Native Forest Silviculture Manual

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Introduction

The purpose of the Manual is to provide the basis for a common understanding of silviculture across the range of native forests in New South Wales. It documents the basis for silvicultural practices, and contains the silvicultural specifications and guidelines required by Regional Forest Agreements made between New South Wales and the Commonwealth under the National Forest Policy Statement.

The Manual summarises silvicultural principles, policies and practices in the context of New South Wales' ecological, social and economic environment.

1. Silviculture policy for native forests

Policy

Silviculture in State forests will sustain or enhance productivity, vitality and diversity of forest ecosystems.

Context

Silviculture will be practised in regional landscapes having comprehensive reserve systems, Forest Management Zones and Ecologically Sustainable Forest Management practices. Silviculture can enhance biodiversity and timber productivity, thereby complementing the mainly passive management in formal reserves.

Objective

Silvicultural practices will:

- Provide for the needs of current and future generations
- Maintain or enhance biodiversity
- Maintain the full range of ecosystems across the regional landscape
- Maintain or enhance the forests' wood production capability.

Strategy

The silvicultural policy will be implemented by:

- Carrying out site-specific assessments of ecosystems scheduled for silvicultural management
- According to forest type and stand condition, specifying appropriate silviculture to conserve or enhance biodiversity and produce timber sustainably
- Specifying intended stand structure, growing stock, regeneration and biodiversity outcomes in harvesting and silviculture plans
- Protecting and enhancing forest health and vitality actively managing threats such as

fire, pests and weeds

- Monitoring and reporting silvicultural and ecological outcomes, continually improving silvicultural practices and undertaking research and environmental restoration
- Training State Forests' staff and contractors in silviculture
- Employing a Silviculturist to guide the development of silviculture in native forests.

2. Evolution, ecology and silviculture

3.1 Opportunism and Persistence

The Australian Flora has evolved under conditions of generally low fertility and fluctuating but increasing aridity. Eucalypts have been in Australia for about 30 million years. With increasing aridity and fire frequency over the last 100,000 years, eucalypts have become the dominant tree species in many Australian environments.

Evolution in relatively arid and fire prone environments has favoured the development in eucalypts of features allowing them to survive or respond rapidly to disturbance, especially fire. Survival mechanisms include lignotubers, epicormic buds and thick bark that insulates living tissues from intense heat. Rapid response to disturbance is facilitated by large stores of seeds protected in woody capsules high above the ground. Huge numbers of seed can be immediately released onto bare ground after an intense fire. The seeds germinate as soon as suitable temperatures and moisture occur. Seedlings can establish and grow rapidly in full sunlight.

> *"Stand dynamics is about the consequences of competition between the components of the forest, and their relationships to each other through time...The ability to observe, describe and interpret the structure, tree condition and 'dynamic status' of a forest is basic to silvicultural practice."*
>
> *(Florence 1996).*

Eucalypts either endure irregular but relatively frequent disturbance by fire or take advantage of fire that eliminates competition and creates a seed-bed for regeneration. The features most strongly expressed by a particular eucalypt species reflect its habitat. For example:

- Species like forest red gum and ironbark that grow in habitats with frequent low intensity fires (woodlands and grassy open forests) persist by using mechanisms such as lignotubers or epicormic buds and thick bark to survive.
- Species such as flooded gum that occur in habitat subject to infrequent catastrophic fire usually die from the fire but rely on prolific seedfall, rapid germination and fast growth to

regenerate new stands.
- Silvertop ash grows in a dry environment with relatively frequent fire, however weather conditions that promote catastrophic fire are common. It grows in the most vulnerable positions on ridges and upper slopes. Silvertop ash recovers from moderate fires by epicormic growth and regenerates prolifically from seed after intense fires.

White cypress evolved in an environment of regular drought and frequent low intensity fire. Cypress trees usually survive these hazards whereas small seedlings are mostly killed. White cypress produces prolific seed ensuring that some seedlings establish despite the odds against early survival. This regeneration strategy maintained a scattering of white cypress trees in open woodlands on the western slopes and plains. However when frequent low intensity fire was removed as a consequence of European settlement, extensive areas of ‘pine scrub’ developed. Silviculture has converted many of these pine scrubs into productive cypress forests that have economic and environmental value.

Rainforest trees are mostly attuned to moist environments where disturbance by fire is very infrequent. Many species have features such as fleshy fruits that ensure seeds are dispersed by fruit eating wildlife or winged seeds that are dispersed by wind. In addition most rainforest species have the ability to germinate, establish and persist under conditions of heavy shade and competition. Thus rainforest trees can take advantage of scattered and limited opportunities, such as are created by the death or fall of old trees, to grow into the rainforest canopy. Rainforest species have the ability to invade some eucalypt forests if fire is excluded for long periods. This invasion of rainforest can impair the health of established eucalypts and prevent their regeneration.

Plants compete with each other for resources such as light, space and water. Species differ in their strategies for competition and survival. Light is the energy source for plant growth. Fast growth requires much light energy. Shade tolerance refers to the ability of some tree species to become established and grow slowly in the shade of other trees. Shade can affect both growth rates and survival. Shade tolerant species will persist or continue to grow in shade whereas shade intolerant trees will stop growing and eventually die when shade reduces the energy available to them below a critical level. Intolerant species will regenerate and develop only in well-lit canopy openings. They are opportunists that rapidly respond to environmental disturbance.

2.1. Intolerance and Crown Shyness

Eucalypts are intolerant of shade and competition. They are also crown shy. The growing tips of their shoots and branches are sensitive to abrasion by other leaves and branches. Vigorously growing shoots produce growth inhibitors that control the buds further back down the shoot or branch. Damage to growing tips removes this control, allowing new shoots to develop further back from the tip. Thus abrasion of shoots causes them to grow away from other shoots and crowns grow away from other crowns.

Crown shyness in eucalypts is related to intolerance. Intolerant species grow rapidly and their growing tips exert strong control (apical dominance) over buds further back along shoots and branches. The growing tips are very soft and easily damaged by abrasion. When this happens, buds behind the growing tip are no longer inhibited and they rapidly develop. Less intolerant eucalypts grow relatively more slowly. Their growing tips exert less control over other buds but are also less easily damaged than rapidly expanding tips.

Crown shyness of eucalypts causes a rapid segregration of growing trees into dominance classes:

- The most vigorous trees develop rapidly in height and their crowns expand symmetrically above the level of other crowns. They become dominant trees
- Trees which are equally as vigorous as their neighbours in the upper level also develop height rapidly but crown shyness causes their crowns to expand asymmetrically away from the closest competing crowns. These are codominant trees
- Subdominant trees develop more slowly than trees in the upper level and their crowns are restricted by other more dominant crowns.
- Suppressed trees are the extreme example of subdominant trees. Crown shyness causes their height growth and crown expansion to stop or recede.

Self thinning of dense even aged eucalypt stands occurs as subdominant and suppressed trees are weakened by shade and root competition from more dominant trees. Crown shyness in both even aged and mixed stands shapes a crown architecture in each tree that reflects its past performance in the dynamic stand development process. Thus the past vigour and future growth potential of each tree can be assessed.

Intolerant tree species have strong apical dominance. Mature trees are relatively flat topped and thin crowned since individual branch units in tree crowns to behave similarly to individual trees in a forest. Tolerant species tend to have denser, more compact and often conical crowns. This is illustrated in Figure 2 which ranks some native tree species of New South Wales according to their relative tolerance.

3.2 The silviculture of eucalypts

Jacobs (1955) elucidated the silvicultural characteristics of eucalypts in great detail. Relative to other tree species around the world, eucalypts range from very intolerant to intolerant.

The very intolerant species generally:

- are prolific seed producers
- do not produce lignotubers
- do not coppice from stumps of mature trees
- have relatively thin bark

The less intolerant species usually:

- produce persistent lignotubers
- coppice strongly
- have relatively thick bark.

Some intolerant species such as Blackbutt are not lignotuberous but produce persistent seedling advance growth on drier sites. On moist sites, heavy shade will eventually eliminate even lignotuberous advance growth.

Response to Disturbance

Past responses of trees and stands to disturbance indicate their history, their survival or regeneration mechanisms and their age structure. Depending on their relative intolerance and associated physiological characteristics, eucalypt species will respond differently to injury. Very intolerant species are more easily killed by fire or defoliation by insects than less intolerant species since they have thinner bark and smaller reserves of energy as a consequence of rapid height growth and crown expansion. In forests of very intolerant species such as silvertop ash and alpine ash, severe fires will kill most of the trees. This is evident in the extensive patches of even aged regrowth which occur even in unlogged forests. Fire may sometimes kill intolerant trees back to the lower trunk where thicker bark can insulate live tissues more effectively from intense heat than can the thinner bark higher in the tree. Vigorous epicormic shoots may develop on the lower bole and take on the appearance of young trees growing on an old stem.

Forests of less intolerant species, such as some gums and stringybarks, often contain redominantly mature or overmature trees that have recovered from severe fires in the past by epicormic growth within the crown. Small groups of regeneration may occur where large old trees have burnt down or fallen. Regeneration mechanisms, relative age classes and stand histories are less easily discernible in forests dominated by less intolerant species. Here silvicultural assessments are more difficult than in forests of more intolerant species.
Canopy opening creates a an opportunity for regeneration. Where seedling or lignotuberous advance growth is already present, it will respond to the canopy opening. Otherwise a source of seed and a receptive seedbed is necessary for a eucalypt canopy to regenerate.

Seed Production and Germination

Eucalypt seeds are very small with a thin seed coat. They do not have large food reserves nor long term dormancy mechanisms. Germination occurs rapidly when temperature and moisture are suitable. If seedlings are to become established, the germinating seeds must be in physical contact with mineral soil so that the developing roots can access soil water and nutrients before the seeds' limited resources are exhausted. Except in dry open forests, seedlings cannot establish unless mechanical disturbance or fire bares the soil. In river red gum forests, seedlings can only establish if flooding provides a period when moisture is sustained through the soil profile. Since there are no dormancy mechanisms, eucalypts do not build up a seed store in the soil as do other species such as acacias. Seed production varies considerably between species and from year to year. Seeds may not be produced each year, however the variability may be damped by carry over of seed in tree canopies from one year to another. This canopy seed store is the only natural reserve of eucalypt seed. Alpine ash has a short term dormancy mechanism. Natural germination of this species mostly occurs in early spring following after-ripening (removal of dormancy) of seed during winter.

Seedling Development

In small canopy openings the development of eucalypt seedlings may be hindered by suboptimal lighting. The effect is most pronounced in tall wet layered forests dominated by very intolerant species. In these forests, eucalypt regeneration depends on large, well lit canopy openings[1].

Where the diameter of a canopy opening is equal to the height of the surrounding trees, diffuse light is reduced by 80% compared with open conditions[2]. In a gap with a diameter of two tree heights relative lighting is still reduced by 50%. In a glasshouse experiment, when light levels were reduced by more than about 70% of open conditions, growth of E.fastigata (a species often growing in wet layered forests) was reduced so that the eucalypt seedlings grew more slowly than mesic understorey plants[3]. In such circumstances replacement of a eucalypt forest canopy would not occur.

In more open forests, seedlings can develop with limited canopy opening. Where adequate light is available for seedling development, retention of some canopy cover may assist seedling establishment by providing seed, shelter from frost or dessication and inhibition of understorey or grass layers. Seedlings of less intolerant species may be able to develop satisfactorily through the sapling stage before overstorey competition seriously affects their form or growth rates.

Following disturbance, canopy regeneration and extension by residual trees and undergrowth may interfere with the development of seedlings. In small canopy openings, seedlings of very intolerant species will succumb to the increasing competition and shading, whilst less intolerant species may persist as small seedling advance growth for longer periods. The least intolerant species will produce lignotubers which may persist for long periods and gradually build up strong root systems. This enhances their ability to respond to subsequent canopy removal. In river red gum forests, seedlings must access deep groundwater to survive root competition from mature trees. Thus although the species is less intolerant to shade than many eucalypts, red gum seedling establishment is unlikely within 20m of a mature tree on a good site and even further on poorer sites.

Silvicultural Requirements

The creation of canopy openings is a basic requirement of eucalypt silviculture for sustainable timber production. High value timber is produced by harvesting mature dominant or codominant trees. The minimum size of an effective opening to grow mature dominant or codominant trees is determined by the relative intolerance of the particular species, the height of the forest and the nature of the subcanopy or understorey.

Due to light requirements, crown shyness and self thinning, stands of highly intolerant species regenerating directly from seed require an opening which can support 10 vigorous saplings, or 100 vigorous seedlings to produce a single mature tree. Seed may come from felled heads or from retained trees. Occasionally there may be insufficient seed in the tree crowns to regenerate a site following disturbance or there may be a mesic understorey or a dense ground cover. Seedbed preparation followed by artificial seeding or planting is necessary in such circumstances to ensure eucalypt regeneration. Otherwise the understorey will gain control of the site.

In open eucalypt forests containing less intolerant species, regeneration systems based on advance growth or coppice may rely on relatively small canopy openings. The irregular nature of some drier forests may lend itself to selection systems but single tree selection systems, in the classical sense, are not applicable to these forests[2].

1 Ashton and Chinner (1999), Kirkpatrick (1997)

2 Jacobs (1955)

3 Barrett and Ash (1992)

3.4 White Cypress

The silvicultural characteristics of white cypress were thoroughly discussed by Lacey (1973). White cypress evolved in a very arid environment (for trees). Drought and fire were frequent but the sparse vegetation did not sustain intense fires. Cypress evolved features enabling recruitment of new trees under consistently difficult conditions. These features include regular production of large quantities of seed, seasonal germination, slow growth and persistence of seedlings. Unlike eucalypts, cypress is not well adapted to survive or regenerate prolifically after intense fire, however its physiology makes it extremely tolerant of competition and shade. Cypress is able to survive in dense ‘wheatfield’ stands for very long periods whilst making negligible growth. Baur[1] quoted an example of a 40 year old stand containing stockings up to 100,000 ha^{-1} of trees only about 2 metres tall with diameters of about 3cm. In the same forest, younger stands which had been thinned contained trees 10m tall and 15cm in diameter.

Seedling Establishment

Seed availability does not usually limit white cypress regeneration. Scattered trees or open stands of white cypress produce substantial seed crops on a regular basis. The small winged seeds are mostly dispersed up to about 60m in the direction of the prevailing winds and occasionally up to several hundred metres. Seed is shed in summer, when the cones dry out, but does not germinate until suitable temperatures and moisture occur in autumn or winter. Germination is reliable. The seeds do not have a dormancy mechanism so there is no storage of viable seed in the soil.

Seedbed conditions are rarely limiting to germination. Maintenance of favourable conditions during a long seedling establishment phase is the main requirement for successful regeneration. Good soil moisture through at least one summer, protection from insolation, grazing and fire are pre-requisites for successful establishment. Grass, litter, logging debris and even standing trees or shrubs can provide protection from insolation.

Fire and grazing regimes have shaped the history of white cypress communities in New South Wales. Dense regeneration of cypress occurred on the western slopes and plains in the late 19th century after Aboriginal burning ceased, the continuity of ground fuels was disrupted by heavy grazing and natural fires were suppressed by European settlers. In the first half of the 20th century grazing by rabbits prevented widespread regeneration until myxomatosis was introduced to control the rabbits. Since then, prolific regeneration has occurred extensively in the white cypress belt.

Stand Development

Wheatfield regeneration of white cypress is not productive of commercial timber and can affect the growth and survival of other trees and plants. Dense white cypress regrowth is relatively drought resistant whilst older cypress and eucalypt trees growing amongst dense regrowth are liable to be killed by drought, probably as a result of the dense regeneration intercepting any water before it can infiltrate down to the root zone of the mature trees. In the absence of Aboriginal burning and natural fires which formerly maintained open stands, spacing and thinning are essential to ecologically sustainable management of white cypress forests. Spacing wheatfield regeneration rather than encouraging regeneration has been the main issue of white cypress silviculture since the 1950's.

Seed production is suppressed in dense stands[2] and regeneration will not become established under a tree canopy with a basal area much higher than about $14m^2ha^{-1}$ so regeneration density can possibly be controlled by manipulating the density of the parent trees. In commercially mature stands, basal areas of about 7 to 9m_ ha^{-1} will normally allow regeneration without the problem of wheatfield regeneration.
Drought can cause dead topping, multiple leaders and sap cracks which reduce the value of trees for logs, or render them useless. Fire scars can affect timber values. Insect and fungal attack may exacerbate other injuries. Jewel beetle or yellow rot may be prevalent in some areas. Widely spaced or isolated trees are liable to develop windshakes.

1 Forestry Commission of NSW (1988)

2 Lacey (1973)

Silvicultural Requirements

Thinning of fully stocked mature cypress stands is necessary to encourage seed production and regeneration. Where there is heavy grazing, exclusion or reduction of stock may be necessary to allow effective regeneration. When effective regeneration has become established, the remaining commercially mature stand can be utilised. When regeneration has developed to several metres in height, dense stands require spacing so that trees may grow to commercial size in a reasonable time.

3. Silvicultural systems and practices

The complexity of Australian forests compared to European forests reflects differences in their evolution. During the last ice age, forests retreated from higher latitudes as the ice advanced. Trees species suited to temperate conditions contracted into refugia with more hospitable climates. Europe lies mostly at latitudes above 45º and its flora is isolated from lower latitudes by east – west barriers including the high mountains of the Pyrenees and the Alps as well as by the Mediterranean Sea. Australia occupies a wide latitudinal band without east - west barriers. Many refugia allowed the temperate and tropical Australian flora to survive and subsequently recolonise areas as climates ameliorated. Thus Australia retained a diverse flora adapted to a wide range of physical conditions. Europe, on the other hand, permanently lost large elements of its preglacial forests, retaining a limited range of trees adapted to harsher conditions

Classical silvicultural systems were developed in relatively uniform European forests and are strongly linked to yield regulation. New South Wales' native forests are naturally complex and have an extremely variable history of utilisation. There are often large differences in growth stages, growth rates, productive potential and products over short distances in the forests. The European yield regulation concepts of rota-tion and cutting cycle are not appropriate to such a complex mosaic of floristics and structures. Also classical silvicultural systems focus on timber production, whereas modified systems are applied in New South Wales to achieve biodiversity objectives.

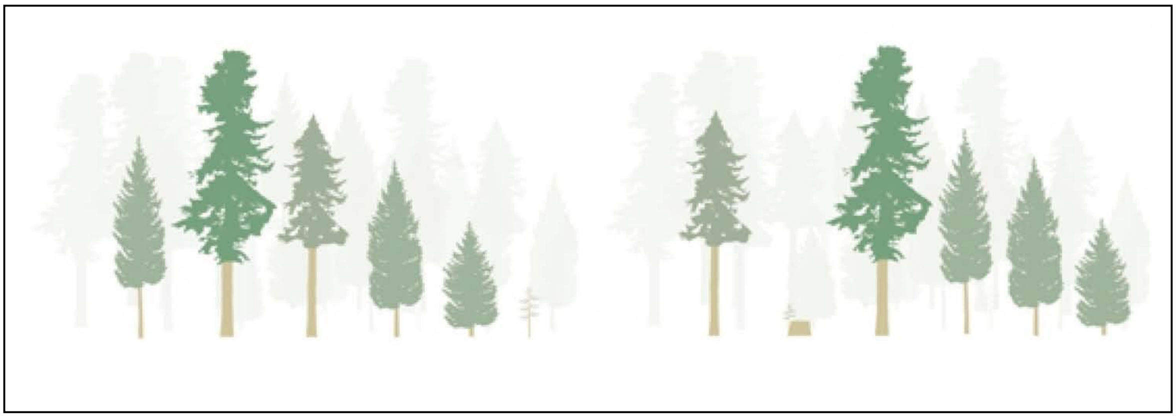
Some silvicultural systems are described below. Silviculture in New South Wales aims to enhance biodiversity and conserve soil, water and cultural heritage. For example, silviculture will be used to enhance habitat quality for fauna such as koalas or regent honeyeaters in some areas. Trees will be retained to provide habitat or structural diversity in all silvicultural systems. Thus clearfelling will not be used in New South Wales' native forests. Financial considerations will also influence silvicultural practices. The opportunity to remove trees will largely depend on markets for their wood. Non-commercial tree removal will be rare.

3.1. Regeneration Systems

Single Tree Selection (Classical)

- A system used with very shade tolerant trees (mainly conifers) where single stems can establish in small openings and all ages and sizes can grow side by side (Jacobs 1955)
- because eucalypts are intolerant of shade and competition, this system is not appropriate to eucalypt forests (Florence 1996)
- an explicit rotation is recognised and each year trees are felled as scattered individuals over all or part of the sustained yield unit
- a rotation is the number of years required for a tree to attain a specified condition of either economic or ecological maturity
- a cutting cycle is the time taken for each cycle of harvesting to cover the sustained yield unit; a number of cutting cycles occur in each rotation

- for example, in each 15 year cutting cycle over a 90 year rotation, one sixth of the stand would be removed, leaving scattered gaps created by the removal of single trees
- objectives of this system are to maintain an even wood flow from a distinctly uneven-aged forest or to maintain a forest of very tolerant species which could be overtaken by intolerant species under a more intensive silvicultural regime
- the system relies upon a balanced distribution of size classes, near full site occupancy at all times, good growth in all size classes, regeneration from each harvest, presence of all size classes in a small area.



New South Wales Selective Harvesting

- since eucalypt forests do not fulfil the criteria for successful application of classical single tree selection, a modified selection system is used where an uneven removal, heavier in some areas and lighter in others is applied across a harvesting tract.
- a primary objective is to minimise harvesting disturbance to retained trees
- usually applied in mixed aged or mixed species stands to conserve useful growing stock
- may be applied where there is useful growing stock scattered amongst a mature stand or where mature trees are scattered amongst a well stocked regrowth stand
- only applicable where the stand structure and floristics will permit successful regeneration establishment in canopy openings created by removing single trees
- sometimes applied in mature stands of low timber value where less intolerant species can regenerate successfully after limited canopy opening.

Australian Group Selection (AGS)

- a system applied to mixed aged eucalypt forests in Australia
- within a harvesting unit, groups of commercially mature trees are selected for harvest and a canopy openings are created to allow effective regeneration
- the objective of the system is to harvest groups of commercially mature trees whilst retaining groups of effective growing stock from previous selective logging operations (Jacobs 1955)
- the system maintains an irregular forest with many small patches of different age cohorts, which when applied to more uniform stands will convert them to mixed aged forests.
- developed as a compromise between: the need to conserve immature growing stock; the regeneration requirements of intolerant species; and the need to consider values other than efficient timber production (Florence 1996).

Seed Tree / Shelterwood Harvesting

- a system in which a new stand is regenerated and established by retaining high quality seed trees across the harvested tract.
- Harvesting promotes regeneration by opening the canopy and creating suitable seedbed conditions; the retained trees provide an aerial seed source and, in some cases, protection for the new regeneration
- A second felling can be undertaken once regeneration is established, removing the seed trees and promoting the growth and development of the young regrowth by removing the competitive effect of the retained trees
- this system maintains an even aged forest for most of the rotation
- a modified shelterwood system can be applied where there is no second felling but the shelterwood trees are retained to provide fauna habitat and structural diversity in the new uneven aged forest.

Clearfelling

- a system in which the forest is divided into harvesting units on which all merchantable trees are felled
- Suitable to be applied in high quality, even aged forests or in poor forests with access to markets for low quality wood (eg. pulpwood or fuelwood)
- this system is not practised in New South Wales' native forests where minimum tree retention rates and landscape offsets are always maintained throughout the harvest area
- the system creates even-aged stands with each harvesting unit being an age class
- particularly suited to tall layered eucalypt forests which naturally regenerate after catastrophic scale disturbance.

3.2. Practices Employed With Regeneration Systems

Alternate Coupe Logging

- a practice which extends a regeneration harvest across a management area in two or more cycles so as to disperse its impacts
- management units (compartments) in the forest are sub-divided into units called coupes, which are harvested in an alternating pattern, in two or more cutting cycles, over the sustained yield unit
- within each coupe, trees and groups of trees are retained to provide seed, fauna habitat and structural diversity (a modified shelterwood system applies)
- the system creates a series of new age classes in an uneven aged forest containing clumps and residual trees of varying ages

Seedbed Preparation

- each system described above may rely upon either coppice, advance growth, natural seeding, sowing or planting to regenerate the canopy openings created by tree removal
- a suitable seedbed is essential for seedling establishment
- mechanical disturbance or fire can create a suitable seedbed where 'leaf litter', vegetation or logging debris would otherwise impede seedling establishment
- suitable seedbeds may occur as a consequence of timber extraction (mechanical disturbance) or hazard reduction burning
- where consequential seedbed preparation is insufficient for effective regeneration of dominant canopy species, deliberate work, such as rough stacking of debris in AGS canopy openings, is essential.

3.3. Intermediate Systems

Thinning

- a system applied to even aged regrowth stands to harvest some trees commercially and redistribute the site resources to the remaining trees.

Thinning from Below

- a system in which trees with the poorest growth or commercial potential (usually subdominant trees) are removed to promote the growth of retained trees so as to realise some future high value product and/or to produce trees of a specified size in a shorter period of time
- allows trees which would otherwise soon die to be commercially utilised.

Thinning from Beside

- a system in which trees are removed to yield a specific high value product (for example: poles, girders, veneer logs, sawlogs)
- some dominant and codominant trees are removed and some are retained to grow on
- when applying this system due consideration must be given to the risk of adversely compromising the quality and vigour of the retained stand
- suited to stands dominated by less intolerant eucalypt species

Thinning from Above

- trees are removed to yield high value products
- dominant and codominant trees are removed leaving subdominant trees
- if used with intolerant species such as eucalypts, the productivity and vitality of the residual stand may be compromised
- can be used to favour less intolerant eucalypts in mixed species forests to enhance non timber values

Vertical Cut System

- a combination of thinning from above, beside and below
- applied in white cypress stands where tolerance allows subdominant trees to respond to thinning
- thinning from above and beside improves the economics of harvesting, whilst retention of good quality small trees allows them to grow into size classes having much greater value.

Spacing (non-commercial thinning)

- a system in which some trees are removed at a relatively young age from regrowth stands to promote the growth of those retained
- the trees removed are not large enough to be economically utilised.

Culling (Timber Stand Improvement)

- removal of unmerchantable mature and advance growth trees competing with established regeneration
- may use felling, ringbarking or poisoning
- in NSW marketing of residual wood will be used in preference to culling.

4. Silviculture as a facet of ecosystem management

New South Wales native forests are managed to conserve biodiversity, cultural heritage, soil and water resources, to provide enjoyment and to produce timber. A comprehensive reserve system and ecologically sustainable forest management (ESFM) ensure conservation. The reserve system includes large formal reserves such as National Parks and Wilderness Areas; smaller formal reserves such as Flora Reserves; and informal reserves or special prescription areas such as Wildlife Corridors. Within this matrix, the reserve system also includes multiple use forests where ecosystems are both conserved and utilised. In multiple use forests, conservation values such as hollow trees and rare plants or animals are protected by management prescriptions.

Management of the formal reserves will mostly minimize human intervention. In a naturally fire prone environment, passive management of formal reserves can only be effective where it is supported by more active management of multiple use reserves. An ecological understanding of natural disturbance processes allows deliberate fire management and utilization of renewable resources in the multiple use forests. Thus Ecologically Sustainable Forest Management (ESFM) includes both passive and active management for conservation and sustainable production. Active management can enhance biodiversity as well as timber values. Applied in a mosaic pattern over time and space, it helps to maintain a rich diversity of life forms and stages across the landscape (Figure 3).

ESFM in State forests is guided by a zoning system. Forest Management Zones (FMZs) dictate the style of management (whether passive or active) and values which are to be particularly protected or enhanced. Silvicultural manipulation of forest structure is a key element of ESFM (Figure 4). Silviculture will conserve old trees and associated environmental values in FMZ 1 and FMZ 2 reserves whilst enhancing structural diversity in Special Prescription Zones (FMZ 3) and General Management Zones (FMZ 4). In FMZ 3, silviculture may aim to enhance conservation. For example: in visually prominent areas, silviculture will maintain or enhance the forest's aesthetic quality; in other areas silviculture will promote tree species and forest structures favoured by wildlife such as koalas or regent honeyeaters. In FMZ 4 silviculture will enhance timber productivity. At the same time, biodiversity will be enhanced through maintenance of structural diversity in the landscape, including habitat for wildlife favoured by disturbance.

Silviculture in native forests will be based on natural disturbance processes and will use natural regeneration of trees, shrubs and groundcovers. When eucalypt seed supply is limiting, hazard reduction burning may be forgone to conserve the seed in felled heads. On the other hand, where understoreys or logging residues impair the seedbed, hazard reduction burning will maximise the contribution of seed from retained trees. This is a benefit in tall layered forests which, unless actively managed, rely upon catastrophic fire disturbance for regeneration1. Silviculture presents an alternative manageable option for maintaining biodiversity in these forests. Where adequate natural regeneration of the tree canopy is not confidently expected, sowing or planting of tree species native to the site may be undertaken1.

Figure 3: AN ESFM LANDSCAPE

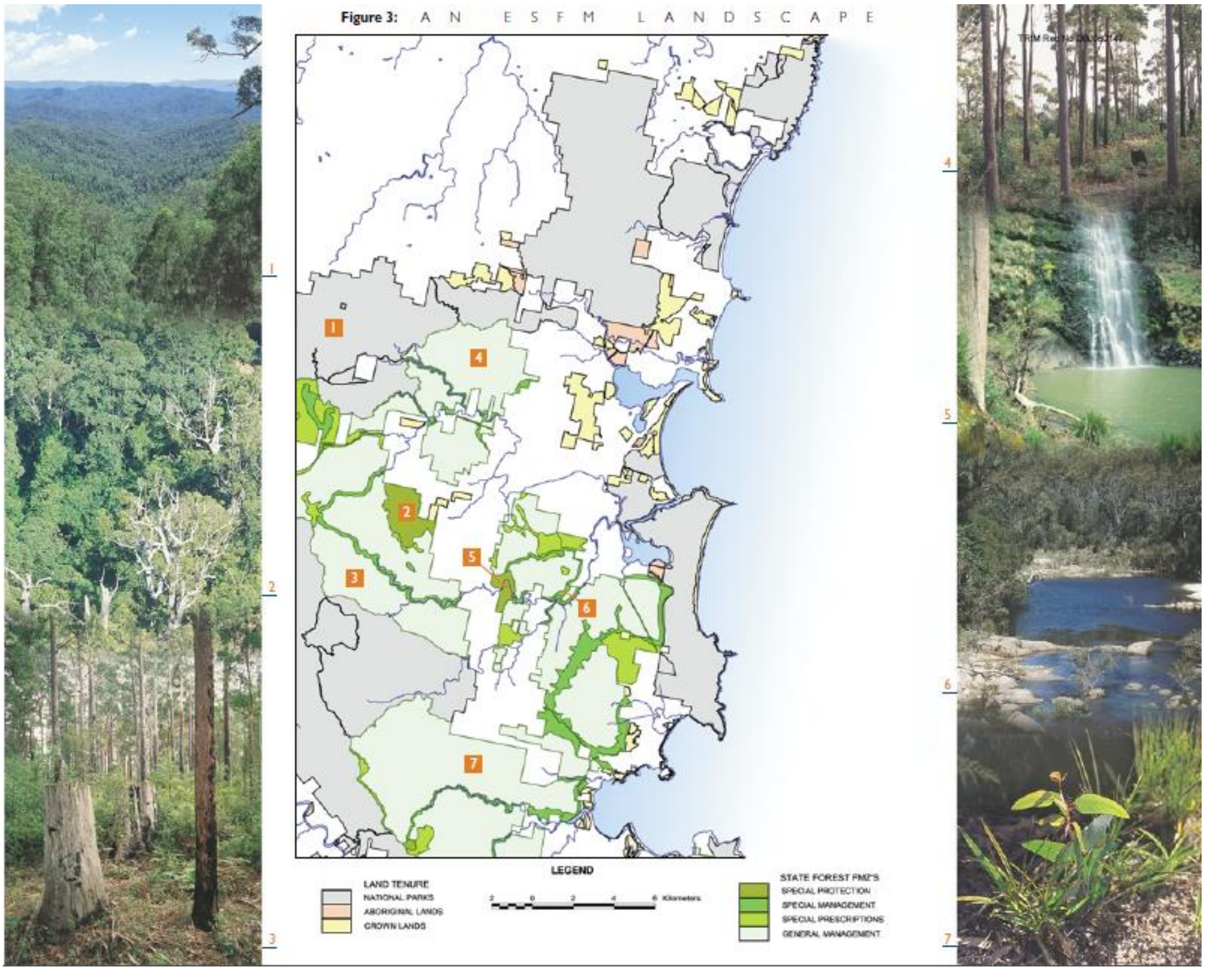
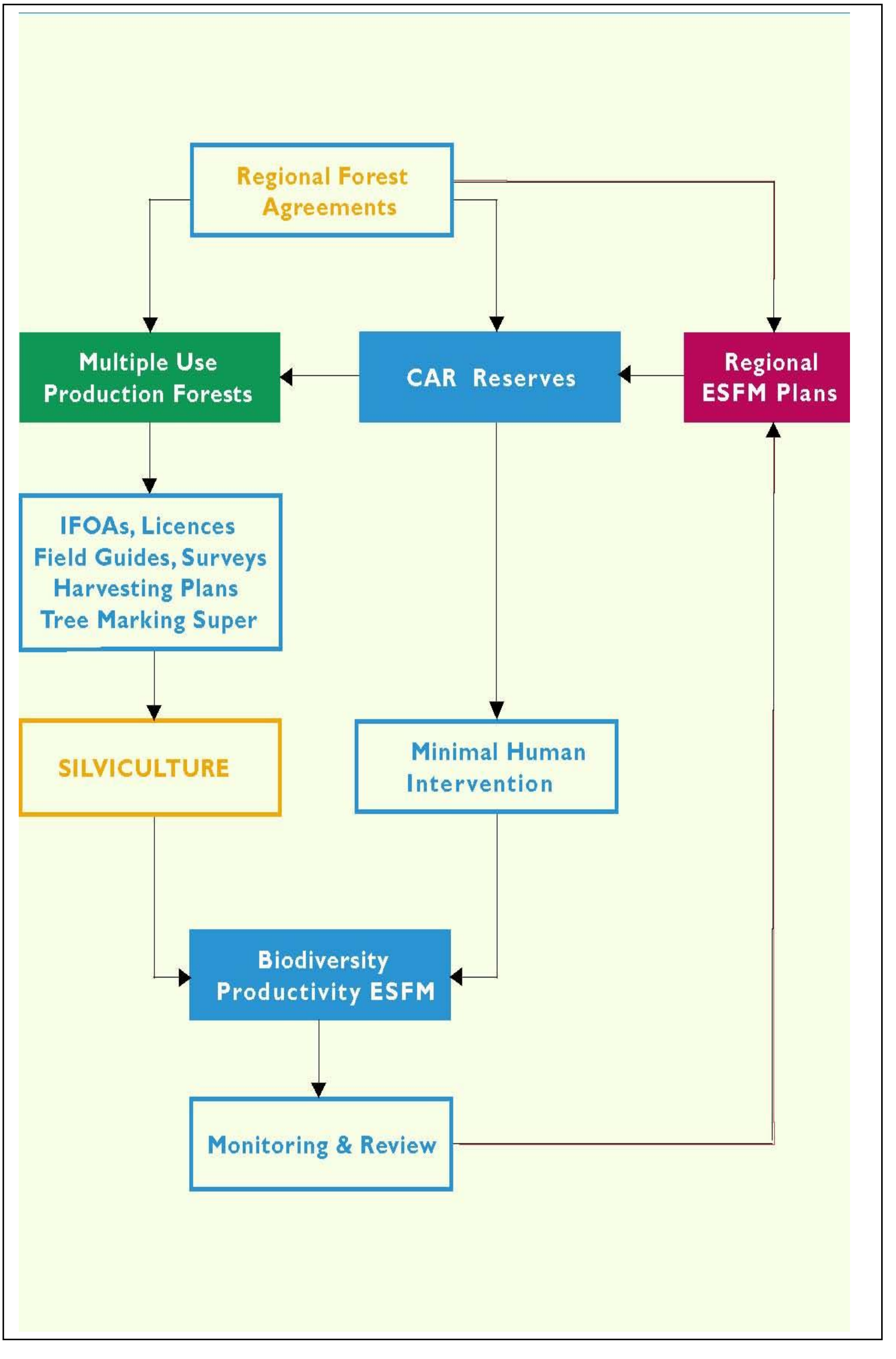


Figure 4:

Silviculture and ESFM



Even though catastrophic disturbance is the natural regeneration mechanism in some eucalypt forests, silviculture will incorporate soil and water conservation practices to maintain ecosystem health and biodiversity. Soil disturbance will be minimised according to regeneration requirements, since forest regeneration is a periodic event of critical importance to ecological sustain-ability. In eucalypt forests relying upon seedling regeneration, harvesting operations will achieve sufficient soil disturbance to re-establish dominant canopy species whilst minimising export of soil from the regeneration area. Since snig tracks are the main source of sediment, cross banks will be used to divert runoff into general harvest areas which trap most sediments[1]. Filter strips and buffer strips will be used to prevent finer sediments from entering watercourses[3].

Some forest types have naturally open seedbeds or abundant advance growth of seedlings and lignotubers. Soil disturbance will be minimised in these areas by limiting snig track construction and, where possible, using 'walkover' methods to extract timber. Ground disturbance will also be minimised when thinning forests. Harvesting and regeneration operations will not be conducted in the critical areas of the landscape where the risk of accelerated soil erosion and water pollution is unacceptably high, such as steep slopes, streams, gullies and drainage lines.

The understorey flora is more variable than the tree canopy. Most understorey plants are smaller, more shade tolerant, and many have shorter life cycles, than the canopy trees. Harvesting and prescribed burning disturbance to the understorey and ground surface also varies at a fine scale. Thus disturbed and undisturbed areas within the actively managed forests create opportunities for the full range of species, with different regeneration mechanisms and life cycles. Detailed flora surveys throughout the coastal and tablelands forests have shown that silvicultural practices using natural regeneration maintain high floristic diversity in multiple use forests.

1 Attiwell (1994)

2 Croke et al (1997)

3 Hairsine (1998)

5. Site specific silviculture

Native forest silviculture in New South Wales is mostly conducted in forests with a complex mosaic of species associations, stand structures, wood products and growth potential. Also wood production is only one amongst a range of management objectives. Thus no single silvicultural system will normally be applicable to a whole compartment. A mosaic of species and structures exists at a sub-compartment scale, requiring a range of silvicultural systems. Yields are estimated and allocated at a much broader scale, hence silvicultural systems are not tied to yield regulation as are the classic European systems. Wood supply objectives over a defined period of time help to guide site specific silviculture by determining the economic maturity of trees and groups of trees. Following harvesting and silvicultural operations, assessments of the residual stands and of regeneration inform yield scheduling systems so that strategic estimates are progressively refined to operational estimates.

Site specific silviculture is assessment of stand conditions in relation to forest management objectives and manipulation of stands to enhance their contribution to those objectives. In the context of comprehensive reserve systems and planning instruments that direct forest management for a range of objectives, site specific silviculture in FMZ 4 is usually concerned with the manipulation of a stand to enhance forest health and wood production. This manipulation occurs within parameters designed to protect other values. In FMZs 1, 2 and 3, however, silviculture will be used primarily to maintain or enhance values such as wildlife habitat or visual amenity.

5.1. Assessing Stand History

To properly evaluate the potential of various elements of a stand to grow in value it is necessary to understand their history. The characteristic responses of trees to injury or disturbance can produce long lasting evidence of disturbance and regeneration events. This allows an appreciation of stand history and consequent planning of appropriate silviculture in the future.

A simple example follows:

Within a dense patch of silvertop ash saplings is a scattering of very large trees with dead branches and secondary crowns originating from epicormic shoots. Another cohort of intermediate sized early mature trees displays a kink in each stem and a slightly ‘swollen’ lower stem. An interpretation of this stand’s history is that a catastrophic wildfire triggered a mass seedling regeneration seen today as the sapling cohort. The large damaged trees are the few survivors of the fire. The time since the fire is reflected by the size of the saplings. The deformed early mature trees were saplings at the time of the fire, killed back to the lower stem. Subsequently they produced new crowns and the remains of the original crowns have decayed. Some of these trees may still have a dry spar protruding from the kink in the current stem. An examination of the log quality below the kink would reveal extensive timber degrade, initiated by the fire injury.

Stands dominated by less intolerant, thicker barked trees such as spotted gum are harder to interpret since they are less susceptible to death or damage by fire. By the same token, regeneration events are less frequent and extensive, since survival and recovery of mature trees impedes regeneration. New age classes cannot develop without some canopy opening so there will normally be fallen trees, stumps or root holes and an opening in the old canopy to confirm that clumps of smaller trees (or occasionally single trees) actually represent distinct age classes. If these clues are absent, smaller trees are likely to be of the same age class as older trees.

Site specific silvicultural assessment relies upon reconstruction of stand histories and identification of the relative age classes in the forest. Since eucalypts are intolerant and can only establish in canopy openings, every eucalypt forest consists of one or more even aged stands. The area of an even aged stand may vary from ten square metres to many hectares. The minimum effective stand area for regeneration is the equivalent of at least one mature dominant crown in dry open forests and of several mature crowns in wet forests or river red gum forests. One age class does not occur immediately under another age class. Different age classes occur beside each other.

To reconstruct stand histories it is convenient to identify the ‘age class’ or ‘cohort’ which occupies the largest proportion of an area. Where the predominant age class consists of regrowth or early mature trees, evidence of the regeneration event that established the trees should be examined. In most cases, either clearing, severe fire or intensive timber harvest will have initiated stand replacement, however many western forests have been created on former woodland sites as a result of historical land management practices.

Substantial canopy reduction is required in forest (compared to woodland) to allow regeneration to establish. There are usually no more than three recognisable ‘age classes’ to be considered at any site since intense fires or logging are infrequent but overwhelm any impacts of recent minor disturbances. Sometimes there will be evidence that a secondary regeneration event has replaced some of the predominant ‘age class’ with younger trees. Unless there is such evidence, smaller trees must be recognised as subdominant trees, not to be confused with younger trees.

Regeneration events are usually severe fires or timber harvests. Cyclones, windstorms or landslides may also initiate regeneration. River red gum and white cypress regeneration may be linked to flood years or wet seasons but there are other factors that have created regeneration opportunities in these forests. These factors in river red gum and cypress forests have included removal of Aboriginal burning, suppression of natural fires and periodic decline in grazing pressure as a result of droughts and rabbit control.

Seedlings may establish over a period of several years following a single regeneration event, however all trees arising from the event form a single age class or cohort for silvicultural purposes. Their crown dominance and their growth potential are determined primarily by competition amongst themselves rather than by any residual canopy which will mainly limit the extent of effective regeneration. Cohorts established by extensive regeneration events may gain an ‘identity’. The 1952 fire regeneration at Eden and the 1950s cypress regeneration in western New South Wales are examples.

5.3. Describing Forest Structure

Eucalypt forests often have a complex structure. To develop appropriate silvicultural prescriptions for an area of forest it is necessary to describe the structure, assess the values of the various elements and decide how to manipulate the structure to achieve management objectives. A stand is a relatively homogeneous unit of forest that may range from about a quarter of a hectare (the area occupied by a small group of mature trees) to tens of hectares in size. A stand may contain one or more age classes. For example, a stand may be a clump of mature trees in a two aged forest or it may be an area of several hectares containing a scattering of mature trees amongst regrowth saplings. To plan silviculture, forest structure (the arrangement of the various stands of trees) must be described in terms of relative age classes (not size classes) of canopy trees and the health or vigour of each class. The presence of seedling or lignotuberous advance growth should be assessed and the nature of sub-canopies, understoreys or ground covers should be described so that prescriptions can be developed to ensure regeneration.

5.4. Silvicultural Assessment

Forest Management Zoning indicates the management objectives for a site. Zones I and 2 exclude timber production. In FMZ 3, the main objective is the conservation of identified non-timber values, whilst enhancement of timber productivity and ecosystem health is a primary objective in FMZ 4. To develop a silvicultural plan each relative age class in a stand should be assessed in terms of its contribution to desired management outcomes. In FMZ 4, each age class should be assessed for commercial maturity and productivity (bearing in mind wood supply objectives over the planning period) and a decision made to retain, thin or replace it with a new age class. The effect of harvesting any commercially mature age class, within the appropriate conservation parameters, should be anticipated. An expected new stand structure, consisting of the residual stand together with any potential regeneration component, should be assessed in terms of site occupancy, health and productivity.

Opportunities to improve age classes or create new age classes should be assessed in the light of markets for residual wood, practicalities of additional silvicultural treatments and economic factors. Rehabilitation may be specified where it is practical and economically feasible to regenerate degraded stands. The assessment process should be applied to each type of stand encountered in a harvest planning unit.

In an even aged stand, the silvicultural decision is quite simple. If the stand is commercially mature, a regeneration harvest should commence. Otherwise, a thinning may be required. If the stand has been previously harvested and is no longer commercially productive, rehabilitation may be required to regenerate a productive stand.

SITE SPECIFIC SILVICULTURAL ASSESSMENT

SITE SPECIFIC SILVICULTURAL ASSESSMENT				
Describe Forest	**Assess Values in context of FMZs**	**Predict Harvest Effects Assess Health Productivity**	**Consider Treatment**	**Formulate Silviculture Plan**
FOR EXAMPLE				
Older Age Class	habitat/seed trees commercial trees growers residual trees	retained trees canopy openings growers residual trees	protect remove protect salvage or cull	identify markets prescribe silvicultural systems
Predominent Age Class	habitat/seed trees commercial trees growers residual trees	retained trees canopy openings future crop spacing residual trees	protect remove protect salvage or cull	prescribe tree retention prescribe tree removal
Younger Age Class	recruit trees commercial trees growers residual trees	retained trees crop spacing future crop spacing residual trees	remove space cull	prescribe regeneration methods prescribe rehabilitation
Advance Growth Seedbed or Coppice	present/absent	protected/removed created	protect improve/sow/plant	where applicable

5.5. Regeneration Harvests

A regeneration harvest involves the removal of a mature stand with the intent of creating a new cohort of regeneration. Stand replacement is the essential aim of the operation. Usually the regeneration requirements of the most intolerant canopy species will determine the silvicultural practices but in some cases less intolerant, slower growing species may be retained to enhance other values such as fauna habitat or visual amenity.

Conservation objectives will sometimes constrain the extent of regeneration harvests in mature stands. Careful planning is required to ensure that subsequent harvesting in the remaining mature stands will not damage the new stands created by the current harvesting operation. Regeneration harvests can be dispersed through the landscape using alternate coupe harvesting or AGS harvesting patterns.

Harvesting only high quality sawlogs from forests with poor timber quality creates limited canopy opening and regeneration opportunity and should be avoided. Markets for residual wood such as small logs, salvage logs, pulpwood and fuelwood should be pursued so that logging can promote regeneration of vigorous stands rather than “high-grading” a stand where poor quality stems are retained and high quality stems removed.

5.6. Intermediate Harvests

Logging of stands in the time interval between each regeneration operation is called an "intermediate harvest"or "thinning". Thinning does not aim to establish regeneration except in shelterwood systems.

- Vigorously growing stands that are not commercially mature may be thinned from below to remove trees with less commercial potential and allow trees with the best high value growth potential to use the site resources.
- Thinning from above may be used under some circumstances to favour subdominant trees of more tolerant species and enhance values such as habitat for koalas.

Optimum spacing for trees at any particular growth stage depends on their tolerance. Tolerant species survive and grow at closer spacings than intolerant species. Tree form (straightness, branching habit and taper) of dominant trees is generally better for timber production when trees are spaced closely. Optimum spacing increases with age. Saplings, poles and mature trees grow at successively wider spacings than seedlings.

The readability (interpretation) of growth potential varies with tolerance. More intolerant species are easier to assess than less intolerant species. For example, Horne[1] emphasised the difficulty of assessing the growth potential of spotted gum which is one of the less intolerant eucalypts. Very intolerant species make successful thinning easy since there is a clear separation between dominant trees and subdominant trees making tree vigour easy to assess. However, regardless of species and tolerance, the relative size of trees in even aged stands shows their relative growth rate or vigour over the life of the stand. Unless they are injured, larger trees will grow faster than smaller trees in the same 'age class'.

1 Forestry Commission of NSW 1994

5.7. Rehabilitation

"Rehabilitation" operations are undertaken in areas where forest regeneration processes have failed in the past. Rehabilitation involves mechanical site preparation and sowing or planting of trees native to the site. Some formerly productive stands have been degraded by wildfire, inappropriate selective harvesting, unsuccessful silvicultural treatment, dieback or other damage so that they no longer carry an adequate growing stock of commercial trees. These stands should be identified, mapped and, where economically feasible, regenerated.

For logistic reasons, rehabilitation should be planned in conjunction with nearby logging operations where possible. Conservation values dictate that rehabilitation should only be carried out in FMZ 3B and FMZ 4 areas outside any buffers or harvesting exclusions specified by IFOAs or other planning instruments. Stands that are unproductive due to environmental or historical factors beyond management control, such as poor site quality or high fire risk, should not receive remedial treatment. Such areas should be identified and managed primarily for conservation and asset protection.

5.8. Other silvicultural treatments

Some traditional silvicultural treatments such as timber stand improvement (TSI) are no longer in general use. Trees that were formerly culled because they had no economic value are now often recognised as having conservation values. The benefits of silvicultural practices were not necessarily assessed on a strict financial basis since they provided social benefits such as rural employment as well as increasing timber productivity. State Forests, as a Government Trading Enterprise, must achieve direct financial returns on investments of public money. Thus silvicultural treatments will normally be restricted to those that can be achieved or subsidised by commercial harvesting activities.

New markets for residual wood are providing many silvicultural opportunities. Planners and supervisors should ensure that these markets are used to silvicultural advantage by scheduling harvesting operations with good utilisation potential in areas where silvicultural treatment is most needed. This will sometimes involve scheduling of salvage operations as a follow up to quota operations or independently of quota harvesting.

Special considerations apply to white cypress as it is a very tolerant species but a strong competitor for limited moisture in an arid environment. Dense cypress regeneration can cause the death of other trees and shrubs during droughts. Individual cypress stems in dense regeneration will not develop to commercial size. Spacing of dense cypress regeneration is essential to achieve Ecologically Sustainable Management for conservation and timber production. This will be difficult to balance with financial objectives. Silvicultural treatments in such forests must be carefully targeted and executed to maximise future financial returns whilst minimising current expenditure.

5.9. Silviculture and fire

Fire is used in managing forest fuels to protect people and the environment from damaging wildfires. Prescribed fire may have additional silvicultural impacts.

Post harvest burning may have silvicultural benefits when it improves seedbeds in mesic forests or helps to reduce unwanted regeneration following thinning. In some situations, however, it may be silviculturally inappropriate. For example, inappropriate use of fire may destroy the seed in felled heads leaving an inadequate supply of seed to regenerate the dominant commercial species on a site. Post harvest fuel reduction burns may be excluded from some areas where they are judged to be silviculturally inappropriate. Site specific assessments should be carried out leading to clear specifications in harvesting plans and burning plans.

Potential negative impacts of post harvest burns include:

- reduced infiltration and water holding capacity of seedbeds
- reduced protection of seedlings from dessication, frosting or browsing
- destruction of seed from felled heads
- destruction of newly established seedlings or coppice
- stimulation of competive fireweeds, grasses, or bracken

Potential positive impacts of post harvest burns include:

- removal of coverings which prevent seeds contacting soil
- improved nutrient availability to seedlings
- reduced microbial or allelopathic inhibition of germination or establishment
- production of a friable surface which holds seeds in place
- stimulation of seed shed from retained trees
- control of unwanted regeneration following thinning

Following a regeneration harvest, fuel reduction burning may encourage or discourage dense regeneration depending on the primary management objectives, forest conditions and the management of the burning.

Some conflicting views regarding the net impact of post-harvest burns on regeneration processes in certain forests may have resulted from inappropriate generalisations across ecological boundaries. In Moist Tablelands Hardwood Types[1], for example, forests dominated by brown barrel can occur in a variety of formations from wet sclerophyll forest with rainforest understorey to open forest with grass or bracken understorey. Post logging burns may assist regeneration in temperate wet sclerophyll forests (eg. brown barrel over blanket bush) whilst mechanical disturbance without burning may be silviculturally preferable in open brown barrel forest[2].

In subtropical wet sclerophyll forests and moist forests, post logging burns may stimulate intense competition from fireweeds which can hinder the development of slower growing, less intolerant eucalypts such as ironbark, tallowwood and spotted gum[2]. On the other hand, burning will favour the establishment of faster growing, more intolerant species such as Sydney blue gum[3], blackbutt and flooded gum by preparing a receptive seedbed and increasing light. Where post logging burning is planned in these forests, the seed crop in the canopies of the highly intolerant species should be assessed. If an adequate seed crop is not expected to be available in the canopies of the retained trees, these species must be sown or planted after post harvest burning.

Broad area hazard reduction burning is used to protect life, property and the environment. It can also assist to maintain healthy forest ecosystems in the reserve system. Within multiple use forests, broad area hazard reduction burning maintains silvicultural options. In the absence of regular mild fires, dry and moist open forests are susceptible to mesic invasion and, in some cases, bellbird dieback. Regular hazard reduction burning can maintain forest vigour by preventing the development of dense mesic understoreys that reduce eucalypt health (Figure 5). Dense understoreys can impair seedling development, advance growth persistence and health of mature trees through competition and by promoting unfavourable microclimates[4,5] and soil microbes[6]. They may also provide habitat for bellbird colonies which can induce chronic psyllid attack of susceptible tree species.

The New South Wales Selective Harvesting system is designed to maintain or create structural diversity in the forest whilst minimising harvesting disturbance and maintaining productivity. It can only be applied successfully in forests where open understoreys and good lighting allow regeneration to develop amongst a moderate residual canopy of mature trees. Selective Harvesting will have increasingly limited application unless open forest ecosystems are maintained by regular hazard reduction burning. A reduction in broad area burning and a consequent increase in the proportion of forest having mesic understoreys will increase the requirement to use more intensive silvicultural systems such as AGS to regenerate forests. Broad area burning must be carefully planned to avoid damaging the youngest ‘age class’ of potential canopy trees in each burning area.

Figure 5: Mesic under-storey development and canopy dieback

Figure 5: Mesic under-storey development and canopy dieback

1 Forestry Commission of NSW (1983)
2 Florence (1996)
3 King (1985)
4 York (2000)
5 Stoneman (1993)
6 Kirkpatrick (1997)

1 Forestry Commission of NSW (1983) 2 Florence (1996) 3 King (1985) 4 York (2000) 5 Stoneman (1993) 6 Kirkpatrick (1997)

6. Regional considerations in silviculture

Variations in ecological and social factors between regions influence silviculture.

Coastal and Tablelands Regions

The Coastal and Tablelands Region contains a wide range of tree species and forest types. The region has an altitudinal range from sea level to about 1400m, rainfall varying between about 700 mm and 2400 mm and a wide range of soil types and landforms. Nevertheless, this region can be distinguished from the other forested regions of the State on broad environmental parameters. Rainfall is generally above 700 mm, the region is not subject to regular drought nor does it regularly receive a part of its annual precipitation as snow. Flooding or shallow ground water do not contribute substantially to soil moisture in the region.

In coastal areas, timber production from eucalypt forests commenced with hightly selective harvesting of favoured species from areas close to settlements. Initially, on the north coast, tallowwood was favoured because its if very strong and durable. Spotted gum was sought on the south coast for similar reasons and because it was good for shipbuilding. In New South Wales' coastal forests, large quantities of blackbutt have been available in trees of good size and form. Since the wood is easily processed into general purpose timbers it has been the mainstay of the hardwood industry since the early 20th century. Mixed hardwood species such as mahoganies, ironbarks and grey gums with their slower growth, smaller sizes and special properties have been particularly used for poles, girders, sleepers and similar applications.

Hardwood timber getting began with highly selective fellings in easily accessible areas. As markets expanded, less selective fellings followed. In blackbutt forests these successive fellings produced irregular forests with groups of different age classes and residual unusable veteran trees. From as early as 1910, Timber Stand Improvement (TSI) was carried out in the blackbutt forests. It was not practised in the more sporadically utilised forest types until the great depression of the 1930's provided impetus for expenditure on labour intensive public works.

World War II and the post-war economic boom brought increased demand for timber as well as improved harvesting technology. Harvesting intensified in all forest types and extended into more remote hinterland and escarpment forests. This more intensive harvesting produced substantial areas of relatively even aged forests, particularly in blackbutt forests which have a large component of usable trees. In the more accessible areas TSI continued or extended into a wide range of potentially productive forest types. At the same time, since regeneration had proved unreliable in the wet layered forests, research programs developed sowing and planting techniques to regenerate these forests. The techniques were applied extensively in flooded gum forests, and to a lesser extent in moist blackbutt forests.

Due to predominantly poor site qualities and severe fire histories, the dry ash-stringybark forests of the south coast had relatively low timber values. They were little used except for sleeper cutting and limited sawmilling until the establishment of a pulpwood export industry at Eden in 1969 enhanced their value for timber production by creating a market for low quality wood and making it economic to process scattered higher quality trees.

From the late nineteenth century, there has been selective harvesting in limited areas of high quality forests on the tablelands. Some small areas have had silvicultural treatment to enhance timber values. Between World War II and the early 1980's, many low quality accessible forests and some areas of better forest with perceived regeneration problems were converted to softwood plantations. Since the war most of the remote tableland forests have been harvested for sawlogs without any additional silvicultural treatment.

Stand Structure

The coastal and tableland forests are either irregular forests with a range of age classes produced by successive fellings or relatively even aged regrowth forests from intensive post war harvests. Exceptions occur at Eden and in some tableland areas where limited selective harvesting of generally low quality forests has not produced effective regrowth. At Eden a modified shelterwood system with alternate coupe harvesting is applied as a consequence of previous highly selective logging and extensive damage by wildfires.

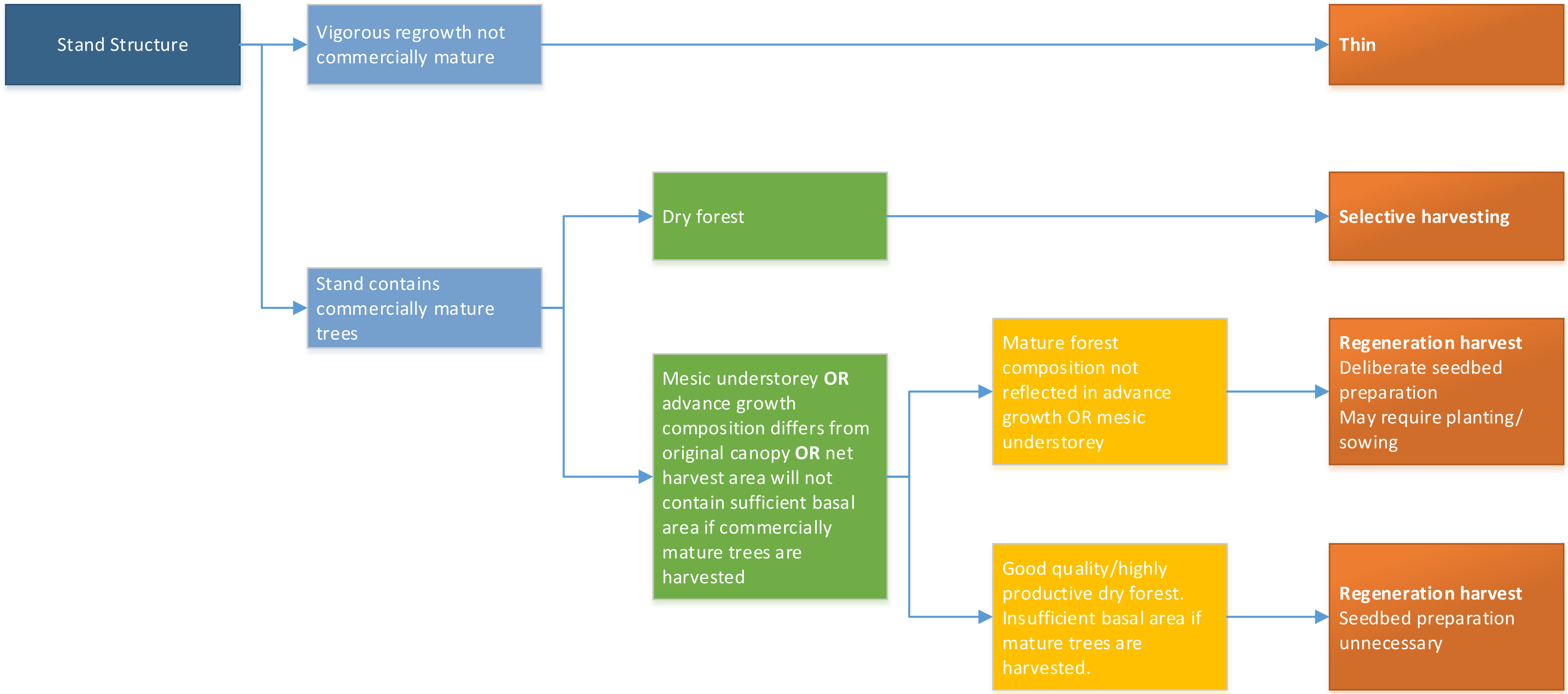
The following decision tree (Figure 6) relates silvicultural systems to stand structure in the irregular and regrowth forests. The decision tree aims to ensure that silviculture is consistent with State Forests' Silviculture Policy, Forest Agreements and Integrated Forestry Operations Approvals (IFOAs). It is not a set of rules but a guide to appropriate site specific silviculture for various stand types. In planning the best available information on stand structure is used to stratify planning units and specify a sequence of harvesting operations that will deliver appropriate site specific silviculture and optimise quota sawlog production during the planning period.

When AGS is identified as the appropriate silvicultural system, planners and supervisors must assess whether it will be applied once, or in two or more successive operations during the 20 year planning period. Successive AGS operations will only be appropriate on sites with relatively uniform mature forests. On such sites, harvesting the useful mature trees in one operation would reduce the stand Basal Area by more than the specified amount and, because there are often dense understoreys or subcanopies, might not provide an effective seedbed nor sufficient canopy opening to ensure adequate regeneration.

Where successive AGS operations are anticipated, careful attention should be given to the potential felling and extraction of groups of trees in subsequent operations. The feasibility of conducting these operations without damaging the regeneration from the current harvest must be assured. First cut groups should generally be marked on lower slopes and away from dumps. Edge trees should not be trees which will be felled in subsequent AGS operations unless it is expected that they will be felled away from the current regeneration openings.

Having determined the silvicultural systems appropriate to the stand types encountered in a planning unit, consideration of floristics and under - canopy vegetation structure will indicate detailed silvicultural prescriptions to be applied with these systems.

Figure 6: Silvicultural decision tree – coastal and tablelands forests



Silviculture using Regeneration Harvests

Canopy structure will determine the silvicultural system applied to each stand. Depending on floristics and under - canopy vegetation structure, regeneration processes in the coastal and tablelands forests will follow one of three paths:

- seed germination to seedling establishment to vigorous sapling growth, or
- release and rapid growth of established lignotuberous or seedling advanced growth, or
- failure of regeneration establishment.

Regeneration failures can occur through lack of germination, failure of seedlings to establish or failure of seedlings and advance growth to develop due to competition and injury These influencing factors can be used to classify the regeneration needs of coastal and tablelands forests into silvicultural types:

FACTORS AFFECTING REGENERATION	SILVICULTURAL TYPES
1 No lignotuberous or seedling advance growth present	
2 Complicating factors	
3 Tablelands frost/grass/bracken	Tablelands fringe forest
3* Mesic understorey [A]	
4* Not layered	Mesic understorey forest
4 Wet layered forest	Layered forest
2* None of these complicating factors	Routine forest
1* Advance growth[B] of seedlings or lignotubers present	
5 Mesic understorey	Mesic advanced growth forest
5* No complications	Routine advanced growth forest

Notes:

[A] *These are the Silvicultural Types in which Regerneration harvesting will usually be applied.*

[B] *The advance growth must include the dominant canopy species, otherwise harvesting may change the floristic composition of the site. In 'small timber' forests an adequate supply of sound stumps may be relied upon for coppice regeneration.*

Silvicultural prescriptions which may need to be considered for each silvicultural type are summarised in Table 1. Each of the silvicultural types covers a range of environments and includes a variety of floristic associations. For each silvicultural type, there is usually evidence in the forest of previous disturbances and regeneration processes which points to the requirements or peculiarities of the type.

Table 1 REGENERATION CONSIDERATIONS BY SILVICULTURAL TYPES

Silvicultural Type	Potential Problems	Potential Solutions
Routine forest	Droughting or burning of seedling regeneration	Post log burn, careful management of broad area burns
Tablelands fringe forest	Dense grass or bracken frost, browsing, seed supply	Limit canopy openings, scalp/poison grass, no post log burn, assess seed supply, winter sowing, repellents/baits
Layered forest[1]	Site occupied by understorey, or subcanopy, poor light, poor seedbed seed supply	Prepare canopy openings, prepare seedbeds, assess seed supply, sow or plant including resistant species from site
Mesic understorey forest[1]	Site occupied by understorey, poor light, poor seedbed, seed supply, dieback susceptible species	Prepare canopy openings prepare seedbeds, assess seed supply, sow or plant including resistant site species from
Routine advance growth forest	Excessive residual canopy	Create canopy openings by salvage logging, culling
Mesic advance growth forest[2]	Inadequate advance growth, site occupied by understorey, poor light, poor seedbed, dieback susceptible species	Prepare canopy openings, assess advance growth[3], prepare seedbed if necessary, assess seed supply, sow or plant including resistant species from site

Notes:

[1]*These are the silvicultural types in which Regeneration harvesting will usually be applied.*
[2]*Substitute "sound stumps" for "advance growth" in 'small timber' forests to be regenerated using coppice* [3]*Floyd (1980) provided species identification keys which will assist in the assessment of advance growth where necessary in coastal forests.*

Harvesting and silvicultural treatment can influence the regeneration process through its effect on canopy cover, understorey structure, seed bed condition, seed supply or advance growth pool. Where poor timber quality creates limited opportunities for canopy opening markets for residual wood such as small logs, salvage logs, pulpwood and fuelwood should be pursued so that logging can promote regeneration of vigorous stands. Where potential regeneration problems are anticipated, harvesting and treatment should target the limiting factors. Where problems are not anticipated, the additional disturbance and expense of deliberate treatments will be avoided. For more detail refer to the Silvicultural Notes by George Baur.

Silviculture using intermediate harvests

Thinning does not aim to establish regeneration.

Thinning from below

In even aged regrowth stands, thinning from below removes smaller trees, considered less vigorous or less valuable than the retained trees. The expectation is that the more vigorous high value trees will now be able to use the share of site resources previously used by the harvested trees. The biggest trees have grown faster than the other trees and will continue to grow quickly. Big trees should always be retained unless poor form or other defects reduce their potential to grow in value. Codominant trees are not the biggest trees but they respond best to thinning because their crowns can expand into space which was occupied by harvested trees. Codominant trees which have poor form or visible defects which reduce their timber value are removed in thinning from below to favour the trees with best potential for economic growth. Harvesting plans should broadly indicate an appropriate range of stocking or basal area of retained regrowth trees, however supervisors will base their selection of trees for removal on dominance, form and defect. Their treemarking will often reflect a variety of stand conditions resulting in variable levels of tree retention.

Thinning from beside

Thinning from beside removes some of the most vigorous and well formed trees in even aged stands allowing other dominant trees to grow on. It can be used to harvest trees which have reached commercial maturity as poles whilst enhancing the growth of other trees which, although unsuitable for poles, will produce high value sawlogs in the future. In some high quality stands harvesting all the poles might reduce site occupancy by the remaining trees to a level which comprises future productivity.

Horne (1993) suggested an approach by which a proportion of the poles may be harvested without significantly reducing site occupancy and stand vigour. This involves specifying a stocking of retained crop trees that is judged appropriate for the forest type and growth stage and converting the stocking to a ‘nearest neighbour’ distance. Poles are marked for removal only where another good quality tree occurs within the specified distance. For example, if it was decided to retain 150 trees per hectare in a blackbutt pole stand, a pole tree would only be removed where another good quality tree of equal dominance was to be retained within a distance of 4 metres. A different retained tree should be counted as a ‘nearest neighbour’ for each pole that is to be removed.

Although guidelines for average stocking and spacing can broadly indicate the desired intensity of thinning, tree marking should aim to provide space for the crowns of codominant trees to expand. Thus a group of a few trees may be retained at close spacings where there is space surrounding the group, whereas good quality codominant trees may be removed from within groups to allow room for crowns of other equally good trees to expand.

Thinning from above

When enhancement of timber productivity is not a primary management objective, thinning from above may be used in mixed species stands to favour less intolerant species such as tallowwood, ironbark, spotted gum or grey gum. These species may have higher values for fauna such as koalas or parrots than more intolerant species such as blackbutt.

Rehabilitation

In the coastal and tablelands region, regeneration failures are most commonly associated with mesic under-storeys and therefore with good quality sites. These are areas that originally had a eucalypt or brushbox canopy over a mesic sub-canopy or understorey and failed to regenerate after harvesting because the sub-canopy or understorey gained control of the site. Such areas should be identified, mapped and, where feasible, scheduled for rehabilitation.

Rehabilitation will usually require site preparation to remove subcanopies, understoreys or groundcovers that would otherwise impede the growth of eucalypt seedlings. Ground preparation may be required to improve water infiltration and drainage and facilitate seedling root development. Appropriate cultivation will facilitate either sowing or planting. The most intolerant eucalypt species native to the site will normally be selected for planting since less intolerant species will usually occur as residual trees or advance growth and contribute to natural regeneration.

Rehabilitation will only be contemplated where there are insufficient trees to support a commercial AGS harvesting operation that would achieve effective regeneration. When the feasibility of rehabilitation is being assessed, the potential for browsing or other damage should be considered as well as the logistics of site preparation. Identification of potential rehabilitation sites or unproductive areas must also feed back into inventory and yield scheduling processes through the regional Management Information System (MIS).

Regeneration failures have occurred at the fringe of the forests on the tablelands. The potential solutions to this problem, outlined in Table 1, include retaining some residual canopy, controlling grass and bracken, winter sowing and protection from browsing animals. These are based on eucalypt physiology and foresters' observations as summarised by Baur[1]. They contradict the recommendations of Silviculture Bulletin No.16[2] which suggests a suppressive effect of residual canopy on seedling establishment in this silvicultural type. Therefore rehabilitation trials will be carried out and the results will be used to update this Manual and associated Training Packages in a continual improvement process as outlined in Chapter 9 (Management of Silviculture).

1 Forestry Commission of NSW (1983)

2 State Forests of NSW (199

Sub-Regional context

In most harvesting areas a range of silvicultural systems will be applied in a fine mosaic according to the different ecosystems and stand structures in the area.

Northern Region

Although the coastal and tablelands areas north of Sydney are divided into two regions for the purposes of IFOAs, the specifications for silvicultural practices are identical. Specified silvicultural practice for regeneration harvests in the north includes light and medium Selective Harvesting and Regeneration Harvesting, including AGS and alternate coupe harvesting. These systems will be applied on a site specific basis as previously outlined.

The current specifications for AGS, Selective and Regeneration Harvesting are based on assumptions used for the purposes of timber yield modelling during the Comprehensive Regional Assessments. They limit the intensity and spatial distribution of regeneration harvesting operations. The specifications for AGS limit deliberate canopy openings and seedbed preparation to areas of up to 0.25ha which may collectively occupy up to 22.5% of the net harvesting area in any single harvesting operation. The return period between successive AGS harvesting operations in the same compartment must be no less than 5 years and must average no less than 7 years after 4 operations. Thus planners must aim to optimise quota sawlog production during the planning period using a maximum of three successive AGS operations in any planning unit.

Selective and Regeneration harvest events must not reduce the basal area across the net harvest area (excluding AGS openings) by more than 40% of the pre logging Basal Area. Thinning may remove no more than about 60% of the pre-existing basal area of the thinned stand. Thinning should maximize the growth during the planning period of retained high quality trees whilst ensuring that site occupancy is maintained.

In harvest planning, units should be stratified using the best available information on stand structure and commercial maturity. The proportions of the net harvest area and basal area to be affected by Regeneration harvesting , Selective harvesting and thinning during each anticipated harvesting operation over the planning period should be estimated. A sequence of harvesting operations to optimise total sawlog production during the planning period should be specified without compromising the IFOA specifications regarding extent and intensity of harvesting. The planned sequence of harvesting operations will be set out in harvest plans at each operation and appropriate tree marking done to set stands up for subsequent harvesting and silvicultural operations.

Southern Region

Specified silvicultural systems to be applied on a site specific basis include Regernation Harvesting, Australian Group Selection and Light, Medium and Heavy Single Tree Selection.

Eden Region

The majority of the forests at Eden had little economic value until the establishment of a market for low quality wood in 1969 allowed economic harvesting of a scattered sawlog resource as well as silvicultural improvement of low site quality forests. Previous utilisation of the mostly low quality and fire ravaged forests had generally not established productive regrowth stands.

Since most trees in the forest now have some commercial value, harvesting has been able to enhance future timber production without a need for additional silvicultural treatment. Recognising that concentrated harvesting could potentially have substantial environmental impacts, a unique silvicultural system was introduced to balance conservation and productivity objectives. Alternate coupe harvesting is used to minimise harvesting impacts by dispersing them in space and time. In alternate coupe harvesting, a modified shelterwood system is applied within the harvested coupes. Trees are retained for fauna habitat, seed supply, further economic growth and structural diversity. Trees not required for these purposes are harvested for sawlogs and pulpwood, creating good regeneration opportunities.

Alternate Coupe Harvesting (in regeneration harvests) and Thinning are the silvicultural practices specified in the Eden IFOA. Alternate Coupe Harvesting is scheduled in mature and mixed aged forests whilst Thinning is scheduled in regrowth stands. Small patches of regrowth in the multiaged forests may be Thinned during Alternate Coupe Harvesting operations. Some stands in the region contain a high proportion of species such as woolybutt, ironbark and bloodwood which are unsuitable for pulp. Marketing residual trees of these species will open up the canopy, ensuring effective regeneration. Residual trees may be harvested during Alternate Coupe Operations or independently in salvage operations. Most of the special species are lignotuberous and coppice strongly so that absence of ground disturbance is not normally limiting to regeneration.

Site specific assessments will be carried out in coupes scheduled for Alternate Coupe Harvesting to identify areas requiring Thinning, special marketing arrangements or special silvicultural prescriptions to overcome potential regeneration difficulties (Table 1). Sawlog supply in the region will come predominantly from alternate coupe harvesting of mixed aged forest until late in the 20 year plan period when harvesting of trees retained in current thinning operations will contribute most of the sawlog volume. In alternate coupe harvesting, all trees which meet quota sawlog specifications (and are not required to be retained for environmental reasons) will be harvested. Vigorous trees which are currently undersized but have the potential to produce quota sawlogs in future will be retained to grow on.

Alpine Ash Region

Alpine ash grows on moist, well drained sites where snowfall regularly contributes to annual precipitation. In New South Wales it is confined to the snowy mountains area where it grows at altitudes around 1000m to 1500m.

History

In the early part of the 20th century, highly selective logging occurred in the alpine ash forests. This created mixed aged stands with a large component of defective trees. Heavy logging with TSI in northern Bago around 1917 produced some high quality even aged regrowth stands which were subsequently treated by spacing or thinning. Following a comprehensive assessment of the Bago forests in 1939 a management plan was produced which prescribed harvesting and regeneration under a group selection system. The Maragle forests were not utilised until much later and since 1968 these forests have been harvested and regenerated using a shelter-wood system with post harvest fuel reduction burning and some culling. Silviculture of the alpine ash is now regulated by the Southern IFOA.

Stand Structure

The Bago forests are mostly irregular, having groups of trees of various age classes which were established by successive harvesting and silvicultural operations. The Maragle forests contain more extensive even aged stands with scattered seed trees and patches of advanced fire regeneration which were retained in the original harvesting operations.

Regeneration Harvests

Alpine ash is a non lignotuberous, very intolerant species which normally carries an abundant seed store in the canopy. Natural regeneration mainly occurs after fire creates a receptive seed bed, induces prolific seed fall, increases light and removes canopy and root competition. Mechanical disturbance can also create an effective seedbed particularly in more open forests[1]. Alpine ash seed has a short term dormancy mechanism. After-ripening during winter allows prolific germination in spring when melting snow provides optimum soil moisture. Regeneration harvests may use Australian Group Selection to maintain the irregular structure of the Bago forests and increase the structural diversity of the extensive logging regrowth stands at Maragle. A modified shelterwood system is preferable to be apply to even aged stands of fire regrowth. In harvesting these stands a selection of mature trees is always retained to provide fauna habitat, seed and structural diversity.

Intermediate Harvests

Baur[1] summarised information on thinning alpine ash. This suggested that although self thinning is very efficient, commercial thinning to 250 to 350 stems per hectare at age 30 produced a good response and could be followed by a second thinning 15 years later.

1 Forestry Commission of NSW (1986)

River Red Gum Region

In New South Wales, forests of river red gum are confined to inland floodplains and riverine areas where soil moisture is provided mostly by flooding or percolation from high water tables rather than directly from rainfall.

History

River red gum forests were harvested selectively for local use during the settlement and agricultural development of the Riverina. Logs were transported by boat to sawmills near settlements. When the area was linked to Melbourne by rail in the 1860's and 1870's markets for red gum timber expanded. As well as sawn timber it was used for paving, house stumps, sleepers, charcoal and firewood. With the cessation of Aboriginal burning and suppression of natural fires after European settlement, a series of wet years in the 1870's allowed dense regeneration to establish in the formerly open red gum forests. During the 1890's TSI and spacing was carried out to speed the development of these regeneration stands into more productive forests. In the first half of the 20th Century rabbit plagues created intense grazing pressures preventing effective regeneration after clearing or harvesting operations in these forests. In 1953 following comprehensive assessments by the Murray Management Survey, a management plan was produced that still provides the basis for management of these forests.

Stand Structure

The majority of the red gum forests comprise stands which regenerated in the late 19th Century and were successively thinned during the 20th Century. They are now well stocked mature forests.

Regeneration Harvests

Survival of seedlings until their roots have developed sufficiently to access reliable groundwater supplies is critical to regeneration of river red gum. Some establishment difficulties include droughting, insolation, frosting, stem girdling, flooding and grazing of young seedlings. Mature trees compete strongly for soil moisture and therefore have a large zone of influence on seedling establishment and vigour. This zone can extend over more than two crown diameters. Apart from water management, which affects the vigour of mature trees as well as seedlings, the main factors amenable to silvicultural manipulation are the stocking and distribution of large trees, soil disturbance and litter retention.

Since mature trees have a strong suppressive effect on seedling regeneration, canopy openings equivalent to at least three mature crowns are required to allow effective regeneration and growth. It should be noted that in good quality stands, removal of all commercially mature trees creating very large openings may not satisfy conservation objectives and consideration should be given to introducing landscape protections for threatened species such as long term patch reserves and aggregated retained trees. In lower quality forests, Single Tree Selection, including marketing of residual trees, will retain many trees to satisfy conservation objectives whilst creating sufficient canopy opening to allow effective regeneration.

Intermediate Interventions/Harvests

Baur[1] summarised information relating to spacing of red gum regrowth. Spacing should be done when trees are about 20 to 30 centimetres in diameter by which time their apical dominance is established.

1 Forestry Commission of NSW (1984)

Retention of the smaller subdominant and suppressed trees to retard coppice growth from cut stumps is favoured. About 170 to 220 crop trees ha^{-1} (equivalent to about $10m^2ha^{-1}$) should be retained. Spacing using a poison axe is quite efficient but visually displeasing. The development of markets for small wood would allow commercial thinning to replace spacing as a silvicultural treatment.

For older commercial stands, the Murray Management Plan[1] provides thinning guidelines. Minimum retained basal areas of useful trees are specified as 16m_ha^{-1} in poorer and average stands to 25m_ ha^{-1} in high quality stands.

1 Forestry Commission of NSW (1985)

White Cypress Region

White cypress mainly occurs on the western slopes and the eastern edge of the western plains in New South Wales. Moderate to flat topography, rainfall between 350mm and 700mm, frequent droughts and generally well drained soils without a shallow ground water resource characterise this region. White cypress typically dominates forests on lighter soils whilst western hardwoods are more prevalent on heavier soils and rockier sites. Black cypress also favours rocky sites and broken topography.

White cypress and western hardwoods occurred naturally as open woodlands with a grassy ground layer maintained by Aboriginal burning, natural fires and grazing by native macropods. European settlement had profound effects on these woodlands, the bulk of them having been converted to agricultural land used for intensive grazing or cropping. Some areas which were without reliable water supplies were less intensively utilized. These were mostly higher, sandy sites. Cessation of Aboriginal burning, suppression of natural fires and destocking during droughts allowed many such sites to develop into thick scrubs in the late nineteenth century.

Since it favours lighter soils and is able to regenerate in high densities, persisting and developing in harsh climatic conditions, white cypress often dominated these scrubs. Western hardwoods, being adapted to persist as mature trees and regenerate sporadically were less aggressive. They are predominant on rockier sites and some heavier soils which are less productive for agriculture. These areas were less affected by Aboriginal and European management practices.

Mixed cypress and hardwood forests with a shrubby understorey are more common in the north of the region, whilst cypress tends to dominate the grassier sites on light soiled ridges which are more common in the south. Waves of cypress seedling establishment occur irregularly on these lighter and grassier forests when wet conditions encourage seedling establishment and reduce grazing pressures through increased herbage production. Seedling establishment is more regular in the north. Height and taper of cypress trees responds to these environmental differences. Better height growth and less taper are produced under the more constant growing conditions in the north.

During the first half of the twentieth century, when feral rabbits in addition to domestic stock exerted intense grazing pressure on the western slopes and plains, extensive areas suffered from severe overgrazing. On harder soils, dramatic loss of topsoil occurred. In the 1950s myxomatosis provided very effective rabbit control, and reduced grazing pressures. White cypress and other woody plants regenerated in massive quantities, particularly where loss of topsoil weakened the competitiveness of native grasses. Lack of regular burning helped to tip the balance in favour of 'woody weeds' rather than grasses. White cypress forests and some western hardwood forests are the result of 'woody weeds' management. They date mostly from the end of the nineteenth century or the second half of the twentieth century. Buloke is a substantial component of some of the new forests but has no commercial value.

History

The first annual report of the Forests Branch in 1883 noted the alarming spread of 'pine scrub' in portions of the Murrumbidgee and Lachlan districts. Some of the earliest silvicultural work undertaken in New South Wales was thinning of pine scrubs in Forest Reserves by lessees under the supervision of Forest Rangers. During the Great Depression of the 1930's thinning, fencing and roading in white cypress forests provided unemployment relief, particularly in the Pilliga. Following the reappearance of wheatfield regeneration of cypress in the 1950's much effort was put into thinning these scrubs by dozing, ploughing and brushing. From the late 1960's extensive culling of eucalypts occurred in the better white cypress forests. Technological improvements saw the emphasis of silvicultural work revert to thinning of dense regeneration using brushcutters from the 1980's.

In mixed forests and western hardwood forests, the strong and durable eucalypts were cut for railway sleepers and similar products. Intensive harvesting and culling of higher quality hardwood stands on heavy-soiled flats produced relatively uniform regrowth. Less intensive harvesting of lower quality hardwood stands on sandier sites and rocky or gravelly ridges created mixed aged forests.

Stand Structure

The better quality cypress and hardwood stands are relatively uniform. Cypress stands which have been heavily thinned may contain dense secondary regeneration. Mixed cypress and hardwood stands usually contain pine advance growth which is able to become established under a eucalypt canopy. Lower quality hardwood stands may be mixed aged stands with patches of advance growth or regeneration where harvesting or other disturbance such as fire has created canopy openings.

Regeneration Harvests

In stands dominated by cypress, regeneration is obtained under a shelterwood system. Since intermediate harvests provide satisfactory conditions for regeneration of this tolerant species, fellings to release regeneration are scheduled after adequate levels of regeneration have become established. These are currently defined as at least 1500 stems ha^{-1} averaging about 1.5m in height.

Single Tree Selection, removing the commercially mature component of low quality mixed aged hardwood stands, will release advance growth and create opportunities for coppice and seedling regeneration. Good quality hardwood stands are mostly not yet developed to a stage requiring regeneration harvests. Harvesting the commercially mature component of mixed pine and hardwood stands using Single Tree Selection favours the pine advance growth and early mature eucalypts having further growth potential. Such operations do not fit neatly into the category of either regeneration or intermediate harvests.

Intermediate Interventions/Harvests

Knott (1995) summarised spacing and thinning trials that have been conducted in white cypress stands over a long period of time. He concluded that unthinned, precommercial stands less than about 30 years of age should be spaced to less than 500 stems ha^{-1} (4.5m spacing) to optimise growth of potential sawlogs over the following 20 to 30 years. Stands over 30 years old with BA greater than 12m^{2}ha^{-1} or stockings greater than 500 to 700 stems ha^{-1} will respond well to thinning. Thinning to about 6m^2 - 8m^2 will be the usual practice.

Good quality hardwood stands will benefit from thinning to similar densities, since they grow in a similar environment and the species are less intolerant than most other eucalypts. Spacing to about 6m x 6m (about 280 trees ha^{-1}) is currently considered to be the minimum treatment that will allow white cypress regeneration to grow to a thinnable (from below) sawlog stand in a reasonable time. In dense stands such a wide early spacing could promote heavy branching, poor form and unwanted regeneration. Priority will be given to spacing regeneration that is large enough to avoid these problems and will reach commercial size more quickly following spacing. Spacing operations should be targeted on a site specific basis to those stands which are overstocked but have potential to produce good sawlogs. Within such stands, patches of regeneration which are more sparse, overtopped by eucalypts or show signs of injury should not be treated. Anticipated markets for small trees, for example as vine posts, would allow spacings to be closer. Stands might be spaced to 4.5m where such markets are anticipated or secondary regeneration is a potential problem.

Older stands which have been previously spaced to less than optimal spacings may be commercially thinned by the ‘vertical cut’ system. This is a thinning from above, beside and below producing an economic yield of sawlogs that could not be obtained by thinning only from below. White cypress’s tolerance allows smaller trees to grow satisfactorily after they are released by thinning.

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GLOSSARY

advance growth
seedling, lignotuberous or coppice regeneration that has already established at the time that a harvesting or silvicultural operation is planned.

boreal
northern; forests at high latitudes in the northern hemisphere

cohort
an age class of trees arising from a single disturbance event such as a fire or logging operation

commercial maturity
the stage at which a tree has attained its maximum realisable commercial value;

conifer
a tree which produces naked seeds in cones; a gymnosperm

crown shyness
a trait which causes tree crowns to grow away from competing crowns in response to damage of growing tips by abrasion

culling
killing or removing trees without using their wood

eucalypt
trees of the genera- eucalyptus, corymbia and angophora

form
the shape of a tree including stem straightness, taper and branching habit

harvesting unit
an area planned for harvesting in a single operational plan
lignotuber
a woody swelling at and below ground level developed by eucalypt seedlings; contains food reserves and dormant buds

spacing
thinning regrowth when the stems that are removed have no commercial value; pre-commercial thinning

wheatfield regeneration
dense regeneration of trees in the seedling or sapling stage; particularly applied to white cypess regeneration occurring with densities in the order of 100,000 stems per hectare

APPENDIX 1

References of particular relevance to silviculture in New South Wales native forests

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Silvicultural Type	RN17 Types	Broad Forest Associations	Baur Silvicultural Groups	Potential Silvicultural Problems
Routine Forest	37 38 40 41 42 (60 61 62) 65 92 93 97 101 105 106 111 112 115 117 119 122 126 129 130 131 138 152 154 155 159 163 164 167 168 169 170	Coastal heath Tablelands dry shrubby Escarpment dry grassy	Dry Sclerophyll Ash Blackbutt Moist Tableland Hardwood	Droughting, Burning of young regeneration
Tablelands Fringe Forest	131 138 140 141 142 150 151 (152) 154 155 (159)	Tablelands grassy	Moist Tableland Hardwood Dry Sclerophyll Ash	Grass, Frost, Seed Supply, Browsing
Layered Forest	36 (46) 47 48 49 51 53 (163 168 169)	Wet layered	Flooded Gum Moist Coastal Hardwood Moist Tableland Hardwood	Fireweeds, Post log burning logistics, bellbird dieback, Seed supply
Mesic Understorey Forest	36 46 47 (53) 54 55 (60 62 70) 71 (74 81) 87 (98) 153 (159 161 163 164) 168 169	Moist shrubby Escarpment moist Moist shrubby blackbutt Moist spotted gum	Moist Coastal Hardwood Moist Tableland Hardwood Blackbutt Spotted Gum	Mesic invasion, seed supply, fireweeds, bellbird dieback
Routine Advance Growth Forest	(36) 37 39 40 41 60 61 62 64 65 70 (71) 72 74 76 80 81 82 83 84 85 92 93 97 98 105 106 111 115 117 119 122 126 129 130 163 167 168 169 163 167 168 169 207	Grassy blackbutt Grassy spotted gum (Mixed coastal grassy)	Blackbutt Spotted Gum	
Mesic Advance Growth Forest	45 60 62 68 70 71 73 (74 80 81) 87	Mixed coastal grassy	Dry Coastal Hardwood	Mesic invasion, bellbird dieback

Native Forests Silviculture Manual Addendum – Description of Single Tree Selection and Australian Group Selection Silvicultural Systems for Coastal Forests.

Background: A special investigation report conducted to verify compliance with AS4708 (Sustainable Forest Management) identified a minor non-conformance regarding the description of silvicultural systems in the Native Forest Silviculture Manual. This addendum is to address that minor non-conformance.

The assessment report found that the terms often outlined in operational Plans "Regeneration STS", "Heavy STS", "Medium STS" and "Light STS" were not adequately described in the manual. The following aims to describe these and point to relevant sections of the manual for relevant information.

Single Tree Selection or 'STS' is described in relevant Integrated Forestry Operation Approvals (IFOA) with limits that apply across a tract of land. These tracts are typically larger than the scale that site-specific silviculture is carried out. The process of balancing the IFOA limits and site-specific silviculture are outlined in Forest Practice Circulars. The requirements of the IFOA silviculture limits are not further described here. The IFOAs for the coastal forests are currently under review with substantial changes to the way silvicultural limits are described and managed expected. The Native Forest Silviculture Manual will be updated to more clearly incorporate those changes when approved. This addendum is to provide a description of the silviculture terms for use with this manual as an interim step until the manual has a had more substantial revision.

Description of commonly used silviculture practices in coastal forests under the Native Forest Silviculture Manual

Figure 6 of the manual describes a silvicultural decision tree for thinning, selective harvesting and regeneration harvesting. The relevant terms are grouped according the terms in the manual.

1. Thinning as a system and its objectives are described in section 3.3 and 5.6 of the manual. The table in section 5.4 identifies relevant site-specific silvicultural assessments that would be considered for thinning operations. A harvest plan for thinning should identify; The location of stands to be thinned, the desired trees to be retained and those to be removed by reference to relevant site-specific factors such as tree species, tree size, tree form and quality, tree spacing or density. As an example, an operational plan might identify:
   <u>Thinning Stands</u>
   - 1990 regrowth blackbutt stand along Internal Break Rd at dumps 1 and 2.
   - Thin stand to a retained stocking of 150 stems per hectare (avg spacing 8m, retained Basal area ~16m2/ha)
   - Retain High quality blackbutt stems with good form.
   - Remove defective stems, smaller stems and any older age class commercial trees not required to meet habitat prescriptions.

2. Selective Harvesting as a system and its objectives are described in section 3.1 – NSW selective harvesting and is primarily applied to stands where a younger age class of trees with good growth potential are retained. These will often be described as a Medium or Light STS in operational plans. The terms heavy, medium and light STS were originally developed to describe silvicultural models and basal area removal limits applied to inventory plots used in FRAMES during the RFA process to model current and future yields at the strategic level. In FRAMES, light STS had a maximum Basal Area removal of 20%, medium a maximum of 30% removal and heavy a maximum of 40% removal.

   When these terms are used in operation plans they are not intended to represent the plot level removal limits previously used in FRAMES but rather are used as short-hand terms to describe the relative intensity of the planned operation. A harvest plan for selective harvesting should identify; The location of stands to be selectively harvested, the desired trees to be retained and those to be removed by reference to relevant site-specific factors such as tree species, tree size, tree form and quality, tree spacing or density. As an example, an operational plan might identify:
   <u>Light/Medium STS</u>
   - Mixed-age spotted gum stand along Divines Flat at dumps 1 and 2.
   - The stand has a younger age class of ~30 cm dbh trees from 1985 harvesting and scattered mature stems from earlier harvesting operations.
   - Retain all high quality spotted gum growers with good form for a future cut in ~15 years.
   - Remove scattered mature stems not required to meet habitat prescriptions along with smaller LQ stems with limited future growth potential

3. Regeneration Harvesting as a system and its objectives are described in Section 3.1 of the manual and can include NSW selective harvesting, Australian Group Selection, Seed Tree/Shelter wood harvesting. In regeneration harvesting systems the primary aim is to replace the stand with a new age-class. This can be delivered under the IFOA silviculture options available on the coast which are single tree selection (STS), Australian group selection (AGS) or alternate coupe harvesting in the Eden Region. Operational plans may describe regeneration harvesting as 'Seed Tree retention', 'Regeneration STS', 'Heavy STS' or 'Alternate Coupe'. In all cases they represent a harvesting practice where, at the site scale, high levels of tree removal occur to create sufficient light and a receptive seed bed to establish a new crop of trees on the site. Where this harvesting is conducted as a STS system, the plan specifies how the IFOA limits are managed across the whole tract in line with the relevant Forest Practice Circular for the region.

   A harvest plan for regeneration harvesting should identify; The location of stands to be regeneration harvested, the desired trees to be retained and those to be removed by reference to relevant site-specific factors such as tree species, tree size, tree form and quality, tree spacing or density. As an example, an operational plan might identify:
   <u>Regeneration STS</u>
   - Mature Regrowth Blackbutt Stand along Lorne Access Road at dumps 1 and 2.
   - The stand is previously thinned and developed from a regeneration harvesting and timber stand improvement (TSI) operation in 1965.
   - The objective of the operation is to harvest the mature forest crop and establish a new crop of trees.
   - Retain Blackbutt seed trees at a spacing of ~40 m.

- Retain scattered koala browse trees and other trees required to meet habitat prescriptions.
- Remove all other commercial stems.
- In the process of harvesting, maximise the removal of understorey and create ground disturbance to help establish a receptive seed bed.

Heavy STS

- Mature Moist Hardwood Stand along Orange Trees Road at dumps 1 and 2.
- The stand has been subject to numerous previous harvesting operations which has left the stand understocked with high quality trees and mesic understorey.
- The objective of the operation is to harvest the mature forest crop, remove low quality stems with limited growth potential and create conditions suitable for establishing a new crop of trees.
- Retain high quality seed trees at a spacing of ~50 m.
- Retain scattered koala browse trees and other trees required to meet habitat prescriptions.
- Utilise salvage and residue markets to maximise remove all other commercial stems.
- In the process of harvesting, maximise the removal of understorey and create ground disturbance to help establish a receptive seed bed.

Silviculture prescriptions will often include additional silviculture practices in addition to the harvesting prescription such as post-harvest burning, enrichment planting and additional seed bed preparation.