Blackbutt occurs both as near-pure forests (where environmental conditions are near optimum for them) and mixed with a large number of other species. Common associates in forest of good commercial quality include tallowwood, white mahogany, red mahogany, grey gum, grey ironbark, pink bloodwood, red bloodwood, turpentine and brush box. There can be a transitional zone between blackbutt and other forest types, for example between blackbutt and spotted gum types. Additionally, blackbutt is a component of some lower quality forest – through associations with pink bloodwood, rough-barked apple, smooth-barked apple, scribbly gum, Sydney peppermint and others.

The blackbutt type occurs in both dry sclerophyll and wet sclerophyll forms. These are sometimes designated as the dry blackbutt and moist blackbutt types respectively. The wet sclerophyll forest may include, in addition to the species listed earlier, Sydney blue gum and flooded gum. Wet blackbutt might not merge directly with rainforest, but typically is separated from rainforest by the moist coastal hardwood type.

Mixed hardwood type

Forest types grouped as the mixed hardwood type are among the most widely distributed of all forest communities in the coastal districts of NSW. The communities are made up of many of the species listed as associates of blackbutt, though not including blackbutt itself. Mixed hardwood and blackbutt types may occur in a mosaic pattern through the coastal forests, with the mixed hardwood dominating where environmental conditions are not suitable for blackbutt which is more site-sensitive.

Some of the more common species associations include those with narrow-leaved white mahogany, tallowwood, grey gum, grey ironbark, red mahogany, turpentine and brush box. Unlike blackbutt forest, these communities are rarely dominated by a single species. Indeed, a typical community may contain between three and eight or more tree species.

Other common associations, which can be placed in this broad type, are those with a grey box component. A diverse grouping of types throughout coastal districts includes the grey box – grey gum associations of northern NSW and the grey box – woollybutt and grey box – Blakely’s red gum associations on the south coast.

As in blackbutt forest, the mixed hardwood forest has both dry sclerophyll and wet sclerophyll forms, the latter commonly merging with moist coastal hardwood and flooded gum types on lower protected slopes. The term moist mixed hardwood or semi-moist mixed hardwood has been used to differentiate wet sclerophyll from dry sclerophyll forest, the latter also known as dry mixed hardwood or dry coastal hardwood forest.

Spotted gum types

Communities dominated by spotted gum are among the most important of the commercial forest types in the state and produce some of NSW’s finest timber.

Spotted gum types have a discontinuous distribution through the coastal districts. They occur under a wide range of environmental conditions, from woodland forests and dry sclerophyll forest to tall wet sclerophyll forest. Site quality varies from poor to excellent, with dominant heights from 20 m to more than 45 m.

The species appears to occur on soils with relatively good fertility, but with heavy-textured subsoil. It also tolerates lower rainfall than blackbutt and other coastal eucalypts. Under these circumstances, its competitive ability may be enhanced through a capacity to produce a deeply penetrating taproot under adverse environmental conditions.

The spotted gum community merges with other coastal types, including blackbutt and mixed hardwood communities. Hence there can be many associated species, including stringybarks, ironbarks, grey gum, woollybutt, silvertop ash, red bloodwood, mountain grey gum and tallowwood. Grey box and spotted gum dominate forests on heavy clay soils on the north coast, and on the south coast the species occurs as wet sclerophyll forest in association with Sydney blue gum and bangalay, with a rainforest understorey.

Moist coastal hardwood types

These are typically tall wet sclerophyll forests or marginal rainforest communities, with emergent trees from 40 m to more than 60 m in height, and often with a dense rainforest understorey. Their main occurrence is in the hinterland escarpment zone of the north coast (300–1000 m above sea level), though they are widely distributed at lower altitude along the north coast in a mosaic pattern with other high quality forest types.

Moderate to high soil fertility appears to be a defining environmental requirement for moist coastal hardwood types. They occur in a wide range of topographic situations where conditions are appropriate and may merge with rainforest where environmental conditions (including high soil fertility) are particularly favourable. There is a view that most moist coastal hardwood sites on highly fertile soils would support rainforest in the absence of fire.

The more characteristic dominant species include tallowwood, Sydney blue gum and brush box. Brush box may dominate on some sites, often in sheltered gullies, but may also occupy ridges where rainforest is widespread. Where conditions become less favourable for moist coastal hardwoods it may merge with tableland hardwood, blackbutt and mixed hardwood types.

It is accepted that moist coastal hardwood has been maintained in its natural condition by intense fire at very wide intervals, for example 300 to 400 years. Where the forest is harvested, intensive site treatment such as fire or mechanical site disturbance is essential for regeneration.

Flooded gum type

The flooded gum type might be considered a variant of the moist coastal hardwood type, but is such a distinctive and commercially significant component that it is regarded as an independent entity. It is widely distributed along the north coast, though individual forests are often of limited extent. The type is most common at lower elevations, but ascends to 750 m in a few localities.

Flooded gum usually dominates tall wet sclerophyll forest, commonly up to 45 m, and on high quality sites, exceeding 60 m in height. The forest occupies moist, fertile (or moderately fertile) gully sites on the north coast, with some of the more extensive occurrences associated with broad alluvial flats. Individual flooded gum can be a lower slope component of both blackbutt and mixed hardwood forest types with the flooded gum forest type characteristically growing in broad valley floors.

Forests with a large flooded gum component will sometimes reflect a history of fire and logging disturbance. The original forests may have had mixtures of flooded gum, tallowwood, brush box, turpentine, swamp mahogany and other species and a rainforest understorey. Flooded gum develops rapidly on disturbed sites and some previously complex forests have been converted to near-pure flooded gum forests. Alternatively, there may be a mosaic of individual flooded gums, patches of flooded gum, and residual mixed species forest.

Silvertop ash – stringybark types

These are the dry sclerophyll forests that have been the resource base for the integrated sawlog–woodchip export industry in the south-east of the state. The forests are mainly in coastal locations but also extend into the southern and central highlands. They are typically associated with low nutrient soils with dominant heights in the 20–40 m range.

Silvertop ash (also known as coast ash) is the most characteristic species. It has many associates, reflecting variations in environmental factors. Associates include four stringybark species (white, yellow, brown, blue-leaved), yertchuk (on some of the poorest soils), Sydney peppermint and the Blue Mountains ash (on more sheltered sandstone sites in the upper Blue Mountains). The forest can at times approach a wet sclerophyll condition, for example on some lower moister slopes with mountain grey gum a common associate.

The silvertop ash – stringybark type is also closely related to a wider grouping of dry sclerophyll communities, including those with scribbly gum and peppermint. It merges with a number of tableland communities at higher elevations.

Tableland hardwood types

These forests extend along the tablelands, mostly at elevations 900–1400 m above sea level, though at lower elevations in the south of the state.

The more common component species include messmate stringybark, brown barrel, ribbon gum, mountain gum, mountain grey gum, shining gum, narrow-leaved peppermint, New England blackbutt, yellow stringybark and silvertop stringybark. There are less common occurrences of other species including silvertop ash, white ash, southern blue gum, gully peppermint and river peppermint.

The forests of the tablelands are variable in quality and commercial potential. Some of the more distinctive of the individual types include near-pure brown barrel forest; associations of brown barrel, messmate stringybark, ribbon gum and mountain gum, associations of narrow-leaved peppermint and ribbon gum or mountain gum, associations of messmate stringybark and silvertop stringybark (on the northern tablelands), and the New England blackbutt type, a widespread and somewhat variable type with many associated species on the northern tablelands. Forests of silvertop ash, more usually associated with the coastal forests, and white ash may be found on some of the less fertile tablelands sites.

The tableland hardwood types adjoin and merge with other communities, including snow gum communities at higher elevations and moist coastal hardwood types at lower elevations.

The forest types in the tableland hardwood grouping range from tall wet sclerophyll forest (brown barrel forest on the most favoured sites, and sometimes with lower slope cool-temperate rainforest species), to more open forest.

Alpine ash type

This is a distinctive forest type on the southern tablelands 900–1400 m above sea level. The alpine ash forest is highly productive (dominant heights 45–55 m); however, there is only a limited occurrence of the type in NSW, the greater part of which is now in national park. There is only a small area of the type on private property.

Snow gum communities replace alpine ash at high elevations. At lower elevations various tableland communities replace alpine ash, including those with messmate, brown barrel, mountain gum and ribbon gum. Alpine ash occurs either as near pure forests, or mixed with mountain gum and ribbon gum, the latter species in moist gully sites. There may also be a subordinate layer of narrow-leaved peppermint.

As might be expected for a highly productive forest, alpine ash only occurs under favourable environmental conditions of deep, well-drained soils and cool moist sheltered slopes. On drier and more exposed sites alpine ash is replaced by mountain gum and peppermint species. On cold low-lying sites alpine ash is replaced snow gum and black sallee.

River red gum types

River red gum has the widest distribution of any species in Australia, forming ribbon-like forests along the banks of most inland watercourses or at the foot of sandhills with reasonably high water tables. However, commercial utilisation of this forest type is concentrated on the extensive stands on the floodplains of the Murray and Murrumbidgee rivers. Historically, these forests have been an important source of durable construction timbers and railway sleepers (now largely replaced by concrete and steel). However, they still support locally important forest industries.

The occurrence and growth of river red gum is dominated, perhaps more so than any other major forest type, by a single factor – regular flooding. The site quality range within the type reflects the frequency of flooding and depth to the water table. The greater the depth to the water table, the lower the site quality. Thus forests may range from woodland trees only 12 m in height to tall forest trees 50 m in height.

There are two component types: those with essentially only river red gum, and those on somewhat more elevated ground where river red gum occurs mixed with various boxes, notably black box and coolibah.

Cypress pine types

The cypress pine forests (based on white cypress pine but including black cypress pine) form a broad belt through the western slopes and the eastern part of the western plains. Cypress pine can occur in near-pure forests, but is usually associated with one or more of a number of eucalypt species. The structure of the now densely stocked forests is very different from that of the pre-settlement woodlands they replaced.

Baur (1965) lists 14 individual types, mainly related to the eucalypt species growing in association with the cypress pine. It is common to have a transition from pine–eucalypt to eucalypt–pine communities, with pine on the more sandy soils, box eucalypts on heavier soils and narrow-leaved ironbark on deep acid soils.

The eucalypt component of the forests includes several ironbarks (silver-leaved ironbark, narrow-leaved ironbark and broad-leaved ironbark), a number of boxes (yellow box, white box, pilliga box, western grey box, western red box, and coolibah), brown bloodwood, Blakely's red gum and river red gum. Other components of the forest include bull oak.

Western hardwoods types

This is a variable group of forests typically dominated by a mixture of one or more western box or ironbark species and may include a component of either white or black cypress pine. Most of these types have a woodland structure – those carrying ironbarks and stringybarks approach dry sclerophyll forest in structure. The types are useful for the local supply of poles, piles, railway sleepers, firewood and other products, but are not a substantial contributor to wood production in NSW.

Environmental factors influence the distribution of species and individual types. For example, the black box – coolibah forest type is associated with poorly drained sites with heavy soils, and these are widespread through western areas. Conversely, the ironbark – western box forest type is usually associated with excessively drained skeletal soils containing red ironbark, silver-leaved ironbark and narrow-leaved ironbarks, and white box, narrow-leaved box and western grey box.

Other types include those identified with box species (western box type), with ironbarks (ironbark – western box), an ironbark – red gum type (mainly tumbledown gum with occasional Baradine and Blakely's gum), a brown bloodwood – ironbark – red gum type and a red ironbark – stringybark type.

Appendix B – Broad forest types of the PNF Code

The table below shows the association between the PNF Code broad forest types and forest types in NSW as described in Baur (1965) and are listed by number (left column) and forest type (right column).

Broad forest type – north coast blackbutt	
Research note 17 number	**Forest type**
36	Moist blackbutt
37	Dry blackbutt
38	Large-fruited blackbutt
39	Blackbutt – spotted gum
40	Blackbutt – scribbly gum
41	Blackbutt – bloodwood/apple
42	Blackbutt – Sydney peppermint – smooth-barked apple

Broad forest type – north coast dry mixed hardwood	
Research note 17 number	**Forest type**
61	Broad-leaved white mahogany
62	Grey gum – grey ironbark – white mahogany
65	Forest red gum – grey gum/grey ironbark – rough-barked apple
80	Grey ironbark – grey box
82	Grey box
83	Grey box – ironbark
84	Ironbark
85	Coastal grey box – forest red gum
92	Forest red gum
93	Eastern red gum
97	Needlebark stringybark
98	Dorrigo white gum
100	Yellow bloodwood
105	Smooth-barked apple
106	Smoothbarked apple – Sydney peppermint – stringybark
108	Bangalay – banksia
115	Sydney peppermint – stringybark
116	Sydney peppermint – bloodwood/turpentine
118	Scribbly gum – silvertop ash
119	Scribbly gum – bloodwood
126	Stringybark – bloodwood
128	Sydney peppermint
129	Rough-barked apple

Broad forest type – spotted gum	
Research note 17 number	**Forest type**
70	Spotted gum
71	Richmond Range spotted gum
72	Spotted gum grey box
73	Spotted gum – Sydney blue gum
74	Spotted gum – ironbark/grey gum
75	Spotted gum – yellow/white stringybark
76	Spotted gum – blackbutt

Broad forest type – north coast moist mixed hardwood	
Research note 17 number	**Forest type**
45	Tallowwood
46	Sydney blue gum
47	Tallowwood – Sydney blue gum
49	Turpentine
50	Bangalay
52	Roundleaved gum – turpentine
53	Brush box
54	White-topped box
60	Narrow-leaved white mahogany – red mahogany – grey ironbark – grey gum
68	Red mahogany
81	Grey box – northern grey gum
87	Steel box/craven grey box

Broad forest type – north coast flooded gum	
Research note 17 number	**Forest type**
48	Flooded gum
51	Dunn’s white gum

Broad forest type – south coast ash/stringybark	
Research note 17 number	**Forest type**
63	Woollybutt
64	Grey gum – stringybark
66	Grey ironbark – stringybark
67	Grey gum – ironbark
86	Coastal grey box – woollybutt
88	Gum – box – stringybark
101	Blue mountain ash
102	Yertchuk

112	Silvertop ash
113	Silvertop ash – peppermint
114	Silvertop ash – stringybark
121	Blue-leaved stringybark
123	Coastal stringybark
127	Stringybark – smooth-barked apple
130	Red bloodwood
132	Stringybark – gum
133	Stringybark – apple-topped box
157	Yellow stringybark – gum
162	White ash
166	River peppermint
169	Yellow stringybark

Broad forest type – tablelands hardwood	
Research note 17 number	**Forest type**
109	Brittle gum
110	Brittle gum – peppermint
111	Peppermint
117	Scribbly gum
120	Scribbly gum/ brittle gum – snow gum
122	New England stringybark
125	Red stringybark – scribbly gum/ brittle gum
131	Peppermint – mountain/manna gum
136	Snow gum – black sallee
137	Black sallee
138	Snow gum
139	Alpine snow gum
140	Snow gum – mountain/manna gum
141	Candlebark
142	New England peppermint
143	Swamp gum/black gum/broad-leaved sallee
150	Messmate
151	Brown barrel – messmate
152	Messmate
153	Messmate – silvertop stringybark
154	Brown barrel
156	Brown barrel/messmate – ash
158	Southern blue gum
159	Mountain/manna gum
160	Manna gum – stringybark

161	Round-leaved gum
163	New England blackbutt
164	Eurabbie
165	Gully peppermint
167	Silvertop stringybark
168	Silvertop stringybark – gum

Broad forest type – tablelands ash	
Research note 17 number	**Forest type**
147	Alpine ash
148	Alpine ash – mountain/manna gum

Broad forest type – river red gum	
Research note 17 number	**Forest type**
199	River red gum
200	River red gum – black box/coolibah
202	Black box/coolibah

Broad forest type – cypress pine	
Research note 17 number	**Forest type**
188	White cypress pine
189	White cypress pine – narrow-leaved ironbark
190	White cypress pine – brown bloodwood
191	White cypress pine – western ironbark
192	White cypress pine – red gum
193	White cypress pine – box
194	White cypress pine – black cypress pine
195	White cypress pine – hillside red gum

Broad forest type – western hardwoods	
Research note 17 number	**Forest type**
99	Red box
103	Apple box
104	Long-leaved box
124	Red stringybark
171	Yellow box
172	Yellow box – Blakely’s red gum
173	Yellow box – white box
174	White box – western box
175	White box
176	White box – stringybark

177	Red gum – stringybark
178	Western red gums
180	Black cypress pine
181	Black cypress pine – ironbark
182	Black cypress pine – box
183	Black cypress pine – red gum
184	Black cypress pine – scribbly gum
185	Black cypress pine – white cypress pine
203	Western box
204	Ironbark – western box
205	Ironbark – red gum
206	Red ironbark
207	Silver-leaved ironbark
208	Narrow-leaved ironbark – bull oak
209	Brown bloodwood – ironbark/red gum
210	Red ironbark – stringybark
213	Bull oak

Appendix C – Common and scientific names of major tree species in NSW

Common name	**Scientific name**
Alpine ash	*Eucalyptus delegatensis*
Bangalay	*E. botryoides*
Black box	*E. largiflorens*
Blackbutt	*E. pilularis*
Blakely’s red gum	*E. blakelyi*
Blue-leaved stringybark	*E. agglomerata*
Blue mountains ash	*E. oreades*
Broad-leaved ironbark	*E. fibrosa*
Brown barrel	*E. fastigata*
Brown bloodwood	*Corymbia trachyphloia* (formerly *Eucalyptus trachyphloia*)
Brown stringybark	*E. blaxlandii*
Brush box	*Lophostemon confertus*
Bull oak	*Allocasuarina luehmanii*
Coast grey box	*E. bosistoana*
Coolibah	*E. coolabah*
Flooded gum	*E. grandis*
Forest red gum	*E. tereticornis*
Gully peppermint	*E. smithii*
Grey box	*E. moluccana*
Grey gum	*E. propinqua/punctata*
Grey ironbark	*E. siderophloia/paniculata*
Messmate stringybark	*E. obliqua*
Mountain gum	*E. dalrympleana*
Mountain grey gum	*E. cypellocarpa*
Narrow-leaved ironbark	*E. crebra*
Narrow-leaved peppermint	*E. radiata*
New England blackbutt	*E. campanulata/andrewsii*
Pilliga box	*E. pilligaensis*
Pink bloodwood	*Corymbia intermedia* (formerly *Eucalyptus intermedia*)
Red bloodwood	*Corymbia gummifera* (formerly *Eucalyptus gummifera*)
Red gum	*E. amplifolia/seeana*

Common name	**Scientific name**
Red mahogany	*E. resinifera*
Ribbon gum (manna gum)	*E viminalis.*
River peppermint	*E. elata*
River red gum	*E. camaldulensis*
Rough-barked apple	*Angophora floribunda*
Scribbly gum	*E. haemastoma/signata/racemosa/rossii*
Shining gum	*E. nitens*
Silver-leaved Ironbark	*E. melanophloia*
Silvertop ash	*E. sieberi*
Silvertop stringybark	*E. laevopinea*
Smooth-barked apple	*Angophora costata*
Southern blue gum	*E. bicostata*
Spotted gum	*Corymbia maculata/variegata/henryi* (formerly *Eucalyptus maculata/variegata/henryi*)
Swamp mahogany	*E. robusta*
Sydney blue gum	*E. saligna*
Sydney peppermint	*E. piperita*
Tallowwood	*E. microcorys*
Turpentine	*Syncarpia glomulifera*
Western grey box	*E. woolsiana*
Western red box	*E. intertexta*
White ash	*E. fraxinoides*
White box	*E. albens*
White mahogany	*E. acmenoides*
White stringybark	*E. globoidea*
Woollybutt	*E. longifolia*
Yellow box	*E. melliodora*
Yellow stringybark	*E. muelleriana*
Yertchuk	*E. consideniana*

Appendix D – Measuring the diameter of a tree

In Australia it is standard practice to measure the diameter of a tree at 1.3 metres above the ground on the uphill side. This is termed the diameter at breast height over bark (dbhob) and is usually expressed in centimetres, rounded down to the nearest whole centimetre (Figure 8).

A height of 1.3 metres is used because it is a convenient height for most people, is usually above any buttressing or fluting at the base of the tree and is usually not obstructed by undergrowth.

Diameter is usually measured with a fibreglass or metal diameter tape.

Figure 8: Measuring tree diameter

Appendix E – Techniques for measuring stand basal area

Introduction

This document provides a guide to the measurement of stand basal area. The Private Native Forestry Code of Practice (the Code) uses the concept of basal area to set disturbance thresholds, or retention limits for single tree selection and thinning operations in private native forests. Basal area is a forest measurement that can help forest owners estimate tree volumes, and understand and manage stand density and competition.

It is the responsibility of landowners and forestry contractors and operators to comply with the Code.

For the purpose of this guideline, and for use in accordance with the Code, there are some important definitions which include the following.

- **Tree basal area:** the cross-sectional area of a tree trunk measured at breast height over bark. It can be thought of as the surface area of a cut stump at a height of 1.3 m (Figure 1).
- **Stand:** an area of forest that can be identified and mapped according to broad forest type and height class as listed in section 3.1 of the Code (section 3.2 in the Code for Cypress and Western Hardwood Forests).
- **Stand basal area:** the sum of the basal area of all live trees in a stand, is usually expressed in square metres per hectare (m^2/ha).

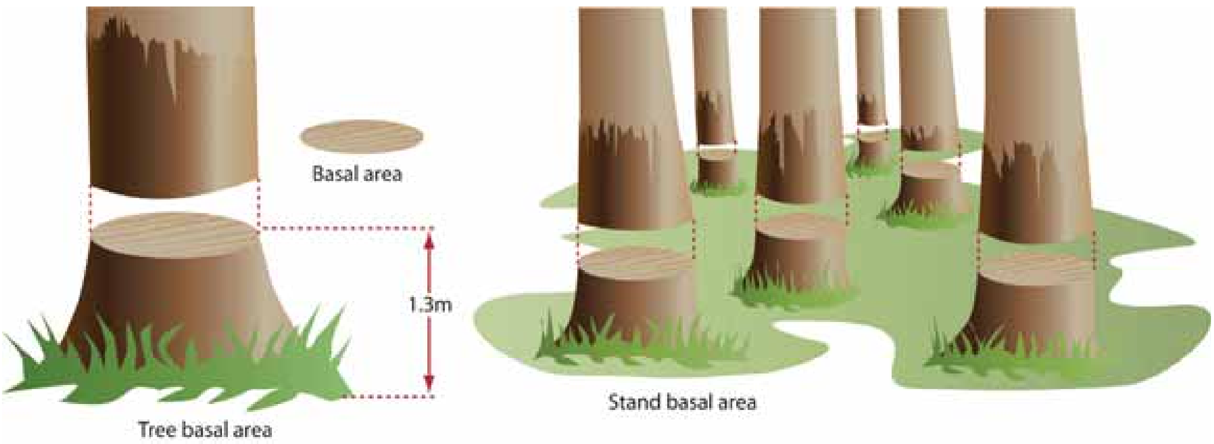


Figure 1: Tree basal area and stand basal area

Methods

Stand basal area can be measured by two methods: angle count sampling or fixed area plot measurement.

Angle count sampling

This method of sampling allows unbiased estimates of stand basal area to be made very quickly without the need to individually measure each tree stem or to set out a fixed sample plot area. A sweep of an area of the forest is made from a sampling point using a relascope, dendrometer or wedge prisms.

Note: Angle count sampling is the method that is described in this guideline for everyday use with the Code.

Fixed area plot measurement

This method involves:

1 the measurement of the diameter of all trees in a set area; one-tenth hectare plots are normal forestry practice (for example 50 m x 20 m)

2 calculating the basal area of each tree in the plot

3 calculating the total basal area.

Fixed area plot measurement should be used where a more definitive measurement than can be obtained from angle count sampling is required. It may be used by officers of the Department of Environment, Climate Change and Water (DECCW) where there is any doubt about compliance with the stand basal area requirements of the Code.

Note: This method may be required for basal area measurement in riparian buffer zones under section 4.4(2) of the Code. See 'Measuring stand basal area in riparian buffer zones' on page 68.

Complying with the Code

Under the Code, minimum stand basal areas have been set for single tree selection and thinning operations below which the stand basal area cannot be reduced. This helps to ensure that an adequate forest structure is maintained for the long term.

Stand basal area will need to be assessed:

- prior to a forestry operation to ensure that there is sufficient existing basal area to conduct the forestry operation in compliance with the Code
- during any forestry operation to ensure continuing compliance with the Code.

For the purpose of this guideline, the minimum stand basal areas in the Code *will be applied as an average* over the *relevant operational area* of a forestry operation. This will require a number of representative measurements to be taken across the area so that an average can be calculated. This allows a reasonable degree of silvicultural flexibility and practicality in planning forest operations.

The relevant operational area of a forestry operation is defined as follows:

- for *current forestry operations*: those parts of the stand within the area described in the current Forest Operation Plan where the current forestry operation has already been implemented – see section 2.1(5)(a)(i)
- for *previously completed forestry operations*: those parts of the stand where forestry operations have previously been conducted under the Code – see section 2.1(5)(a)(i).

While the stand basal area provisions of the Code are applied as an average, there are limits to this principle.

- Averaging can only occur within contiguous forest areas. Isolated patches or physically separate areas of forest must be treated individually.
- No more than half of the sampling points in the relevant operational area can be below the minimum limits.

Note: Calculations undertaken during a harvesting operation to ensure that the average stand basal area complies with the Code cannot include areas outside the Forest Operations Plan boundary or areas within the Forest Operations Plan boundary that are yet to be harvested.

It is important that everyone involved with any single tree selection or thinning operation understands the minimum basal area requirements of section 3.1 of the Code (section 3.2 of the Code for Cypress and Western Hardwood Forests) and this guideline. This may include landowners, forest contractors and forestry consultants.

To comply with the Code, this procedure must be followed:

- Classify the proposed area for single tree selection or thinning into broad forest types and map on the Forest Operation Plan.
- Classify each broad forest type into two height classes of less than 25 metres or greater than 25 metres, and map or note on the Forest Operation Plan.
- Comply with the relevant minimum stand basal area.

Note: The first two points above do not apply to the river red gum broad forest type.

While not required by the Code, it is beneficial to mark the boundaries of the above areas on the ground prior to commencing forest operations.

Angle count sampling

Instruments

Stand basal area can be measured using a variety of instruments, ranging from the sophisticated and expensive which can be obtained from forestry equipment suppliers, through to simple home-made devices. These instruments are referred to as relascopes or dendrometers, and there are a number of versions. Glass wedge prisms can also be used.

The simpler instruments are hand-held gauges with sights which are held at a pre-determined distance from the operator’s eye. There is a mathematical relationship between the width of the sight of the instrument and the distance from the eye which is known as the basal area factor (BAF). Most relascopes and dendrometers have a BAF of 1, 2 or 4; generally using a BAF of 2 is a good starting point.

Bottle-opener dendrometer

A bottle-opener dendrometer combines BAFs of 1, 2 and 4 and can be obtained from forestry equipment suppliers. It is flat and fits comfortably in a pocket. It has an attached cord so that the distance at which it is held from the eye is constant (Figure 2).

Rod relascope

Unlike a bottle-opener dendrometer, each rod relascope measures a single BAF; a set of rod relascopes to measure various BAFs can be easily made from metal (Figure 3). Instructions for constructing a rod relascope are given on page.

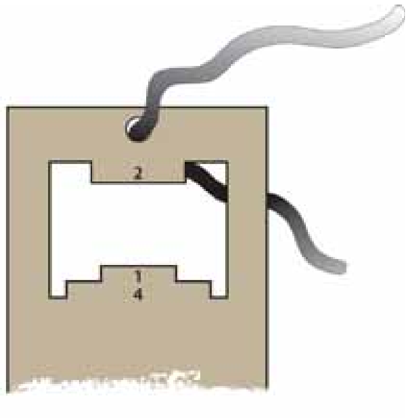


Figure 2: Bottle-opener dendrometer

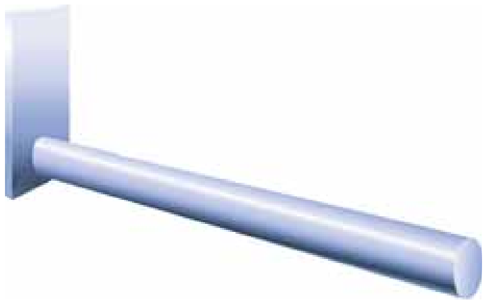


Figure 3: A rod relascope

Method

Angle count sampling requires a sweep of an area of forest from a set sampling point within the forest stand. A sweep is where the operator stands in one spot and turns through 360° sighting each tree with a relascope or dendrometer. A number of sweeps throughout the forest stand will be required.

When using a relascope or dendrometer the cord (which must be kept taut) or rod is held against the operator's cheek just below the eye. If using an instrument with multiple BAFs only use one BAF per sweep (Figure 4). To assess a tree that is partially or fully hidden behind other trees or undergrowth, move sideways until the tree is fully in view. Move back to the sweep centre before assessing the next tree. Trees under 10 cm in diameter at breast height and dead trees should not be counted.

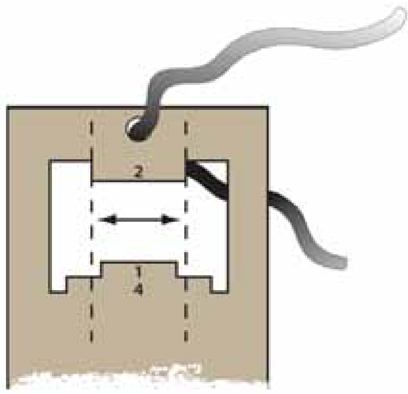


Figure 4: Dendrometer sight with a BAF of 2

The angle count sampling method is described as follows:

Step 1: Select the sampling point where the angle count sweep is to be taken.

Step 2: While ensuring that the eye remains over the sampling point, complete a 360° sweep around that point. Aim the sight of the instrument at the stem of each tree at breast height and count trees as follows (Figure 5):

- If the stem of the tree is wider than the instrument sight, the tree is 'in' and assigned a count of 1.
- If the stem of the tree matches the width of the instrument sight, the tree is deemed to be borderline and is assigned a count of ½.
- If the stem of the tree is narrower than the instrument sight, the tree is deemed to be 'out' and is not counted.
- Tally the number of counts as you conduct the sweep.

Step 3: Calculate the stand basal area (m^2/ha) by multiplying the tally for the sweep by the BAF used.

There is no set area covered by an angle count sweep. Trees will appear either in, equal to or out according to their diameter, the distance from the sighting point and the BAF of the instrument being used. It is important to select a BAF that is suitable for the forest being assessed. To obtain the best accuracy, the aim should be to have a tally of approximately 10 to 12 trees per sweep. This may mean using a higher or lower BAF instrument.

Note: It is a good idea to occasionally check your accuracy using this method by calculating the basal area at the same site using the fixed plot method.

The existing stand basal area prior to a forestry operation must be entered on the Forest Operation Plan.

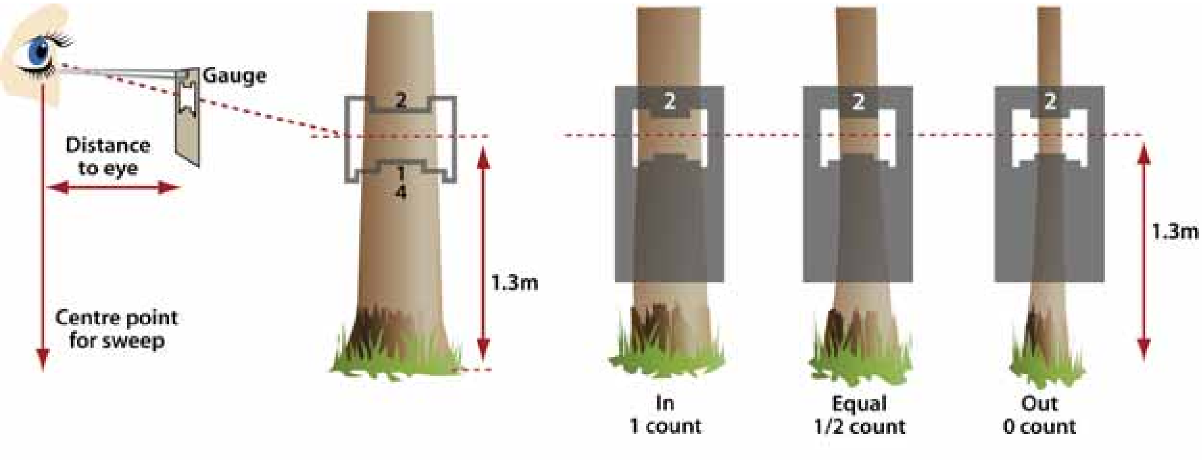


Figure 5: Assessing trees which are in, equal, and out for a BAF of 2

Tips to remember:

- View each tree at breast height (1.3 m above ground).
- The operator's eye must remain over the centre point of the sweep during the whole sweep.
- View at right angles to the stem of leaning trees. If the stem of the tree is not upright, hold the instrument at a tilt (Figure 6).
- View trees hidden by undergrowth or other stems by moving to the side.
- Use an instrument BAF that counts 10 to 12 trees for each 360° sweep.
- Include all living trees with a diameter greater than 10 cm at breast height.

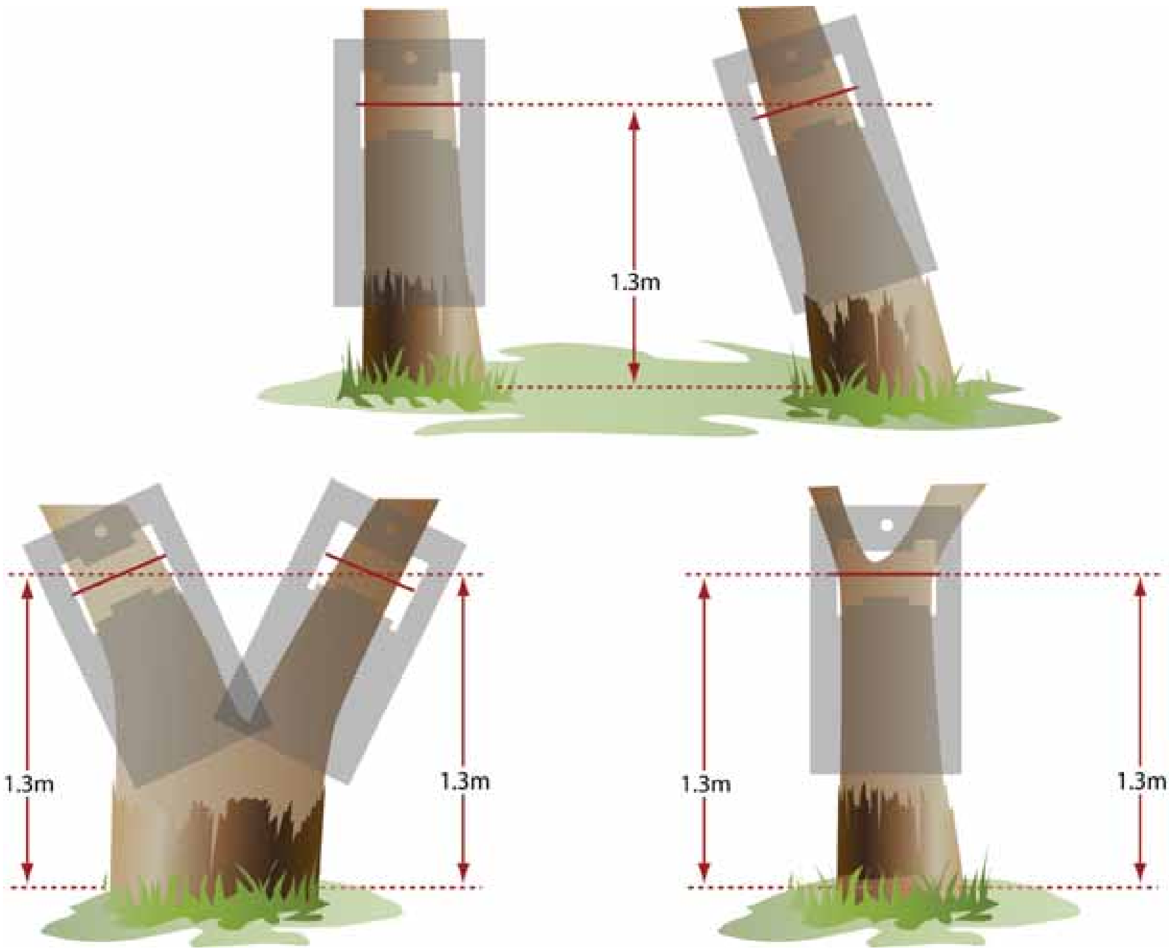


Figure 6: Measuring tree stems

Determining the number of sweeps

It will usually be necessary to conduct a number of sweeps across the current operational area in order to obtain a reasonable and accurate average measurement of the stand basal area.

There is no set rule as to how many sweeps should be made, but the results will be more accurate as the number of sweeps increases. A guide for native forest stands is 10 sweeps for any area up to 30 hectares, and up to at least 30 sweeps for larger stand areas. The greater the variability of basal area throughout the stand, the greater the number of sweeps that should be conducted.

Note: You should conduct at least enough sweeps to ensure that you are confident of compliance with the Code.

There are a number of considerations when selecting sampling points.

- Sweeps should be located at random and not overlap with other sweeps.
- Sweeps should sample a range of topography and not be conducted within or near canopy openings, roads, tracks or log dumps.
- Although within the general operational area, natural openings (not created by current or past forestry operations) in the forest should be avoided.
- Sweeps must not include areas of forest that may not be felled under the Code, for example old growth forest, rainforest and riparian exclusion zones.
- All readings should be at least 30 m from the edge of the timbered area. This may mean that the angle count method may not be suitable for small patches of forest.

DECCW officers check basal area as part of routine audits of compliance with the Code.

Measuring stand basal area in riparian buffer zones

In the Code for Northern NSW, Southern NSW and River Red Gum Forests, riparian buffer zones apply to specified drainage features (riparian buffer zones are not required under the Code for Cypress and Western Hardwood forests). Within these buffer zones additional basal area restrictions apply where only 30% of the pre-harvest basal area can be removed in any 10-year period (section 4.4(2)). This means that basal area within riparian buffer zones may need to be measured separately from the remainder of the harvest area.

Riparian buffer zones vary from 10 to 30 metres in width. Because of this limited width it will not be possible to conduct a full angle count sweep, and therefore alternative basal area measurement methods must be used.

The alternatives are as follows.

- In wide buffer zones (25 and 30 metres) it may be possible to conduct half sweeps (180°) and multiply the result by two to obtain the basal area. To conduct the basal area sweep in these cases, stand on the boundary of the buffer zone and the adjacent riparian exclusion zone.
- In all other cases it will be necessary to conduct a fixed area plot measurement to obtain an accurate result.

Alternative method in river red gum forests

The minimum stand basal area across all river red gum forests is 12 m^2/ha, and therefore an additional method to assist retention of the stand basal area, based on tree spacing, can be used. The maximum tree spacing is given by d/4 x 100 (or ¼ diameter x 100), where d is the over bark tree diameter in centimetres at breast height.

To determine the distance to the next tree of the same diameter that must be retained:

- Measure the over bark diameter of a retained tree at breast height in centimetres. This is best done using a diameter tape.
- Divide the diameter by 4 and then multiple by 100 to express the measurement in metres.

For example, if the diameter of a tree is 60 cm, then d/4 = 15cm. To achieve the minimum basal area of 12 m^2 /ha, another tree of the same diameter must be retained within 15 m from the measured tree (15 cm x 100 = 15 m).

To determine the distance between trees of different diameter, an average of the distance required for each tree diameter can be used. The following table shows the required distance between trees of different diameters.

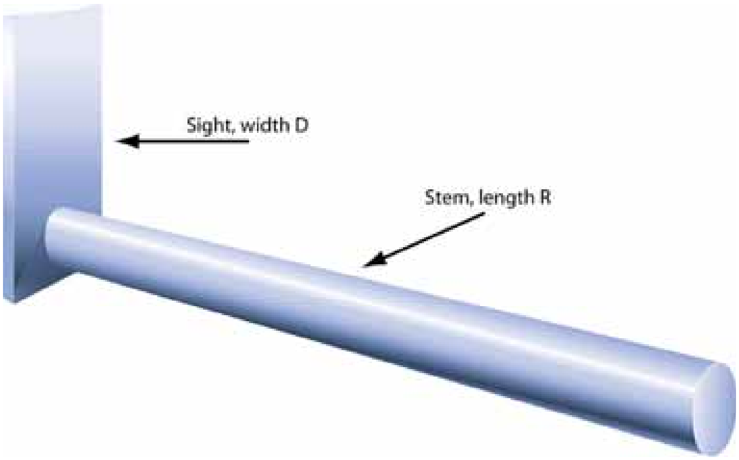
Tree spacing (centre to centre) to average 12 m^2 /ha basal area (to nearest ¼ metre)

Distance between trees (m)										
Tree diameter (cm)	Tree diameter (cm)									
	100	90	80	70	60	50	40	30	20	10
100	25.00									
90	23.75	22.50								
80	22.50	21.25	20.00							
70	21.25	20.00	18.75	17.50						
60	20.00	18.75	17.50	16.25	15.00					
50	18.75	17.50	16.25	15.00	13.75	12.50				
40	17.50	16.25	15.00	13.75	12.50	11.25	10.00			
30	16.25	15.00	13.75	12.50	11.25	10.00	8.75	7.50		
20	15.00	13.75	12.50	11.25	10.00	8.75	7.50	6.25	5.00	
10	13.75	12.50	11.25	10.00	8.75	7.50	6.25	5.00	3.75	2.50

Building a rod relascope

The rod relascope can be simply and cheaply constructed from a straight rod with a flat sight attached to the end of the rod at a right angle. The length of the rod and the width of the sight must be to exact specifications to achieve an accurate BAF.

The following table gives measurements for the length of the stem (R) and the width of the sight (D) for three values of BAF.



BAF	R (mm)	D (mm)
1	500	10
2	460	13
4	400	16

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