TIMBER PRODUCTION FROM PLANTATIONS SHELTERBELTS AND NATIVE FORESTS

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UNIT2
TIMBER PRODUCTION FROM PLANTATIONS SHELTERBELTS AND NATIVE FORESTS

1 LEARNING OBJECTIVES

>+ Be able to evaluate wood production options for woodlots and timberbelts.

- Understand the influence of factors such as site, tree species, genetics and management objectives on silvicultural regimes.

- Be able to discuss the influences of site and management regime on tree tending (thinning and pruning) regimes.

>+ Be aware of the benefits of shelter for livestock and crop production and have a good understanding of the key design principles for effective shelter systems.

2 INTRODUCTION

The rapid growth of the forest industry is a result of a long term decline in the value of sheep and beef products, contrasting with the relatively good long term demand for wood products in world markets. Hill country farmers can dramatically increase farm profitability by including forestry in their enterprise. This is clearly shown in: "Evaluating Forestry Development on Pastoral Farms" in the Introduction to this study guide. Large areas of hill country will probably need to be converted to forestry if sustainable land use is to be achieved on this land class. This unit covers the management of trees, plantations and shelterbelts for the production of timber. It is presented in five sections detailed below.

Tree Species

A brief description of the economically important or potentially important tree species in New Zealand. The description includes the main attributes (including timber) and the management requirements of the minor species only. Management of the minor species is included here to allow Tree Culture and

Management of Plantations to concentrate on *Pinus radiata.* A full description of a wide range of native and exotic species can be found in "New Zealand Timbers" by N.C. Clifton (GP Publications Ltd).

Tree Culture

The propagation, planting and management of *Pinus radiata* for timber production. A brief mention of alternative species (Eucalyptus) only.

Management of Plantations

Planning, species selection and choice of management regime. Factors influencing timber yield. Marketing, harvesting techniques and postharvest management.

Shelterbelts and Timberbelts

The benefits of sheterbelts to agricultural production and the principles of shelterbelt design. Management of Timberbelts to provide effective shelter and income from timber.

Native Forests

A brief look at the issues surrounding the sustainable harvesting of native logs including legal requirements and opportunities for management to optimise output.

3 TREE SPECIES

3.1 Introduction

Pinus radiata dominates the forest industry in New Zealand. However, it has long been recognised that alternative species have a role to play in providing wood which is naturally durable or decorative. Alternative species also have a place on extreme sites (e.g. high country) and may also have a role in the production of high quality paper products for which *Pinus radiata* is not suited. They are widelyused for landscaping.

Almost without exception, alternative species are more difficult to grow, less productive and more difficult to market than *Pinus radiata.* Apart from a few Eucalyptus species, poplar, Cypress and *Acacia melanoxylon* there has been little genetic improvement among the alternative tree species in NZ.

3.2 Pinus radiata

Approximately 89% of NZ's Forests are planted in this species. It originated in California around the Monterey Peninsula and is sometimes referred to as Monterey pine. First planted in New Zealand last century, this species was quickly identified as having potential to replace the rapidly diminishing supplyof accessible native forest. In particular, the rapid growth of *Pinus radiata* in N Z meant that trees could be felled after about 30 years of growth. This compares with over 100 years for native species and for *Pinus radiata* in the Northern Hemisphere (Figure l}.

Pinus radiata is tolerant of a wide range of sites, is relatively easy to propagate, quick and easy to establish, free of any major pest and disease problems and the wood is very versatile. It can be utilised to produce sawn timber, various panel products including veneer and particle boards, paper production as well as posts, poles and railway sleepers. Two important deficiencies are low natural durability, and relative unattractiveness of the wood for furniture manufacture.It also has limited strength and hardness. *Pinus radiata* readily accepts chemical treatment to control insect and fungal attack, overcoming the low natural durability. The development of chemical preservatives in the 1950's was one of the major developments contributing to the eventual dominance of the species in this country.

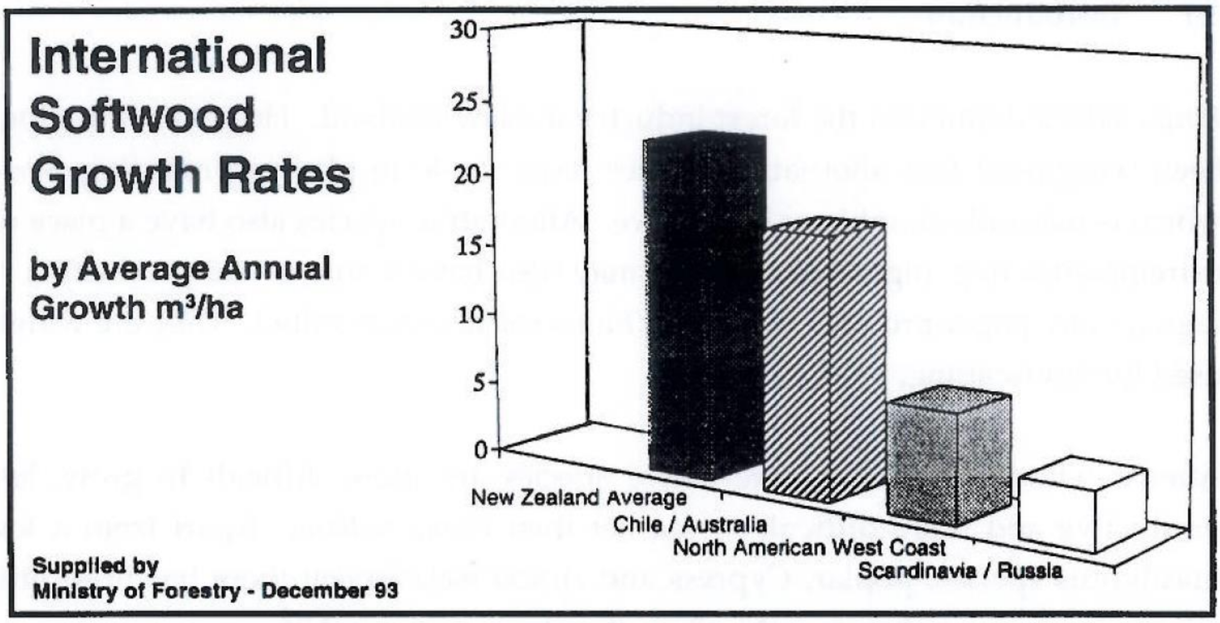


Figure 1: International softwood growth rates

Pinus radiata dominates the New Zealand forest industry because it is so productive and has no serious weaknesses. This was recognised last century when it was nicknamed" the remarkable pine". Do you agree with this observation?

Figure 2: Pruned Pinus radiata, about 15 years old

3.3 Eucalyptus

Eucalyptus species occur naturally in Australia with a few species found in Papua New Guinea, Timor and Indonesia. They are the dominant forest/woodland tree in almost all of Australia. There are over 550 species (some texts say 700), man y of which will hybridise. Eucalyptus are often grouped according to the characteristics of the bark, buds, flowers and seed capsules. Occasionally form is also used. The following broad categories group Eucalyptus species according to bark characteristics.

Smooth bark

The Gums

e.g. *E. nitens* (Shining Gum)
E. saligna (Sydney Blue Gum)
E. botryoides (Southern Mahogany)

Rough bark

Stringybarks e.g. *E. muelleriana(Yellow* Stringybark)
E. globoidea (White Stringybark)

Ironbarks e.g. *E. sideroxylon* (Red Ironbark)

Peppermints e.g. *E. linearis* (White Peppermint)

Boxes	e.g.	*E. bosistoana* (Coast Grey Box)
Ash	e.g.	*E. delegatensis* (Alpine Ash) *E. regnans* (Mountain Ash) *E. obliqua* (Messmate)

Other small groups also exist, e.g. bloodwoods, mallees. Differences between species in different groups are often difficult to detect. Many species are not easily categorised into any single group.

The timber characteristics of the Eucalypts range from moderate density and hardness (e.g. ash) to extremely heavy and hard (e.g. ironbarks). Other wood qualities varying widely from species to species include durability, colour and strength. The Eucalypts provide some of the worlds hardest, strongest and most ground durable timbers, making them excellent for general construction. They can also be used for decorative end uses, including high quality furniture. Otherend uses include pulp for paper, making shelter against wind, and control of erosion on slopes.

Some genetic improvement is occurring with several species (e.g. *E. nitens, E. regnans, E. Fastigata)* but selection has been based on suitability for pulp and paper production rather than sawlogs.

3.3.1 Site requirements

Eucalypts are capable of growing in a very wide range of sites with different species capable of thriving in extremes of temperature, fertility, moisture and the ravages of fire. Compared to *Pinus radiata* they are very site specific, having low tolerance of variation in site characteristics.

Many of the early Eucalypt plantings in NZ were unsuccessful, mainly as the result of species being planted on unsuitable sites.

Most of the Eucalypt species utilised in NZ originate from the South Eastern regions of Australia, in particular coastal NSW, Victoria and Tasmania. These areas tend to have average rainfalls and temperatures which are similar to those found in NZ. The broad climatic zones and the species best adapted to them are described below (Table 1).

Table 1: Site characteristics for important Eucalypt species grown in NZ

Warm temperate	E. *saligna*	E. *pilularis*
7050-2000 mm rainfall	E. *botryoides*	E. *nitens*
Min Temp -8 °C	E. *muelleriana*	
Av. Temp >12.5 °C	E. *obliqua*	
Cool temperate	E. *regnans*	
750-2000 mm rainfall	E. *obliqua*	
Min Temp -10 °C	E. *nitens*	
Av Temp 10 to 12.5 °C		
Cold temperate	E. *regnans*	
750-2000mm rainfall	E. *delegatensis*	
Min Temp -14 °C	E. *nitens*	
Av Temp 7.5 to 10 °C		

Source: *What's New In Forest Research* No. 124

Apart from adaptation to these broad climatic zones, Eucalypts may also have specific site requirements (e.g. good drainage). In contrast, others may exhibit tolerance to drought or exposure. The information in Table 1 refers to adult trees. Seedlings are often more sensitive to site conditions than mature trees.

Species choice will depend on suitability for use in a particular environment. However, wood characteristics will also influence choice.

Table 2: Eucalypt wood characteristics		
High Natural Durability	Most Suited to Milling	Decorative
E. bosistoana		
E. botryoides	*E. botryoides*	*E. botryoides*
E. globoidea	*E. muellerana*	*E. saligna*
E. muellerana	*E. obliqua*	*E. fastigata*
E. paniculata	*E. pilularis*	*E. regnans*
E. pilularis	*E. regnans*	
E. saligna	*E. saligna*	

Wood is described as having high natural durability when 50mm + 50 mm stakes are still sound after 15-25 years in the ground. This level of durability is similar to that of Totara which was heavily exploited in situations where durability was essential, but contrasts with *Pinus radiata,* which is classed as non-durable (5-10 years in the ground). The most durable wood in the world is reputed to be *E. paniculata* which may last over 100 years in the ground.

As a group the Eucalypts are regarded as being difficult to mill. This is due to the presence of growth stresses or tension wood typical of hardwoods. Logs which contain tension wood are prone to splitting, distorting and collapse during milling. This results in low recoveries of sawn timber and, potentially, damage to saws. These growth stresses are reduced in large diameter logs. Consequently, it is recommended that Eucalyptus should not be felled until a diameter at breast height (DBH) of at least 75 cm is achieved. This means low tree stockings and also longer rotations. As a comparison, typical *Pinus radiata* regimes aim to achieve average DBH's of 60 cm at 28-30 years. Some Eucalyptus species, particularly the ashes, are usually quarter sawn to minimise these defects. Some require steam reconditioning after drying because of the collapse which occurs during both kiln drying and natural air drying. *(See 5.3.5 Reaction wood. Unit 1)*

Some species have high natural durability, are suitable for milling and decorative, (e.g. *E. botryoides* and *E. saligna)* making them potentially very useful species.

3.3.2 Silviculture

It has been traditional to establish around 1500 stems / ha and progressively thin to 100-200 stems/ha at about 20-25 m height. Because of the early competition from the high initial stocking, self pruning should result in little hand pruning being needed. High initial stockings encourage good tree form and allow high selection ratios. Some growers have found that with the use of good quality, container grown seedlings much lower initial stockings are feasible.

Eucalypts are very responsive to applications of fertiliser at planting. It is recommended that urea (60g/tree) be applied into the soil 15-20cm to one side of the tree. Phosphorus may also be required on very poor sites.

Eucalypts are sensitive to many of the herbicides normally used to control weeds in *Pinus radiata*. Alternative strategies include weed control prior to planting e.g. Glyphosate. Bare rooted seedlings may be treated with atrazine and caragard but container raised trees (peat pots and rootrainers) are susceptible to these.

3.4 Cypress *(Cupressus* spp.)

Two species from this group are grown in NZ. *Cupressus macrocarpa*, commonly referred to as 'macrocarpa', and *'Cupressus lusitanica'*. Macrocarpa originates from the Monterey peninsula in California, as does *Pinus radiata. Cupressus lusitanica* occurs naturally in the highlands of Mexico and Guatemala.

Macrocarpa was planted in New Zealand from the early days of European settlement. It was mostly used for shelter and landscape planting. The trees resulting from these plantings were seldom tended, becoming large, very heavily branched and, in exposed areas, tangled and gnarled. These trees often blew over during strong winds, requiring a lot of work to clear up, repair fences etc. This gave the species and shelter belts a poor reputation.

However, macrocarpa produces wood with highly desirable characteristics. It is attractive, making it sought after for furniture manufacture. It is also moderately durable, making it useful as a construction timber in exterior situations and as a replacement for Kauri for boat building. Durability is not high enough to allow its use in the ground without preservative. When grown in a woodlot (Figure 3) many of the undesirable growth characteristics described above are eliminated.

Macrocarpa will tolerate a wide range of sites but, requires moderate fertility and good drainage. It is tolerant of salt winds. However, it is susceptible to the cypress canker fungus caused by fungi from the *Seiridium* genus which can cause poor growth, poor form or tree death in severe infections. This disease is mainly a problem in coastal and northern areas (mild) of the North Island and in stressed crops e.g. heavily pruned.

Figure 3: **Macrocarpa of good form**

Cupressus lusitanica is resistant to cypress canker and is preferred in those areas where macrocarpa suffers this disease. In exposed or cold areas macrocarpa is better than *lusitanica* e.g. most South Island areas with the exception of Nelson.

There are a number of hybrids using both macrocarpa and lusitanica which are planted for a range of uses including shelter and timber. The best known of these is ‘Leylands’ cypress, a cross between *Cupressus macrocarpa* and Nootka cypress (*Cupressus nootkatensis*), mostly used for shelter and hedges. *Cupressusocyparis ovensii* is a cross between *Cupressus lusitanica* and *Cupressus nootkatensis* planted as a timber species (Figure 4). It has good growth and has some resistance to canker. Information on a range of cypress species can be found at the link below.

https://www.nzffa.org.nz/system/assets/2043/Cypress_Information_Note_1_-_Species_choice_and_minimising_the_risk_of_canker.pdf

3.4.1 Traditional regimes

The cypresses are less tolerant of the herbicides normally used for weed control in forestry than *Pinus radiata* or Douglas **Fir** for example. Consequently, weeds should be controlled prior to planting. High initial stockings are desirable to allow sufficient selection of final stocking trees. Recommended densities are 1100/1200 stems/ha. Final stocking may vary from 300 to 200 stems/ha with pruning to 6.0rn. Pruning should be done little and often to avoid the risk of canker resulting from heavy early pruning and the large branches resulting fromlate pruning. This is known as pre-emptive pruning and should be done annually. However, where this is not possible prune when stem diameter at the lowest branch is 12 cm with the height of each pruning lift being no more than 50% of tree height.

Trees should be thinned for poor growth, heavy branching, stem straightness and also stern fluting. Stern fluting is a characteristic of the cypresses. It results in lower volume recoveries when logs are milled. Lusitanica has a much lower tendency to produce fluted stems than macrocarpa. Heavy branching, as many as 60 branches/m of stem, means that pruning costs are high, particularly if branches are large. Harvest at around 35 years can be expected.

3.4.2 Recent intensive regimes

To overcome the problems of branching and to take advantage of the shade tolerance of the cypresses (allowing high basal area accumulation) aggressive regimes have been developed. These regimes also utilise the fact that cypresses begin to produce heartwood after only 2/3 years (whereas P. radiata doesn' t produce heartwood until around age 15). The important differences are that these regimes use final crop stockings of 400 to 600 sterns/ha, increasing log volume at harvest, and early pruning. Early pruning means that branches are so small that they can be pruned with secateursrather than loppers. Because of early heartwood formation rotational length can be decreased. Some regimes call for clear felling at 15/20 years, but this is not typical.

Figure 4: **Ovensii hybrid cypress**

3.5 Poplar ***(Populus spp.)***

Poplars have traditionally been grown in NZ to stabilise slopes and provide shelter from wind. Their use as a source of wood is being promoted but as yet there is no real industry interest. Poplars are used for wood production in the northern hemisphere, particularly in Europe and Korea. NZ grown poplar has similar properties to *Pinus radiata,* though it is probably not as strong as radiata. Because it offers few advantages over radiata it is doubtful that it will ever become an important timber.

3.5.1 Erosion control

On erosion prone hill country, poplar is the preferred species for slope stabilisation. The trees are easy to establish, even in the presence of grazing animals (not cattle), quick to grow, have extensive root systems, and being deciduous, do not seriously shade pasture in winter. Because of these characteristics poplar is being promoted as an agroforestry species for hill country. It is estimated that around 8.0 million ha's of land in pastoral use requires wide spaced trees (plus other soil conservation measures) if production is to be sustainable.

An additional benefit from planting poplars for erosion control is the effect of diversity and colour produced in the landscape. In many regions poplars provide an attractive autumn display. The tall, slender Lombardy poplar (P. *nigra)* is particularly attractive but is not often planted because of its susceptibility to poplar rust, a foliar disease. It is often used as a parent of new hybrids due to its ideal shape and some hybrids have the narrow or fastigate growth pattern e.g. ‘crows nest’.

Because they are so easy to propagate vegetatively, poplars are produced by cloning. Many clones are available, mostly hybrids of American Black Poplar *(Populus deltoides).* Examples are:

Kawa	Fast growing, high wood density. Unpalatable to possums. Somevulnerability to wind.
Flevo	Fast growing, moderate wood density. Palatable to possums. Some resistance to wind damage.
Tasman	Moderate growing, moderate wood density. Palatable to possums.
Veronese	Fast growing, good form, moderate wood density. Wind resistant. Palatable to possums.
Crows Nest	Lombardy (P. *nigra)* hybrid. Rust resistant but palatable to possums. Very narrow crown.

New clones are being developed continuously, mostly crosses between *Populus deltoides* and *Populus nigra.*

3.5.2 Wood production

If poplars are grown for wood production they may be grown as single trees, in much the same manner as trees planted for erosion control, or they may be grown in plantations. For agroforestry plantations tree densities may vary from 100 to 280 stems/ha. If stock can be excluded for the first year or two, 1 year old rooted stakes may be used. These are cheaper and easier to use than poles.

Poplar wood is light and has a fine texture. Natural durability is low. However when treated it can be used in a wide range of exterior situations. Overseas it is utilised as a pulpwood, particularly in North America.

Choice of clone is important due to the wide variation in wood quality produced by different clones. In the past clones have not been selected for wood quality. This issue is currently being investigated by Hort+Research, Palmerston North.

Wood yields of about 200 - 250 m3/ha can be expected from spaced trees (100 stems/ha) at around 15 - 18 years provided the clone used has been matched to the site. At 200 stems/ha yields will be about twice this at around 20 years. Intensive pruning is required to produce high quality clearwood. *Pinus radiata* regimes would be suitable for poplar. There are considerable risks associated with producing wood from poplar. T he variation in wood quality between clones and the effect site has on wood quality are significant but of most importance is the virtual absence of a NZ market for poplar.

3.5.3 Wind shelter

Poplar is very suitable for shelter, particularly on seasonally wet soils, and especially since the development of clones which do not lose their bottom branches. This was a characteristic of poplars used for shelter in the past. Modern clones are fast growing, respond well to trimming and have narrow crowns. Veronese, Crows Nest and Tasman are suitable.

3.6 **Douglas Fir** *(Pseudotsuga menziesii)*

A native of the northwest of North America, this is one of the world's major softwoods. It is used as a structural timber and for interior decorative beams. It is not suitable for exterior use because it is very difficult to treat with preservatives and is not naturally durable.

In NZ it has never been able to compete with *Pinus radiata* and today occupies around 5% of total plantation forest area. However, this still makes Douglas fir one of our more important forest species.

Douglas fir has several major disadvantages compared to *Pinus radiata*

Slow growth rates. Douglas fir takes twice as long as *Pinus radiata* to reach maturity although annual increments in wood volume can approach that of *Pinus radiata*, mainly because of the high basal areas (see section 3.3 Factors influencing yield) resulting from high stockings.

Specific site requirements. A free draining soil is essential. It has low tolerance of drought.

Poor early vigour. Seedlings are slow to establish and vulnerable tocompetition from weeds for a longer period of time than *Pinus radiata*.

Douglas fir does have greater tolerance of low temperatures and wind than *Pinus radiata* and can be planted on high altitude sites where snowfall would be a problem for *Pinus radiata*. Douglas fir branches don't angle upwards and droop at the tips meaning that snow falls off rather than building up to weights which damage the canopy. It is these sites, particularly in the South Island, that are best suited to Douglas fir. An additional feature of the species is its attractiveness, having a dark green colour and very dense foliage.

Management regimes for Douglas fir are much less intense than *Pinus radiata*. For example, pruning has been found to be uneconomic because of the long rotation lengths. Consequently, Douglas fir is planted at high initial stockings of ar o un d 1200 - 1500 stems/ha. This minimises branching and branch size. The stand is thinned to around 750 stems/ha at an early age but may be production thinned at 25-35 years if markets are available. Clearfelling is at 45-50 years.

3.7 **Australian Blackwood** *(Acacia melanoxylon)*

This is a legume species, originating from Tasmania and eastern regions of Victoria and New South Wales. It is being grown in New Zealand for the production of high-quality cabinet-making wood. The wood colour gives the treeits name, being very dark. The largest stands, in Westland, probably resulted from plantings made in cut-over native bush. Many small stands have been established on farms over the past 15/ 20years.

The poor apical dominance means almost continuous form pruning is required to produce acceptable stems in this species when planted without an existing canopy. Producing marketable logs is very challenging and not feasible on a large scale.

3.8 **Californian redwood** *(Sequoia sempervirens)*

The Californian redwood is an important timber species in the Pacific North West. It is a very tall tree when mature and capable of accumulating very high basal areas (Figure 5). In the US it is often used for interior purposes such as panelling but is also utilised for exterior cladding and joinery. The heartwood is moderately durable allowing exterior use (except ground contact) without chemical preservatives.

Interest in redwoods in New Zealand is increasing mainly because of the large existing market in North America, decreasing supply as more forests in the United States are protected from logging and the tolerance redwood has for wetsites. Many gully bottoms too wet for *P. radiata* are quite suitable for redwood.

Figure 5: Redwoods growing near Rotorua

3.9 Western red cedar *(Thuja plicata)*

Western red cedar is also native to the Pacific North West. It is one of the world's best exterior cladding timbers and certainly one of the best known. Cedar is imported from North America to New Zealand for use as weatherboards. It hasgood durability (heartwood) and tolerates damp sites but does not do well in exposed sites. Again because of the large existing market for the timber and its tolerance of damp sites it is frequently included in farm forestry plantings.

3.10 Concluding remarks

None of the species mentioned here are New Zealand natives. Without exception, the commercial native species have very low productivity compared to the exotics. Given the restrictions on the harvesting of natives from natural forests, it is unlikely that significant quantities of native timber will be available in the future. Of the native species, kauri and totara probably have the greatest potential for plantation forestry. Both species may be able to produce sawlogs in under 100 years, a long time compared to exotics, but of much higher value.

4 TREE CULTURE

This section will focus on Pinus radiata with only a brief mention of alternative species.

4.1 Nursery management

Pinus radiata seedlings are nearly all produced as bare rooted seedlings, meaning they are not produced in pots or containers, Improvements in nursery management and the transportation of seedlings has meant that (with correct planting practices), seedling survival and vigour is very high. This allows a reduction in planting densities and a reduction in subsequent blanking operations.

There are several ways to determine the quality of seedlings. Firstly, the seedling should have originated from certified seed. Certification provides guarantees as to the growth potential of the seed and may also indicate disease resistance or special wood characteristics. There should be no obvious signs of disease or mechanical damage. Seedlings should be well grown (20-40cm high) with enough fibrous roots to promote early growth. Above this height range there is increased risk of moisture stress while seedlings < 20 cm tall have small food reserves, reducing survival after transplanting. Some anchoring roots should be present and all straggling roots trimmed. Mycorrhiza fungi should be present on the roots. These fungi greatly improve the uptake of moisture and nutrients by trees.

Mycorrhizal fungi are described in UNIT 1: Mycorrhizae.

The following steps are necessary for production of high quality planting stock:

Root wrenching

Root wrenching involves undercutting seedlings in the nursery bed. This removes the tap root, encouraging greater root development near the soil surface.

Root trimming

Roots are trimmed to 100 mm to prevent deformation resulting from planting long roots. Deformation reduces growth and increases vulnerability to wind damage.

Lifting

Care is taken to minimise mechanical damage and roots are kept moist at all times. Lifting speed is important. Speeds greater than about 2.5 m/s are likely to result in trees with a high proportion of damaged roots, few root hairs and little soil or Mycorrhiza adhering to roots.

Transport

Seedlings should be planted as quickly as possible after lifting, preferably within 24 hours. During transport, wind and direct sunlight should be avoided. If planting is delayed, seedlings should be held in cool storage.

Survival rates of 90% plus should be the norm with good quality, correctly planted seedlings.

Alternative species

Bare-rooted seedlings can also be used to establish most alternative species including eucalypts, cypresses and Douglas fir, provided they are wrenched, carefully lifted and have longer roots trimmed. On less favourable sites e.g. low fertility or dry soils, container-grown seedlings have better survival and early growth. However, container grown seedlings must be planted out when 15-25 cm tall to avoid root distortion. Two types of containers are used.

Peat pots: These are planted with the seedling allowing the roots to simply grow through into the surrounding soil.

Rootrainers: Most Eucalyptus seedlings destined for small plantations, shelterbelts etc on farms are grown in rootrainers. These are small elongated plastic containers which train roots to grow down. They allow easy removal of the seedling from the container and better root form in the ground.

Bare rooted eucalyptus seedlings need to be undercut when 15-20cm tall to a depth of 6-8 cm. This stimulates the development of a fibrous root system. Planting should occur within 24 hours of lifting.

4.2 Genetic potential

Genetic improvement of *Pinus radiata* began in the 1950's. New lines or strains were developed and given a rating depending on the level of genetic improvement. Classification was mainly based on the **growth** rate and tree **form** of each line. These are referred to as GF ratings. Unimproved material has a GF rating of 1. Currently, most seedlings produced are GF 17/19. 90% of seedlings are classified according to growth and form with the remainder classified according to resistance to Dothistroma needle blight (DR), length of internode (LI) and wood density (HD). Selection of improved strains has been based on tree performance on forest sites rather than farm sites. Initially, seed was collected from superior trees in forests. Because the pollen source was largely from surrounding non-superior trees, progress was slow. The next step was the establishment of seed orchards by taking cuttings from superior trees and planting together. This greatly increased the probability of obtaining seed for which both parents were superior trees. However, pollination is left to chance without the opportunity to select individual parents in order to combine desirable characteristics from each parent.

The GF ratings indicate rank only and not a lev el of performance relative to some other rank. Productivity of different ratings is indicated in table 3.

Table 3: The benefits from high GF rated trees

GF Rating	% Volume Gain (m^3/ha) Over GFl	% Acceptable Stems
1 (unimproved)	0	45
7	5 - 10	50
14	13 - 18	65
16	15 - 20	70
19	19 - 23	70
23	27 - 32	80

Source: *What's New in Forest Research* No. 157.

4.1.1 The GF Plus Scheme

The development of control pollinated seed orchards has facilitated the identification of seedlots with a range of genetic traits (described below) desirable to different end users. Seedlots are rated for each trait using estimates of the genetic worth of the parent trees within the seedlot. Genetic worth is derived from progeny tests. Ratings for each trait are based on -

Growth:	measurement of tree diameter.
Stem straightness:	visual assessment of log straigh tness.
Branching:	number of branch whorls produced per year.
Dothistroma:	visual assessment of the proportion of live crown in Dothistroma prone areas.
Wood density:	measurement of juven ile wood density in growth rings 6 to 10.
Spiral grain:	measurements of grain angle in standing trees.

gh ratings

High ratings mean a greater level or higher incidence for all traits except spiral grain where a high rating means lower incidence (which is good).

These ratings will allow managers to make decisions about the combination of traits they require in the seedlings they purchase. The addition of wood quality characteristics to complement growth and form (GF) will give growers much more control over the quality of the wood they produce and is long overdue. For example, growers utilising production thinning regimes may require seedlings with high juvenile wood density and low spiral grain whereas growers in warm, moist areas may require a high degree of Dothistroma resistance.

4.3 Establishment

4.3.1 Introduction

Successful establishment requires seedlings which have been properly conditioned and planted as soon after lifting as possible (< 24 hours). It is very important to ensure roots do not dry out prior to planting. Apart from a high survival, well planted seedlings are less likely to develop lean. Lean can result in otherwise good trees being culled or reduced log values at harvest. Leaning trees are also more vulnerable to toppling in strong winds.

4.3.2 Methods

Most planting is done manually with teams of planters using a spade to open the ground. A hole (30cm deep & 40cm wide) is cultivated with the spade. A slot is opened up and the seedling/cutting placed in the slot. After soil is replaced around the roots the seedling is pulled upwards (10cm) to straighten any swept- up roots. Soil is then firmed around the stem.

Although mechanical planters have been developed their use is limited. Their greatest attribute is speed, but they are unable to cope with steep slopes, uneven terrain and debris. They are also unable to recognise variation in seedling size.

4.3.3 Planting density

Site and intended management regime influence planting density. Regardless of intended management and site it is normal to plant greater numbers of trees than required for the final tree stockings. The single most important reason for this is to facilitate selection of trees with the best growth and form. Weed suppression and discouragement of excessive branching are additional benefits of initial high stockings. Factors influencing initial stocking include:

Final stocking:

An agroforestry regime with a final stocking of 100 stems / ha may be planted at lower densities than a plantation regime with intended final stocking of 300 stems/ha if a similar selection ratio is used.

Site:

A site which is harsh and therefore likely to suffer high losses, will usually be planted at higher initial stockings.

GF rati ng:

High GF rated trees have a lower probability of being thinned than low GF rated trees. This allows a lower selection ratio.

Selection ratio:

Selection ratio is the proportion of initial stocking selected as the crop trees. With low GF rated trees, it has been normal to use selection ratios of 4 or mor e to allow sufficient selection to achieve final stock trees of good quality. Selection ratios are now typically 2-4 on most sites. High GF rated trees require lower selection ratios. Cuttings can greatly reduce selection requirements. For example, on high fertility farm sites seedlings may require a 4:1 selection ratio whereas aged cuttings will allow a 2:1 selection ratio.

Most *Pinus radiata* plantings on farm sites range from around 800 stems/ha to 1000 stems/ha. This assumes seedlings of GF rating 17-19 are used, and a final stocking of ap proximately 300 stems/ha.

Alternative species in general require high initial stockings and high selection ratios. This is because of higher potential seedling losses and relatively poor tree form. There has been much less genetic improvement in the alternative species compared to *Pinus radiata* (See Table 3).

In practice, initial stocking is controlled by the distance between trees within rows. Rows are typically 4m apart. Trees planted at 2.5 m intervals at 4m row spacing will result in initial stocking of around 1000 sterns/ha. Thinning down to an average spacing of about 7.5m between trees in the row will achieve around 330 sterns/ha final crop.

Time of planting

Planting is almost always done during winter. Bare rooted seedlings are much more able to withstand the shock of planting during winter. In drought-prone soils (e.g. sand, scoria), plant in early winter. For frost intolerant species and very cold sites(high altitude), late winter or even early spring is preferable.

4.4 Weed control

Control of weeds in new plantations is standard practice. The competitive effects of weeds can greatly reduce tree survival, tree growth and access for tending operations (e.g. pruning). Weed competition reduces soil moisture availability and access to nutrients, particularly nitrogen. Brush weeds may have the additional effect of competing for light. The response of tree growth to weed control has been greatest at low rainfall sites.

EXERCISE

However the financial benefits from weed control may be greater at high rainfall sites than low rainfall sites. Is this a contradiction?

Virtually all control methods are based on chemicals, with the major exception being clearing of scrub etc by mechanical methods prior to planting. Choice of chemical is dictated by the tree species being grown and the weeds required to be controlled. There are a wide range of chemicals available for use in *Pinus radiata* but alternative species are generally far less tolerant of herbicides.

Weed control in new plantings on farm sites is relatively easy to achieve, provided there are no brush weeds present. Pasture can provide strong competition for young trees but is easily controlled usually with a selective herbicide applied after planting. Examples are terbuthylazine combined with terbumeton (e.g. Caragard) which can be used on a wide range of species including *Pinus radiata*, Eucalypts and Douglas fir for control of grass and broadleaf weeds. Terbuthylazine (e.g. Gardoprim) is also commonly used. Both are from the triazine group of herbicides. This operation is often referred to as 'releasing'. Competition is reduced for 6-12 months after which time young treesare large enough to withstand competition and able to suppress competing weeds.

Brush weeds suppress tree growth and restrict access to young trees for pruning and thinning, greatly increasing the cost of these operations and reducing final yield. The presence of brush weeds (e.g. buddleia, blackberry) may require an aerial blanket application of herbicide prior to planting. Glyphosate and metsulfuron (e.g. Escort) are commonly used for this. Because perennial weeds are hard to kill very high application rates are often necessary. In badly infested forests, follow-up control with spot spraying may also be required, often until young trees are 3-4 years old.

4.5 Tending

There are substantial differences in tending schedules being practised in NZ forests. These differences reflect diversity of opinion as to how to manage plantation trees, differences in site and, most importantly, differences in production objectives. The key operations are thinning and pruning. Thinning and pruning determine the size, number and grade of logs produced from a forest. Thinning is the culling of young trees not considered good enough to be a final crop tree. Pruning is the removal of branches from the base of the tree to a pre-determined height, resulting in the production of knot-free wood (clearwood).

The description and specification of different log grades is given in section three of this UNIT (Table 9).

4.5.1 Thinning

Thinning is normally done early in the rotation. Trees of poor form (multiple leaders, heavy branching, stem defects) and poor growth are identified and removed, reducing competition to the selected crop trees. Most tending regimes employ two thinnings but some will utilise just one, usually after the final pruning, if low initial stockings were used. Thinning is nearly always associated with pruning. Trees which have been pruned will suffer a check in growth and so unpruned trees which are likely to seriously compete with these trees are removed at that time. Thinning before pruning means that the remaining trees will develop heavier branching as a result of less competition. The first thinning may be delayed until after the first pruning to help encourage good form in the pruned trees (*i.e.* straight stems and narrow crowns). This may also assist with control of brush weeds. This practice is most often found in plantations which have utilised a low initial stocking so that competition between trees during the first few years is minimal and in high basal area sites in order to help control branch size. Delaying thinning also increases the opportunity to identify superior and inferior trees. With agroforestry regimes trees are thinned at the earliest opportunity to minimise suppression of pasture growth.

Thinning during the early part of a rotation usually means cutting and leaving culled trees to decompose. This is known as 'thin to waste'. On some sites some thinnings may be extracted for posts. However, thinning may be delayed until late in a rotation (around 18 years) allowing production thinning to occur, thus generating early cash flow. Usually it is only sites with very low harvesting costs and with access to a market for small logs that can economically utilise production thinning (e.g. coastal sand country.)

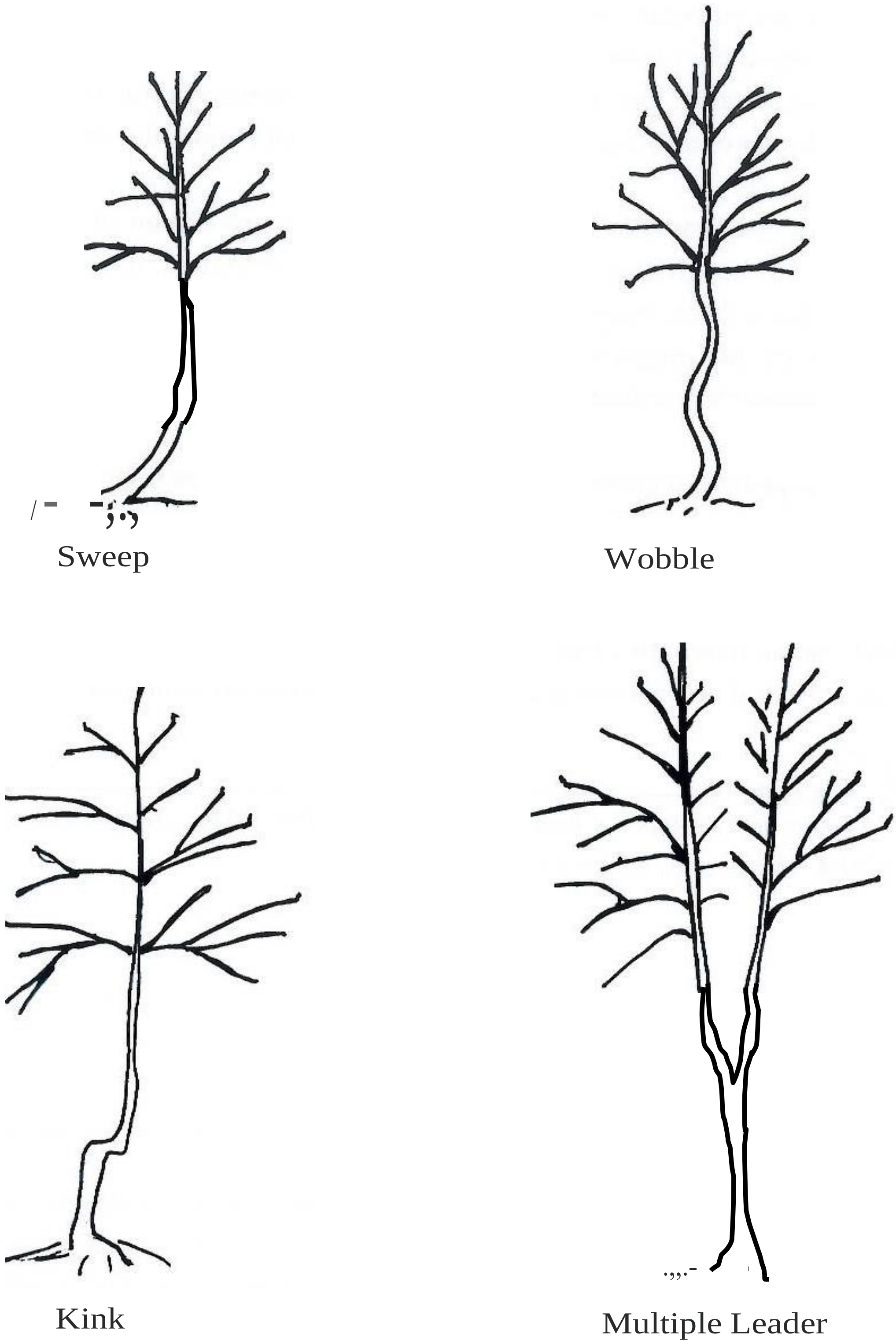
Exercise

The benefit of production thinning is early cash flow. What are the potential disadvantages?

Trees are thinned because they have shown poor growth or poor form. The defects which will qualify a tree for being culled are described below. See figure 6.

Sweep:	The stem is curved, usually as a result of lean after which it has straightened to vertical. May result from wind damage.
Lean:	Any tree more than 5 degrees from vertical should be culled.
Wobble:	Stem is not straight. Sometimes found in fast growing trees on high fertility sites.
Kink:	Usually the result of a side branch developing as the leader.
Heavy Branching:	Because large heavy branches will decrease the value of unpruned logs these trees are best culled.
Multiple leaders:	If developed very early and therefore near the stem base are unlikely to be corrected without malformation.
Poor growth:	Small weak trees are likely to produce small logs at harvest.

Figure 6: Tree defects which may result in culling



4.5.2 Pruning

Pruned logs are currently attracting a premium over unpruned grades however in the past these premiums were small leaving some managers questioning the economics of pruning. See Table 6. However, the Asian economic meltdown has seen the volumes of unpruned grades destined for that region plummet.

Pruning removes branches from a tree to allow the production of high value clear wood. Although a labour intensive and costly operation, the premiums for clearwood have been highly in favour of pruning. However, most, future predictions are for premiums to return to previous levels. Other advantages include increased access through a forest and reduced fire risk.

Not all management regimes include pruning. Forests planted with the intention of producing wood for pulp are not thinned or pruned. However, there are now fewer forests being established exclusively for this purpose. Forests established to produce boxing or framing grade timber are usually not pruned but may be thinned. Alternative tree species may also not be pruned e.g. Douglas fir. Used as a decorative timber (e.g. internal beams), knots can be beneficial.

EXERCISE

There are two types of knot found in sawn timber. What are they and what effect do they have on timber quality?

Pruning removes branches from the base of the tree. Most management regimes for *Pinus radiata* specify pruning to a height of no more than 6.5m. This allows the production of sawlogs or peeler logs of 5.0 - 6.0m length, a standard length in the industry for trucking and processing. Each additional height increment is more expensive to prune that the preceding increment. Pruning from the ground to a height of 2.0m costs less than pruning from 4.0 to 6.0m which requires carrying ladders, climbing trees and much moreattention to safety. Managers assess the costs of pruning to different heights and compare them with the potential financial gains from producing clearwood. For some managers this has resulted in a decision to not prune whereas others will prune to 4 m and others up to 6 m.

EXERCISE

Apart from the increased costs associated with pruning, what other negative effects make pruning to 8.5m economically questionable?

4.5.3 Pruning objective

Pruning is timed to produce a log which has a target diameter over the pruned stubs (DOS). The DOS is the diameter of the stem over the stubs of pruned branches (figure 7). Pruning begins when the DOS of the bottom branches reaches the target DOS. This ensures that the log resulting from that tree has the minimum defect core and therefore maximum clearwood. Setting the correctDOS is very important. Target DOS is usually <20 cm and will vary with the site.Pruning which leaves the DOS too small will reduce tree growth and final crop yield whereas leaving the DOS too high will lower the value of logs. Each time a tree is pruned the same target DOS should be used. The size of the defect core is determined by the largest DOS. Achieving the target DOS will only be of benefit if clearwood is subsequently produced on these stems. Selecting the correct finalcrop stocking is therefore very important. Low crop stockings produce maximum clearwood growth on pruned stems but may produce unpruned logs of lowvalue. High crop stockings will limit clearwood growth, reducing the effectiveness of pruning.

Having made a decision to begin pruning, how high up the tree? Traditional pruning was based on lifts of the same height for each tree. This resulted in short trees having almost no crown left after pruning and large trees having too muchcrown left. This results in unacceptable variation in the size of the defect core among different trees.

4.7.4 Variable lift pruning

The height pruned at each lift is determined by the size of the crown on each tree. The objective is to leave 3-4m of crown. This can be assessed by eye or measured. A quick method is to measure stem diameter from a sample of trees 3- 4m from the top of the tree. This value is then used to construct a plywood calliper which is fitted over all trees to be pruned. When the calliper just fits over the stem, pruning stops. Callipers are usually about 10 cm wide (10 cm stem diameter) but will vary with site. To achieve the final pruned height of 6.5m several lifts are usually required. The exact number is dependent on site and the GF rating of the trees.

Alternatively, pruning can be programmed to achieve a target DOS with allowances made to ensure that 3-4m of crown are retained after each lift.

Figure 7: Cross section of a pruned log showing the defect core including post pruning occlusion scars. The remainder is clearwood.

5 MANAGEMENT OF PLANTATIONS

5.1 Introduction

Management of a commercial forest begins with the initial economic feasibility study, which will include decisions on species choice, establishment, silviculture, etc, finishing with clearfelling and preparation of the site for the next rotation. In addition to these production decisions, today's foresters are required to considerland use and environmental issues, and in particular, the constraints being imposed on all managers of natural resources under the Resource Management Act 1991.

About 90% of New Zealand 's annual wood production is *Pinus radiata.* Given that 90% of new plan tings have been of *Pinus radiata,* this situation will continueat least until the second quarter of next century. There is no evidence of a moveaway from *Pinus radiata.* Although the need to grow wood with specific characteristics *(e.g.* durable, decorative) has been identified it is only in quantities sufficient to meet New Zealand domestic requirements. New Zealand forestry will continue to be dominated by *Pinus radiata.* Why?

Pinus radiata dominates the New Zealand forest industry because economic analysis has consistently shown it to be more profitable than the alternatives. These include other softwoods *(e.g.* Douglas fir) as well as high value hardwoods such as Australian Blackwood. The normal analysis technique for comparing project alternatives is the internal rate of return (IRR). The IRR is a break-even rate that equates the present value of a forest at harvest with the current value of costs. It is the closest identifiable figure to the return you might expect from fixed interest investments. Projected forestry investments typically return from 8 to 12% after tax. Table 4 compares the IRR of a range of alternative species with *Pinus radiata.* This analysis was published in 1985 but little has changed since them in terms of relative profitability. However, in some years cypress log prices can be very high resulting in returns at least comparable with *Pinus radiata*.

The IRR is probably the major criterion for evaluating any forestry proposal. However, other factors which must be taken into account include risk and the long payback period of forestry investments. The IRR can also be used to compare different management regimes. Table 4 indicates that Pinus radiata is more profitable than alternative species. However, because Pinus radiata is so dominant in New Zealand forestry, some foresters think it prudent to diversify toother species. They regard the dependence on a single species as 'risky.'

EXERCISE

If you were considering the risks involved with a forestry proposal, what would they be and how would you rank them?

Table 4: Comparison of IRR for *Pinus radiata* and alternative species

	IRR
Pinus radiata	7.9
Cypresses	6.5
Eucalyptus	5.9
Australian Blackwood	6.9
Black Walnut	4.8

Source: *Cavana and Glass* (1985)

The IRR's given in table 4 depend heavily on the assumptions used in their calculation, e.g. input costs, yields and prices.

Assuming a decision to plant *Pinus radiata* has been made, additional decisions on forest production policy and management regime are required. Alternatives range from short rotation pulp logs, to intensively managed forests producing pruned logs or clearwood. Often location plays a major part in these decisions. Is the proposed plantation close to a pulp mill, a veneer mill, a sawmill or a port?

The increased supply of wood which will develop over the next 25-30 years has meant that most new plantations are situated in the vicinity of a port. This allows access to the export market but minimises interna l transport costs. The increased supply of wood will greatly outstrip any increase in domestic requirements.

About 50% of new plantations are managed with the objective of producing a pruned butt log. At clearfelling, such a plantation will produce pruned logs, unpruned saw logs and pulp logs. The exact mix will depend on site characteristics, the genetic potential of the trees, plantation management and log grading at harvest. All logs are graded according to size particularly the small end diameter (SEO) and length. For unpruned logs branch size is also import ant. Peeler or veneer logs are required to have minimal sweep or taper.

EXERCISE

Why is SED (sawlogs) and sweep (peeler) important criteria for grading logs? Think about the effect they may have on log utilisation during processing.

Production options, management programmes (thinning, pruning,) harvesting decisions and log volumes can all be evaluated with the use of a computerised modelling systems.

5.2 Site Productivity

The potential yield of a plantation is limited by the productivity of the site. Site productivity can be estimated from the site index (height of *Pinus radiata* at 20 years). Tall trees produce more logs at harvest. The size or diameter of logs is influenced by the basal area (cross sectional area of a tree at breast height - 1.4m). Site index is determined by environmental factors such as temperature and moisture and therefore valued by foresters as a measure of site productivity which is independent of management. Basal area potential is influenced by soilfertility and soil moisture. Fertile sites produce large diameter logs. Greatest wood yields occur on sites with high index and high basal area (Table 5).

Table 5: The effect of site index and basal area potential on yield of *Pinus radiata* at 28 yrs (m^3/ha at harvest) for a Hawkes Bay site using a clearwood regime.

Basal Area	**Site Index**		
	20	25	30
low	460	586	707
medium	585	676	765
high	635	736	808

High basal areas tend to be a characteristic of farm sites, primarily because of the high fertility status of soils which have been used for pastoral farming. Log quality, particularly unpruned logs, may be low on these sites because of stem malformation, heavy branching and wind damage. There is a strong relationshipbetween log diameter and branch size - big logs mean big branches.

The objective of forest management is to realise the potential yield for a given site and to maximise the proportion of higher priced log grades at harvest. There are substantial differences in value between different log grades. The recent value of a range of grades is given in Table 6.

Table 6: Value ($/m^3) of domestic log grades. All prices are based on MPI 12 quarter average for logs delivered to the mill.

Pruned	**2015**	**2021**
P1	188	180
P2	164	182
Unpruned		
S1	148	138
S2	137	129
L1/L2	128	118
Pulp	50	53

Prices available from:

https://www.mpi.govt.nz/forestry/new-zealand-forests-forest-industry/forestry/wood-product-markets/

Table 6 clearly shows the price advantage of pruned compared to unpruned logs. This differential does not strongly favour clearwood regimes as much as it used to which is why many stands are not pruned. The value of unpruned logs has increased relative to pruned because of the good demand for relatively low quality logs in China. The greater the proportion of a tree which falls into the pruned grades, the better. However, a tree pruned to 6.0m will yield a greater volume of unpruned logs than pruned logs (Figure 5). On low basal area sites, about 35% of log volume will be pruned but may be higher on high basal area sites. There are also substantial price differentials between unpruned log grades. Tree growers cannot afford to ignore these grade effects on log/tree value.

5.3 Factors influencing yield

GF rating

The advantages of using high GF rated trees are clearly evident in increased volume and a greater proportion of stems of acceptable form. High GF rated tree stocks cost more, but the benefits outweigh any price differential. This mainly results from an increase in log value at harvest as well as the expected increase in log volume. For example, GF 14 rated trees, producing 15% more volume than unimproved trees, may actually increase returns to the grower by 40%. Managers should use the highest GF rated planting stock they can obtain. The most recently selected mate rial, being in short supply, is also available as cuttings. Cuttings are more expensive than seedlings but may be economically viable on some sites, (e.g. high fertility, agroforestry). On these sites increased planting costs are expected to be outweighed by reduced pruning/thinning costs and increased log value at harvest.

Final crop stocking

Final crop stocking has a major influence on log volumes and size at harvest (Table 7). Generally, the higher the stocking density, the greater the wood volume per unit area. However, the widespread use of clearwood regimes has meant that it is necessary to maximise the size of p run e d logs. Consequently, final crop stockings have been declining. This allows maximum production of clearwood over the stub s of pruned trees. On fertile (farm) sites reduced stocking tends to lower the value of the unpruned logs because of excessive and large branching. Final crop stockings on fer tile sites are usually higher than for forest (low fertility) sites to overcome this. For forest sites 200-300 trees/ha and for farm sites 300-350 stems/ha are optimum in most situations.

Table 7:	Effect of stocking density on tree growth at Tikitere (19 years)		
Stocking (trees / ha)	MeanDBH (cm)	Height (m)	Total Volume (m3/ha)
50	67.1	24.4	116.4
100	64.5	26.2	236.5
200	53.8	28.0	380.0
400	44.9	32.1	624.5

Source: *Knowles, Hawke and Maclaren,* 1992.

EXERCISE

The data in table 7 appears to contradict what was written in 3.2 (Site productivity). Can you identify the contradiction and explain it?

When the premium for pruned logs is high, 65-70% of net return may be from the pruned butt log. Downgrading of top logs may not be so important.

5.4 Management of Large Forests

Very large plantations (e.g. Kaingaroa) are not made up of trees in a single age class. They are divided into compartments, which, from the air, give the forest a patchwork appearance. Each year in different parts of the forest, seedlings are being planted, young trees are being thinned/pruned and mature trees are being clearfelled. There may be hundreds of compartments containing trees from different age groups, species, genetic quality and management regime.

Consequently:

Having an accurate inventory of the trees in such a plantation is essential if each compartment is to be managed efficiently. Information on weeds, tree growth etc needs to be collected and used to determine future inputs.

There needs to be a comprehensive monitoring and recording system which allows forest managers to manage each compartment optimally. For example, if planting date is recorded and tree growth is monitored then the need for pruning and thinning can be accurately predicted. Failure to attend to such operations on time can result in a large reduction in log value at harvest.

5.5 Fertilisers

Pinus radiata is very tolerant of low fertility, particularly low nitrogen. Consequently, the application of fertiliser onto NZ forests has not been a routine operation. For most of the newly planted forests on ex-farmland, high fertility is probably a greater problem. However there are regions where the application of fertiliser has been necessary to achieve acceptable growth rates in *Pinus radiata*. These include the coastal sand country forests in the North Island and the recent pumice soils of the Central Volcanic Plateau. It has been found that trees now in the second or third rotation are suffering reduced growth as the available nutrients decline with each rotation. Many sites were of low fertility when first planted.

Confirmation of nutrient deficiencies is achieved through foliage analysis. The most common deficiencies are nitrogen, phosphorus, potassium and magnesium. Visual symptoms may also be used but these will usually appear after significant production losses have already occurred. Foliage analysis allows early detection of developing deficiency and correction prior to occurrence of growth reduction. Critical nutrient levels for *Pinus radiata* are given in Table 8.

Table 8:	**Indicative values of the nutrient status of *Pinus radiata* (% dry matter of leaves)**		
	Low	**Marginal**	**Satisfactory**
Nutrient	<		>
N	1.2	12.-1.5	1.5
P	0.12	0.12-014	0.14
K	0.30	0.30-0.50	0.50
Mg	0.07	0.07-0.10	0.10

Source: *Will,* 1978.

In addition, deficiencies of some micronutrients are also known to occur, *(e.g.* boron, copper). Deficiencies of these two nutrients tends to result in tree deformity rather than loss of growth. For example, boron has been implicated in the formation of resin pockets which reduce recovery during milling and also results in downgrading of processed timber.

Application rates for nitrogen are usually around 200 kg N / ha in a single application. Phosphate is applied at 50-100 kg/ha. Volume responses to such applications often exceed $8m^3$/ha/yr for nitrogen and average about $30m^3$/ ha/ year for phosphate.

Nitrogen deficiency can be particularly severe in the North Island sand country forests. However, trees in these forests have benefited from the presence of tree lupin *(Lupinus arboreus)* used to stabilise moving sand dunes. These lupins areable to fix significant amounts of nitrogen prior to forest canopy closure, virtually eliminating nitrogen deficiency. The arrival of a fungal disease *(Colletotrichumgloeosporioides)* which causes dieback in lupins has resulted in lower lupin density and vigour, and negatively influenced the ni troge n availability in these forests. Research is underway to find an alternative legume for these sites.

5.6 Marketing

International log prices vary as much as the prices of many other commodities. Domestic log prices will reflect this variation. Whether selling to a local sawmill or exporting it is very important to know the market if maximum prices are to be obtained. A complicating factor is the location of logs at the time of sale. Location has a major influence on costs incurred and therefore price. Logs can be sold standing, at the landing site, at the mill door or on the wharf. When negotiating with potential buyers this needs to be specified so that misunderstandings are eliminated. A tree grower negotiating a price thought to apply to standing trees will be very disadvantaged if the price actually applies to logs at the mill door!

The other factor influencing buyer/seller negotiations is log specification and grading. Standard log grades vary according to quality and size. Table 9 describes the grades commonly produced in New Zealand. Some log grades cannot be determined by eye assessment alone. For example, the premiums paid for pruned logs are dependent on the defect core being of acceptable size. However, the defect core is very difficult to determine without sampling trees prior to clearfelling and it is difficult to obtain a representative sample from a plantation. This uncertainty means the buyer and seller may view the same plantation differently. The buyer may require proof of log specification prior to price negotiations beginning. These problems can be eliminated by obtaining a Pruned Stand Certificate. These are administered by the New Zealand Forest Research Institute (FRI), providing a guarantee of log specifications to the log buyer and allowing buyer and seller to negotiate with confidence. Pruned StandCertificates provide a land description, a record of pruning lifts, the DBH, the DOS at pruning and maps of the plantation. Certification is normally carried out by registered personnel or audited by a registered person if this is not possible. Most NZ forestry organisations recognise these certificates.

Table 9: Domestic log grade specifications

log

Pruned	Min SED (cm)	Max branch diameter (cm)	Length (m)
Pl	40	0	3 to 6
P2	30	0	3 to 6
Unpruned			
S1	40	6	3 to 6
S2	30	6	3 to 6
L1/L2	30	14	3 to 6
Pulp	10	-	4 to 8

These are examples only. Buyers are free to set their own specifications.
SED = Small end diameter

5.7 Harvesting

The timing of harvest at the end of a rotation is determined by several factors:

5.7.1 Tree size

For *Pinus radiata* DBH's of 50-60 cm are sought by harvest. Stands with small DBH's will have a high proportion of small logs which will end up in lower price grades (see Table 2). Hardwood species e.g. Eucalyptus require a large DBH (min 75cm) to minimise problems associated with tension wood during milling. *(See 5.3.5 Reaction Wood, Unit* 1).

5.7.2 Market

Harvesting may be brought forward or delayed beyond the intended clearfelling age according to market prices. If prices are high and trees are large enough not to suffer serious downgrading, early harvest may be economically viable. This situation occurred in 1993 during a period of very high international wood prices. Alternatively, low prices can delay harvest. Trees will continue to increase in volume so that final yield will be greater.

5.7.3 Wood Density

Wood density is important in some end-use applications. Old trees have greater density than young trees, however region of production also influences density. *(See* 5.3.3 *Wood density, Unit 1).* Wood density has become an important quality issue for NZ *P. radiata.* Unfortunately, economic pressures have resulted in stands being harvested at well under 28 years. This has resulted in wood being sold overseas with low density (low strength), damaging the reputation of radiata. Stands on farm sites are more likely to being cut at an early age (20-25 years) because their rapid diameter growth means they have achieved minimum DBH at an early age. To an accountant early harvesting is attractive if IRR or NPU are used to measure profitability.

Harvesting is an expensive operation requiring a heavy financial commitment in roads and machinery. It is also dangerous, requiring skilled operators if optimum results are to be achieved. The objective is to extract the maximum possible volume of appropriately graded logs without injuring workers or causing undue environmental damage. This requires considerable planning to ensure maximum efficiency. The location of access roads, landing sites and choice of harvesting system are important decisions influencing costs and effectiveness of the harvesting operation.

Roads need to be constructed to allow access for crews and machinery. They need to be of high standard, allowing fully laden logging trucks to work unimpeded. Constructing access roads costs start at around $60,000/km of road depending on slope and availability of materials. Trees are typically cut down and trimmed using chainsaws. Wastage can occur at this stage for example by careless felling causing stem damage or leaving stumps too high. New strategies for harvesting include using feller bunchers which cut and stack trees which are then extracted either by skidder on gentle sloes or by cable using grapple hooks. The objective is to minimise the number of people on the ground during harvesting operations which traditionally have caused severe injury or death to many forestry workers.

Up until this point, harvesting is fairly standard. The process of removing logs from the point of felling to an area where they can be graded, cut up and loadedonto trucks varies according to topography.

5.7.4 Systems

There are two main systems.

Skidders: A four-wheel drive, centre pivot vehicle with pneumatic tyres. It is capable of making small tracks (skid tracks) which provide access and a winching platform for logs within 30m of the track. Logs are then dragged back to the landing site or skid site. On steep terrain skidders may not be able to leave the skid tracks so they are best suited to flat and rolling topography. A tracked version allows them to operate on steeper slopes.

Cable haulage: In very steep country logs have to be hauled to the landing site by large overhead wire cables.

5.7.5 Harvesting costs

In many plantations both systems will be used. Skidders are quick and relatively inexpensive, while cable systems are slow and relatively expensive. Approximate logging costs in NZ are detailed in Table 10. Transport costs to point of sale (wharf or mill) are around 40c/ km/t. If the site is yielding 600 t/ha then harvesting costs may be around $28,000/ha and transport to point of sale 100 km away may add another $25,000/ha.

Table 10: Approximate log harvesting costs on farm sites

System	Logging & Loading Costs ($/ t)
Low	24
Typical	46
High	87

Source NZFFA: https://www.nzffa.org.nz/farm-forestry-model/the-essentials/roads-earthworks-and-harvesting/reports/report-small-scale-grower-harvest-costs-and-returns/

The costs in table 10 will be influenced by terrain, distance from existing roads and harvest yields. High yields lower costs on a per tonne basis. Yields for many plantations are typically 600 - 800m3/ha. Many forest proposals are budgeted on more expensive cable systems because of the reduced environmental impact, even though other options may be feasible. Regional Councils will often specify harvest systems and erosion mitigation requirements on highly erodible sites.

Logs are graded at the landing site. This is a skilled job requiring a knowledge of the specifications required by the buyer of logs being harvested. Logs will be graded according to size, length, whether pruned or unpruned and if pruned, branch size (Table 9). Landing sites are spaced at regular intervals through the area which is being harvested. About 5% of ground area will be utilised for skidtracks and landing sites. These areas present difficulties for subsequent rotationsbecause they are usually heavily compacted. The movement of heavy machinery and the removal of ground cover during harvest can leave the soil on many sitesvery susceptible to erosion, particularly on the steeper slopes with pumice soils found in the Central Volcanic Plateau forests. Procedures to minimise erosion resulting from harvesting operations are required by the Resource Management Act. Regional Councils will normally require a soil conservation plan before consent to log is granted. One of the major management techniques used to minimise erosion after harvest is oversowing herbage species.

The use of fire to remove residues in forests after logging is no longer a routine practice because of the risk of escalation. Residue is usually windrowed prior to replanting.

5.7.6 Erosion control

Quickly establishing herbage species can reduce erosion resulting from heavy rainfall by reducing the impact of rain on the soil surface and by binding soil, preventing it being washed down slopes. For example, a trial in the Kaingaroa forest recorded annual sediment losses averaging 0.664 kg/ m^2 on slopes ranging from 18° to 22°. This is equivalent to 6.64 t / ha/yr. Oversowing with Maku lotus (5 kg/ha), Massey Basyn Yorkshire Fog (20 kg/ha) and Concord Italian ryegrass (5 kg/ ha) with 500 kg/ha of 12:10:10 fertilizer significantly reduced sediment loss. Fertiliser may not be needed on some sites. Lotus usually becomes the dominant species in such mixes but is slow to establish, so other species are utilised to provide quick cover. Other potentially suitable species include browntop and cocksfoot. Cocksfoot is tolerant of shading.

The risk of erosion immediately after harvesting is becoming more prevalent because of the increased incidence of very heavy rainfall events. This can result in the slash left after harvesting being washed into waterways resulting in downstream blockages. This damages infrastructure and causes flooding. Riparian management is important during forestry operations to minimise the risk of these events by, for example keeping slash well away from waterways.

5.7.7 Brush weed control

In second rotation forests many of the common brush weeds provide severe competition for establishing trees as well as restricting access. These weeds benefit from the soil disturbance generated during logging operations. Problem weeds include buddleia, Himalayan honeysuckle, blackberry, broom, gorse, bracken and pampas. These brush weeds are vulnerable to competition as seedlings. Oversowing with fast establishing herbage species has been shown to greatly reduce the incidence of these weeds in forests. Large savings in herbicide costs and subsequent hand releasing operations have resulted. This improves profitability and reduces the reliance on chemicals.

EXERCISE

Some of the species included in the group of important forest weeds above may surprise you. One is a plant used for shelter and forage for livestock and another, a garden ornamental. This highlights a continuing problem in New Zealand - plants useful to one sector becoming an expensive problem to another. How do you assess the potential benefits and dangers of new species?

SHELTERBELTS AND TIMBERBELTS

6.1 Shelterbelts

Shelterbelts provide protection from wind for livestock and crops. Reduced wind velocities reduce evapotranspiration, increase air and soil temperature, reduce physical damage from wind and reduce soil erosion of cultivated paddocks. The potential benefits to livestock include increased lower critical temperature, reduced feed requirements for maintenance and growth as a result of reduced air velocity and protection during storms (particularly from snow). Other important benefits include habitat diversity for wildlife and aesthetic value. A well sheltered farm is a much more pleasant place to work than an exposed farm. The data in Table 12 demonstrates the proven benefits of shelter for reducing lamb mortality in bad weather, however there is very little evidence of increased growth in animals grazing pasture from natural shelter in New Zealand.

EXERCISE

On a cold day being out of the wind can make a big difference to your comfort level (as well as the risk of becoming hypothermic). The benefit of shelter to livestock would seem obvious. Why is there little evidence for this in New Zealand? There is virtually no evidence of the benefits of shade for livestock in New Zealand. Do you believe there are benefits and if so why?

Table 12: The effect of shelter on wind speed and lamb mortality

	Sheltered	Unsheltered
mean wind speed (m/s)	1.6	4.5
Lamb mortality (%)		
0-48 hrs old	7.2	20.0
48+ hrs old	2.0	3.4

Source: Egan et al., 1972

For virtually all major horticultural crops, effective shelter from wind is essential for achieving acceptable yields and quality. However, shelter may also benefit arable crop production (Table 13), particularly in low rainfall regions, and reducewind erosion in recently cultivated paddocks.

Table 13: The effect of shelter on the yield of oats, Methven, Canterbury

Distance from shelter	Yield (t / ha)
4 x height	7.9
Average 1-6 x height	7.1
Average 6-30 x height	5.25

Shelter height 7 m

Source: *Sturrock*,1981.

There is some evidence that shelter may increase pasture production in summer dry regions (Figure 6). Recent research has indicated that the response evident in Figure 6 is probably due to soil fertility transferred by grazing animals, which naturally tend to camp in the sheltered zone. Pasture and crop production is reduced in the immediate vicinity of shelterbelts as a result of competition and shading. This effect may extend to 1 to 2 times the height of the shelter.

The article by Hawke and Tombleson (below) clearly demonstrates the effect of shelter on pasture production, probably explained by nutrient transfer by grazing animals seeking shelter. By using pots filled with soil collected at various distances from the shelter the effect of fertility can be isolated from the shelter effect. This work clearly shows that pasture production varies with soil fertility, which is highest in the most sheltered part of the paddock.

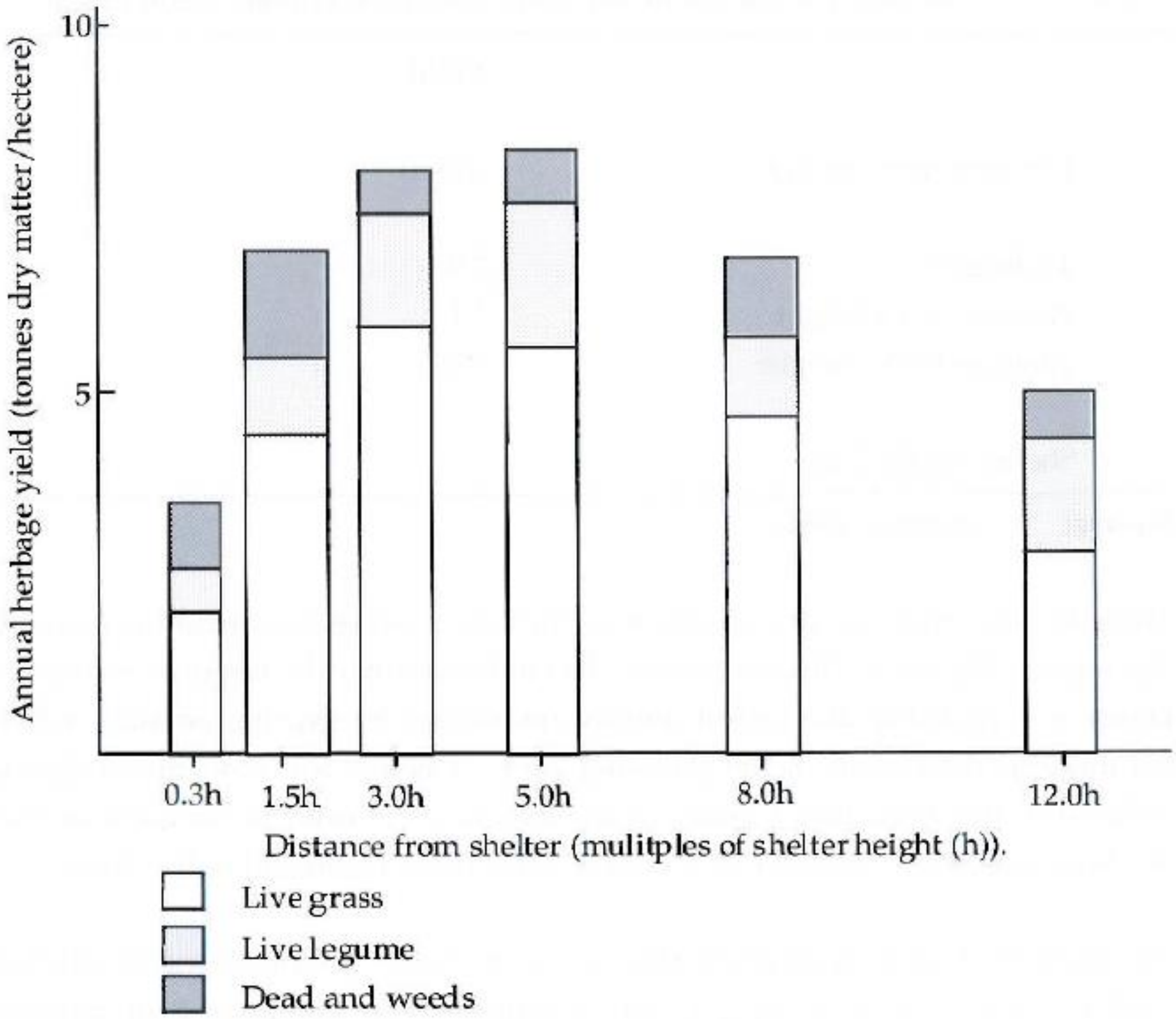


Figure 8: **The effect of shelter on pasture production on stony soil in Canterbury.**

The prevailing wind is from the Northwest. Porosity of the belt was 50%, length 550m and height 17m.

Source: Radcliff 1985

Production and interaction of pastures and shelterbelts in the central North Island

Proceedings of the New Zealand Grassland Association 55: 193-197 (1993)

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Abstract

Many New Zealand farms contain shelterbelts which have generally been unmanaged, resulting in dubious shelter benefits and poor log values at harvest. The effect of a 6- and 7-row Pinus radiata

shelterbelt on adjacent pasture production was monitored at Matea, Taupo during 1992193. Pasture production was measured at a range of distances parallel to the shelterbelts on both sides and on open pasture. A 15% increase in pasture production was recorded at 0.7 tree height distance on both sides of the shelterbelts. There was also a gradual trend of increasing dry matter production as distance from the shelterbelts increased. However, on average, the sheltered zone produced slightly less dry matter than the open pasture. Increases in soil and herbage nutrient levels close to the shelterbelt suggest nutrient transfer by animals to the sheltered zones may have occurred. Shelterbelt tree growth was assessed and projected forward to maturity. Merchantable log volume at age 28 years was predicted to be 2300 m3/km of shelterbelt. Based on current log prices the 7-row shelterbelt was estimated at age 28 years to have a net value of $130 000/km.

Keywords: log value, nutrients, pasture production, pasture composition, Pinus radiata, shelter, shelterbelt, wood yields

https://www.grassland.org.nz/publications/nzgrassland_publication_822.pdf

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6.1.1 Shelter design

Three major components of a shelterbelt are important.

Height
The distance a shelterbelt provides effective shelter is directly proportional to its height. When at 90° to the wind good shelter is provided from 6-10 x the height.Wind speed gradually returns to the original so that by 20 x height shelterbelts will have no impact (Figure 7).

Length
Shelterbelts provide best protection when at 90° to the wind. However if wind veers then adequate shelter depends on shelterbelts having sufficient length to provide protection. Ideally shelterbelts should be as long and as continuous as possible. Any gaps provide a funnel.

Permeability
A solid barrier is not effective for providing shelter. Solid barriers displace wind upwards creating increased wind velocity, turbulence and greatly reduced protection. Ideal optical permeability is 40-50 %. This means that 40-50% of the light arriving on one side of a shelterbelt will pass through.

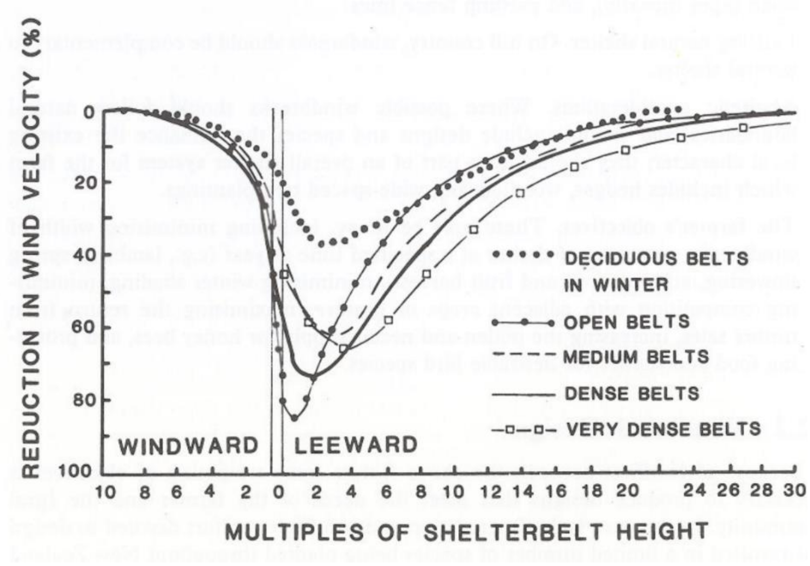

Figure 9: The effect of shelterbelt porosity on wind speed reduction.

Source: *Agroforestry in the Semiarid Tropics.*

Shelterbelt placement is determined by the direction of the prevailing wind. In NZ this is nearly always from the westerly quarter although southerly winds are probably more of a threat, particularly in eastern regions. Distance between shelterbelts is determined by the vulnerability of the crop to wind damage. Horticultural crops will require intensive shelter with belts every 6-10 x height, whereas pasture may only require belts every 20 x height. Other considerations include shading for belts planted in an east-west configuration.

Species

A wide range of species are potentially suitable for shelterbelts depending on the site, (temperature, salt winds etc) the required final height and whether deciduous or evergreen. Commonly utilised species include:

Poplars:	Deciduous, quick growth, tall, tolerant of brackish water and salt winds
Willows:	Deciduous, quick growth, medium height
Macrocarpa:	Evergreen, medium growth, tall, tolerant of salt winds
Pampas:	Evergreen, medium growth, short, tolerant of salt winds
Japanese cedar:	Evergreen, medium growth, tall
NZ flax:	Evergreen, slow growth, short, very hardy - tolerant of wind, salt, cold
Eucalypts:	Evergreen, fast growth, short tall, site specific
Pinus radiata:	Evergreen, fast growth, tall, site tolerant
Banksia integrifolia	Evergreen, medium growth and height, tolerates salt wind

Shelterbelts require maintenance to be effective and also to minimise undesirable characteristics. Excessive crown development should be avoided through species choice or trimming. This reduces the risk of wind damage, helps to prevent belts becoming impermeable and minimises excessive shading. Trimming needs to be done regularly from an early age. Allowing belts to develop large straggling crowns prior to trimming results in large branches having to be trimmed and often the consequence is no regrowth. Many macrocarpa shelterbelts have had this treatment. They are ugly and ineffective as shelter. One of the most common complaints of shelterbelts is that they suffer windthrow, damaging fences and creating work. The most effective method of minimising windthrow is to remove and replace shelterbelts when they become mature. This provides an opportunityto generate income.

EXERCISE

The above list of species includes both deciduous and evergreen species. How would you utilise both to provide comprehensive shelter but minimise any negative effects on pasture production?

6.2 Timberbelts

It has long been recognised that shelterbelts can be managed as a dual purpose asset. They are capable of providing effective shelter and a source of income from the sale of logs. As yet few farmers have taken advantage of the benefits offered by timberbelts. The Radiata Pine Growers Manual covers this topic.

The need to produce marketable logs restricts species choice to *Pinus radiata*, Eucalyptus, Cypress and perhaps poplars. These species are all tall, quick to grow and marketable. *Pinus radiata* probably offers the greatest potential return. As with plantation forestry the objective should be to produce clearwood (pruned logs). Pruning to a height of 6m will result in clearwood but renders the belt ineffective as a windshelter. This problem can be overcome in several ways.

Companion species
Timberbelts can be established with two species. One will be the species to be utilised for log production and the other will be a slower growing species which will provide bottom shelter to replace branches pruned from the tall species. The slow growing species should be offset to the windward side.

Differential pruning
A single row of the commercial species is planted but only every second tree is pruned to produce clearwood. The remaining trees are fan pruned, removing branches growing at 90° to the fencelines to provide the bottom shelter. They may also provide commercial logs when the belt is harvested, mainly low grade unpruned sawlogs or pulplogs.

Planting configuration is usually 1 tree every 2.0 - 2.Sm. If a companion species is also planted, this is planted l m to windward at similar spacings but offset by half the planting space. It is very important to use high GF rated stock if using *Pinus radiata*. Aged cuttings would be preferred to seedlings. High GF rating and cuttings minimise the incidence of tree defects which tend to be high on high fertility sites planted at low density. It must be remembered that every tree planted may be a crop tree. Pruning will need to be intensive because of the tendency of trees planted at low density on fertile sites to have large diameter growth relative to height. This means control of DOS is difficult and may actually require annual pruning.

Growth rates can be extremely high. Timberbelts of *Pinus radiata* achieve millable size in 20-25 years, however wood density may be a constraint to early harvest. Log volumes at harvest will range from 1000-1200 m^3/km of belt at a stocking of400 trees/km but may be high er on very good sites (fertile, not exposed). The butt log will be of high value and comprise up to 40% of total volume but the unpruned logs may be downgraded to L grade (due to large branches), comprising 45% of the total volume with the remainder grading pulp. Side trimming may help reduce branch size as well as reduce shading. Tree growth rates will be reduced, however. On very exposed sites tree growth and form may be poor.

Figure 10: A good example of a *P. radiata* timberbelt. The supplementary species is C. *macrocarpa.* The radiata has been pruned to 6.0 m and most of the butt logs will be of good form. The porosity of this belt is ideal, and it is aligned in a north/south direction, perpendicular to the prevailing wind from the westerly quarter.

7 NATIVE FORESTS

7.1 Introduction

There are approximately 6.4 million ha of native forest in NZ nearly 80% of which is managed by the Department of Conservation (DOC). The remainder is owned privately. While large scale clearfelling of native forest is now a thing of the past, there is considerable scope for ‘sustainable' harvesting of target species on private land and on land held in the conservation estate. Examples of this include the harvesting of beech in western Southland. The felling of native forest is controlled by an amendment to the Forests Act (1949) and requires that harvesting be done in a sustainable manner. What does this mean?

7.2 Sustainable forestry

In 1993 the Indigenous Forestry Provision (Part III A) of the Forests Act was introduced. It requires landowners/managers wishing to harvest, mill or export native timber to provide a sustainable management plan. This plan requires an accurate description of the forest to be harvested, harvest volumes and details of harvest methods. For small areas (applicable to most farmers) a permit is more appropriate. A permit allows for pre-specified harvest volumes of nominated species. For example, up to 250 m^3 of podocarps or 500 m^3 of beech over a ten year period, providing that the volume of timber does not exceed 10% of the standing volume on the property. The issuing of subsequent harvest permits is conditional on the forest replacing the previously harvested timber volume through growth. Both management plans and permits are administered by the Ministry of Agriculture+ Forestry (MAF). Penalties for non-compliance with the Forests Act are substantial.

The definition of sustainable management under the Act is as follows.

> " The management of an area of indigenous forest land in a way that maintains the ability of the forest growing on that land to continue to provide a full range of products and amenities in perpetuity while retaining the forest's natural values."

This definition of sustainable management changes the way many foresters have previously viewed a stand of trees. Sustainable simply meant that timber could be harvested in perpetuity i.e. harvest was sustainable. However, the above definition is much more complete and requires issues such as erosion, water quality, forest structure and wildlife populations to be considered.

7.3 Natives in plantations

Natives have been planted on many sites around NZ but the early growth of the economically important species (Table 14) has not been sufficiently encouraging to see significant areas of native plantations established. Today most natives are planted for revegetation (conservation) purposes rather than production forestry.There are small plantations of Kauri in the Northland region which may be harvested at around 80 years. However, harvest age may need to be nearer 150 years to obtain heartwood.

Table 14: The growth of native tree species over a range of NZ sites

	40 years		**60 years**	
Species	DBH (cm)	Ht (m)	DBH (cm)	Ht (m)
Kauri	27	16	42	18
Rimu	29	14	40	17
Matai	17	9	19	13
Black Beech	34	18	49	21
Red Beech	32	18	45	19

Source: What's New in Forest Research, No. 173

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GLOSSARY

Bare rooted seedlings:	Tree seedlings raised in open nursery beds with seed sown directly into the soil.
Blanking:	Replanting dead seedlings.
Control Pollinated:	Seed from female cones where pollination results from selected pollen only.
Coupe:	Area within a forest selected for clearfelling.
Crop Trees:	Trees selected as the final stocking.
Clearwood:	Wood free of knots and major defects.
Defect core:	Central core of log containing the pruned stubs plus the occlusion scars formed over these stubs as well as distortion which may result from sweep **or** kink in the stem.
DBH:	Diameter at breast height.
DOS:	Diameter over stubs.
Fluting:	Longitudinal grooves of the stem, usually near the base of trees. Prevalent in macrocarpa.
Lower critical temperature:	The temperature at which animals are forced to increase respiration (heat production) to maintain body temperature.
Open pollinated:	Seed from female cones on selected trees but no control over pollen source.
Progeny test:	Measurement/ assessment of the average performance of unselected progeny of individual trees.
SED:	Small end diameter.

Stocking:	Number of stems/ ha.
Stubs:	Base of branch remaining after pruning.