Continuous Cover Forestry

A Handbook for the Management of New Zealand Forests

by Ian Barton

Tāne's Tree Trust
Native Trees for the Future

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2008

"Forestry is based on
the knowledge of
nature,
the deeper we
penetrate its secrets,
the deeper the depths
before us."

(Cotta's Preface 1817)

Disclaimer

In producing this manual reasonable care has been taken to ensure that all statements represent the best information available. However, the contents of this publication are not intended to be a substitute for specific specialist advice on any matter and should not be relied on for that purpose.

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PREFACE

This is the first attempt to assemble in one place all of the information about Continuous Cover Forestry (CCF) which is applicable to New Zealand conditions. It has drawn heavily on the situation in continental Europe and particularly the United Kingdom, where the history of forest management has some striking similarities to New Zealand.

After the First World War the forests of Britain were in a sorry state, having been almost destroyed because of wartime requirements; in New Zealand we had, in less than 100 years almost destroyed the unique forests with which the country was covered. Both countries faced uncertain forestry futures and, as this coincided with the beginning of the new plantation age in forestry, decisions were made to re-forest using fast-growing exotic species — in Britain mainly with Sitka spruce and in New Zealand mainly with *Pinus radiata*. One hundred years ago even-aged plantation forests were also becoming the norm through much of Europe, so in New Zealand we went with the tide!

More recently some of the disadvantages of even-aged forestry have become apparent, especially in Europe, and a swing back to more natural forest systems has begun. In New Zealand the last 20 years have seen a considerable change in forestry policy with the ownership of even-aged plantations largely privatised and the management of State indigenous forests placed under the control of the Conservation Department. This, and the 1993 amendment to the Forests Act, has increased the interest in managing private indigenous forests for timber production. At the same time a few Farm Foresters have been seeking better ways to manage their exotic woodlots and another group of people, led by Tāne's Tree Trust, is seeking to establish new indigenous forest on previously un-forested land. Most recently the Government is proposing to allow forest owners to acquire carbon sequestration rights if they plant forests and manage them using CCF. If this proposal, the Permanent Forest Sinks Initiative, goes ahead then this manual could be very useful.

Now seems to be the right time to assemble in one place as much information as possible about more natural methods of managing forests. And what is more natural than CCF, which by definition means that the forest is managed as naturally as possible by keeping the canopy of the forest, which is so important for protecting the soil beneath, as intact as possible.

The writing of this manual has been complicated by the need to provide background material while, at the same time, coherently covering the practical aspects. This has been overcome to some extent by highlighting the practical aspects throughout the publication.

More difficult has been deciding how to deal with the separate, but at the same time closely interwoven, issue of indigenous species *versus* exotic. One option would have been to write separate sections for each but this would have necessitated considerable repetition. Management of existing indigenous forests is separate in that they are dealt with under Part 3A of the Forests Act 1949; however, the issue is not simple when we come to deal with exotic species or planted indigenous forests, or even mixed forests of indigenous and exotic species.

While the main interest of Tāne's Tree Trust is the establishment of new forests of native species by planting, much of what we do flows into the management of existing indigenous forests, and the requirements pertaining to planting and management apply also to exotic species. And there is no doubt that exotic species are important in New Zealand because, unlike most other countries in the world, we are unique in having a very large component of exotic trees in our parks, gardens, and forests.

Another problem which has complicated the writing is New Zealand's lack of an inclusive Forest Law. While forest management in New Zealand is theoretically divided into separate indigenous and exotic areas, in reality it is more of a continuum from completely protected indigenous forest, through indigenous forest managed under the Forests Act 1949, woodlots of planted and mostly exotic species, to exotic forestry on land which has no protection from exploitation. Therefore, it is difficult to try to deal with exotic and indigenous forests separately when considering the introduction of continuous cover systems. Consequently the decision was made that, in this publication, indigenous and exotic would be treated together, although dealt with separately where required.

Finally the author accepts that, along with the above complications, there is still a considerable knowledge gap relating to the practice of CCF in New Zealand. This publication will hopefully be the first of many on the subject as a great deal more remains to be learnt.

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CHAPTER 1: INTRODUCTION

The objective of this handbook is to collate information about Continuous Cover Forestry (CCF) from a wide range of sources. It seeks to define the concept, outline its history, and explain how it might be adapted to New Zealand requirements. In order to explain more clearly how CCF might work in New Zealand, four case studies are presented as appendices. Because some of the terms used are new to New Zealand forest practice, a full glossary is included (Appendix 4).

CCF has been defined as "the use of silvicultural systems whereby the forest canopy is maintained at one or more levels without clearfelling" (Mason *et al.*, 1999). To achieve this, felling is carried out continually or irregularly through the whole of the forest area followed by regeneration, and there is no clearfelling of stands when trees reach some pre-determined age (Helliwell, 1999). As a general rule the clearfelling of areas wider than two tree heights is avoided and this means that felling coupes are, in practice, less than 0.25 ha in area.

A more suitable definition for New Zealand conditions is: the management of forests by following natural processes so that the forest canopy is always maintained at one or more levels and the forest will largely self regenerate. Harvest removals will be undertaken as single tree or small coupe fellings so that biodiversity, soil and water values, and the landscape are not compromised. However, it must be noted that some natural processes are quite large, sometimes cataclysmic, as with areas of beech forest several hectares in extent being blown down.

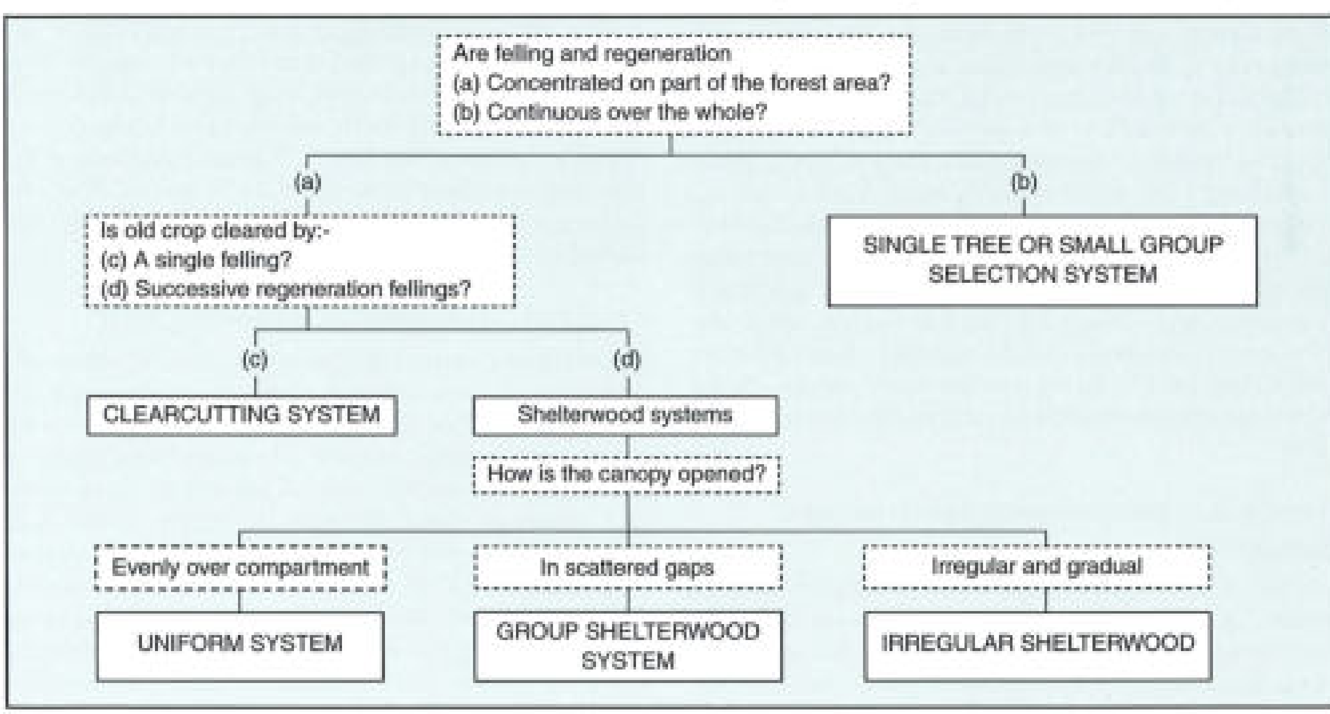
Sustainability is at the heart of CCF and in a timber-producing forest this means that the annual or periodic cut does not exceed the annual or periodic increment. With CCF the ability to maintain the forest canopy and protect, to a much greater extent than with clearfelling, the ecology and biodiversity of the site means that CCF is a system which is almost ecologically sustainable.

There are many alternative names for CCF; for example, Dauerwald (lit. constant forest), ecological forestry, selective cutting, close to nature, near-natural forestry, positive impact forestry, low-impact forestry, and holistic forestry (Benecke, 1998a,b; Helliwell, 1997; Pommerening & Murphy, 2004; McEvoy, 2004). Basic to all of these terms is the concept of maintaining forest cover as complete as possible. It must be understood that CCF is not a silvicultural system, but rather a method of management which can be based around one or more silvicultural systems. These can be arranged along a gradient, depending upon the degree of stand interference, viz

Single tree selection < group selection
< shelterwood < clearfell

An important part of the process is the selection and maintenance of frame trees around which the stands are built. As well as ensuring the appropriate size-class distribution of trees, selection concentrates on the better timber species, better quality trees, and those more suited to CCF practice; the reverse "J" curve is a guide to achieving this. Possible systems are outlined by Matthews (1989) and are illustrated in Figure 1.1 (also see Glossary).

FIGURE 1.1: Classification of the main silvicultural systems (adapted from Kerr, 1999)



One of the most important aspects of CCF is that it can include a wide range of forest uses with minimum compromise and without needlessly affecting the health of the forest. Management of the forest for such important environmental and social factors as bio-diversity, natural ecological processes, landscape protection, recreational use, and soil and water values is as important a part of CCF as economic viability (Benecke, 1997, 1999; Matthews, 1989).

In a world becoming increasingly conscious of environmental degradation, CCF must be regarded as a viable option for forest management. This especially applies to the growing of high-quality timbers as opposed to fibre wood growing — which, because fast-growing light-demanding species are used, will remain the province of clearfell forestry.

1.1 OBJECTIVES AND PRINCIPLES OF CCF

The overriding objective is to maximise the forest benefits outlined in the definitions above, while letting natural processes do as much work as possible; that is, basing the whole process upon the ecology of the natural forest (Helliwell, 1999; Matthews, 1989) (Plate 2 No.6). Thus natural regeneration is preferred to planting, single tree or small coupe felling to clearfelling; unproductive thinning is minimised, there is no age-based rotation, and species natural to the site are preferred (Helliwell, 1999; Benecke, 1999).

Principles 1 to 4 have been adapted from those defined by the CCF Group of Great Britain as outlined by Helliwell (1999). Principle 5 is included to cover the special circumstances relating to the management of New Zealand's indigenous forests. Note that Part IIIA of the Forests Act 1949 embodies all of the principles.

Principle 1: Adapt the forest to the site

Work with the site and its inherent variations rather than attempting to impose some form of artificial uniformity. In particular, species must either grow on the site or be known to be suited to the site; for example, kahikatea could be sited in wetter areas and totara in drier. When establishing a new forest on bare ground, work within the ecological patterns that are expected to occur locally. Or if attempting to establish a species outside its normal range (which would include all exotics), but on a site which is in other ways compatible for that species, adapt the process of establishment to the ecological processes in its natural habitat. If creating a mixed forest, species should be not only site compatible but also compatible with each other.

Principle 2: Adopt a holistic approach to forest management

Instead of concentrating upon the growing of trees for timber, CCF operations are intended to create, maintain, and enhance the functioning ecosystem. Although one of the main aims of the system is to produce timber, the forest must retain features of the wild forest (for existing indigenous forest this is covered by Part IIIA of the Forests Act). Because the silvicultural system used is based upon ecosystem management, higher values for factors such as biodiversity, landscape protection, and soil and water benefits can be obtained. For example, an exotic forest in New Zealand will rapidly become home to a range of indigenous species, carried in by wind and birds.

Principle 3: Maintain forest conditions and avoid clearfelling

The maintenance of forest conditions is an essential tool in achieving the aims of CCF. Clearfelling and excessively large felling coupes modify the forest floor to an unacceptable extent unless, as with *Nothofagus*, the species regenerating is likely to be subjected to large-scale natural processes such as windthrow (Plate 1 No.4). CCF harvesting processes, with single tree or small coupe removal, ensure that the forest floor and the soil structure are maintained in a condition as natural as possible for that ecosystem.

In New Zealand the natural regeneration processes are dictated, at least in part, by natural disturbances — usually wind but sometimes snow, flood, vulcanism, or fire. Several species, notably the beeches, have evolved survival strategies to accommodate this and are able to rapidly regenerate disturbed areas.

CCF processes must maintain the vertical structure of the forest. Although beech forest may have only two or three strata, other New Zealand indigenous forests usually have four fairly clearly definable strata (dominant, sub-dominant, shrub, and ground). Because the plants in each stratum are important parts of the ecosystem, their individual integrity is vital to the ecological integrity of the forest.

A vital factor in maintaining forest conditions is the method of harvesting. This must be built around low-impact methods such as helicopter extraction and small-scale ground haulers (cable, wheeled and tracked); even horses may have a role here. Of great importance is the planning and layout of the forest road network. When re-creating a forest on bare ground, planning for extraction should be done before planting.

Principle 4: Management of the growing stock.

Stand improvement is concentrated upon the development of individual trees rather than stands or compartments of trees. Therefore the manager will usually select for retention rather than removal. The main characteristic of the approach is that yield control is based on regeneration and increment (stem diameter and height) rather than rotation, stand volume, and area (Hawley & Smith, 1954). Thus CCF is not of itself a silvicultural system; rather it uses that silvicultural system which is best suited to the site ecology of the species at the time. At different stages of growth or conversion to CCF from another management system, different silvicultural systems may be required (for a more detailed explanation refer to Chapter 3).

Principle 5: Indigenous forests

The ecological approach implicit in Principles 1–4 forms the cornerstone of CCF; additionally, and as far as the management of New Zealand indigenous forest is concerned, the forest manager requires a good understanding of the ecology of individual species and the forest types where these are found.

1.2 HISTORICAL BACKGROUND

European

One of the most important components of CCF is sustainability, the forestry concept of which probably originated with the German forester von Carlowitz in 1713. It was his countryman Gayer who first developed sustainability into a silvicultural system. In France and Switzerland, foresters Gurnard and Biolley began to develop selection systems and the Swiss forest Couvet has been managed in this way since 1889. But it was another German forester, Möller, who in1922 took Gayer's ideas and developed them into the modern concept of CCF (Möller, 1923). To Möller the forest is an organism where cautious management follows natural successional processes (Benecke, 1996, 1999), in contrast to the wood factory that many modern forests have become. Forests managed using CCF principles continue to function in Europe, although there was a decline in interest after Möller's death as critics of the system succeeded in discrediting it in favour of plantation forestry. To meet its growing wood demands, Europe had opted for plantations with clearfelling. In this the Europeans were followed by countries like New Zealand which had rapidly depleting wood supplies from natural forests, while others — for example, U.S.A., Canada, Brazil — continued to exploit their natural forests, often unsustainably (Pommerening & Murphy, 2004).

In the 1980s the incidence of forest decline, following the phenomenon of acid rain, revived the debate on CCF. The discussion was given impetus by the severe storm events in Europe during the late 1980s, which damaged large areas of forest, and by severe flooding. Since the Rio de Janeiro summit of 1992 the climate warming syndrome has further forced governments and forest managers to rethink their overall forest strategies (Pommerening & Murphy, 2004).

In Europe today the movement from clearfelling and uniform conifer plantations to CCF gathers momentum and has strong support from small private owners (Benecke, 1998a; Mason *et al.*, 2004). However, this change is taking place largely with species indigenous to Europe (the main exception being Sitka spruce (*Picea sitchensis*)), is supported in most countries by cohesive forest law, and is underpinned by subsidies (I. Platt, pers comm.).

Early New Zealand

As early as 1874, management concepts similar to those current in Europe were placed before the New Zealand Government with the suggestion that these methods be applied to New Zealand's indigenous forests (Benecke, 1996). The move to better utilise New Zealand's indigenous forests began in 1868 when T. H. Potts, the man widely regarded as New Zealand's first conservationist, supported by Major Charles Heaphy, proposed the following motion in the House of Representatives: "That it is desirable government should take steps to ascertain the present condition of the forests of the Colony with a view to their better conservation" (N.Z.P.D., 1868).

Several years later this was followed by the first survey of New Zealand forests when the Government requested the Provincial Governments to provide details of the forests in their regions. The report duly appeared (Hector, 1874) with the quality of the Provincial response varying considerably. Auckland claimed that its forests were "generally valueless except for firewood and fencing, with occasional patches of kauri". On the other hand Otago's report was complete and reasoned.

Included with the provincial reports were several papers written by Captain Inches Campbell Walker, at the time Deputy Conservator of Forests, Madras (India), whom it was proposed to make New Zealand's first Conservator of Forests.

Campbell Walker had come to New Zealand at the invitation of the Premier, Julius Vogel, to investigate and report on the forests. In his report Campbell Walker re-emphasised the issues raised in his publications, and in earlier publications by others. While he advocated the supplementation of timber supplies from indigenous forests by the establishment of plantation forests, he was also strongly supportive of placing indigenous forests under sustainable management for wood production.

In his reports he wrote about the practice of forestry in the United Kingdom and Germany and outlined some of the forest management methods then current in Europe. In his summary Campbell Walker urged taking steps to:

> "… improve our 'Plenter-betrieb' or selection of single trees to be felled so as to gradually arrive at groups of trees of the same age, description and class and eventually at blocks worked in rotation, and containing always a sufficient stock of crop coming on to meet the requirements of future years. To arrive at all this the most careful observations and experiments will have to be made as to the rate of growth and yield per acre of each description of forest, the condition under which trees grow best and form the most timber, some requiring close and some open planting, some nurses and some not, some, like the oak, requiring a great deal of light, while others, like the beech, do well for many years in shade" (Campbell Walker, 1877).

Campbell Walker was not received with great favour by the colony of New Zealand; in fact, he was denigrated by newspapers and politicians alike — usually with false calumnies. So he left New Zealand and we lost the opportunity to retain the services of an extremely well-qualified and experienced forester (Brown & McKinnon, 1966).

Unfortunately New Zealand not only lost the services of Campbell Walker but the proposals he recommended fell on deaf ears, as have subsequent urgings to better manage New Zealand's indigenous forests. In fact, apart from brief spasms of interest in sustainable forest management, Governments of more recent years have demonstrated a similar lack of knowledge and interest in this subject.

New Zealand — the last 100 years

By the early 1900s forestry in New Zealand had begun to go down the even-aged, exotic plantation track. Matthews (1905) explained that natives were disregarded because their slow growth rate meant that their management would not pay. This hypothesis was based upon the minimal growth rate information of the time, gleaned largely from slowly growing natural forests. According to Matthews, the time required to produce millable timber ranged from 130 years for red beech to 600 years for kauri. However, it was still maintained that existing indigenous forests could be managed in perpetuity using group selection systems, Hutchins* proposing single-tree and group selection systems for kauri (Hutchins, 1919).

While the era of the Forest Service (1919–87) saw considerable effort made to sustainably manage indigenous forests for timber production, early efforts were spasmodic and tended to concentrate on mature stands instead of the more amenable regenerating forests.

Ensor (1954), reviewing the situation pertaining to beech, stated that harvesting up to that time had been confined mainly to high grading which often left the forest in a derelict condition. He recommended that beech forest, depending upon the age class and stocking present, could be managed either by a selection or a uniform system. This approach was supported by others (Conway, 1952; Gleason, 1982). Wardle (1984) contrasted single-tree removal with conversion of beech forest to even-aged forest plantation and rejected both, opting instead for a management system which imitated natural processes (see Appendix 3a). The objective was to manipulate the beech canopy in order to increase the light reaching the forest floor (Plate 1 No.2). This is best achieved by creating gaps of a size sufficient to encourage regeneration of desirable species. Recommended gap size was 20 to 30 m (320–700 m^2), or not greater than the height of surrounding trees. Since 1998 the 11 580-ha Rowallan Forest in Southland has been managed as a continuous cover forest, albeit with coupes to 0.5 ha, by Lindsay & Dixon Ltd (R. May, pers. comm.). Their management system has evolved to one based on "Tree Selection Areas" as the basic management tool. Forest management is based upon a custom-built digital forest management and record system which includes a geographical information system (GIS), and has been operating since 2005.

Studies on rimu centred mainly around the apparently even-aged, almost pure stands in Westland, Taupo, and Whirinaki. An early study (Chavasse & Travers, 1966) concluded that selection management of these stands would be twice as productive as attempting to manage them as even-aged stands. Attempts were made to test this by strip felling and selectively logging — using patch felling (Plate 2 No.8), group felling, and single-tree removal — and scarifying to increase regeneration (Gover, 1972). Later examination of these trials and the establishment of new ones concluded that losses of trees post harvest, by windthrow and death, were too high and that if they continued the stands would either fail or take at least 60 years to return to pre-logging volumes (James & Frank, 1977; Herbert & Beveridge, 1977; Herbert, 1980; Six Dijkstra *et al.*, 1985). More recently the use of helicopters for single-tree extraction has enabled a sustained management approach of minimum intervention to be used (Hammond & Richards, 1995). Unfortunately the recent untimely cessation of this management process in Government-owned forests of Westland has meant curtailment of work in this area. Another issue is the lack of data from helicopter-logged areas; we cannot yet say with confidence that the minimal disturbance caused by helicopter logging will be sufficient to induce regeneration, especially podocarp (I. Platt, pers. comm.).

Kauri management studies originally concentrated on the extraction of mature trees, but the large size, often dense stands, and poor soils involved proved unsuitable for sustainable management. The emphasis has moved to second-growth stands which can be successfully managed using single-tree and group selection (Halkett, 1983; Barton, 1999) (Plate 1 No.3). Recent investigation has revealed that one man, Rudolf Hohneck, managing his own forest at Mangatawhiri in the Franklin District between 1926 and 1956, succeeded in developing workable principles for the management of regenerating and cutover kauri forest. The secret of his success was to fully utilise all material from firewood to kauri poles down to 15 cm small-end diameter, and to encourage regeneration and growth by manipulating the forest canopy (Barton, 2007).

Today the practice of CCF in New Zealand is beginning to gather momentum. Udo Benecke has written several articles and papers about its use with indigenous forests and some farm foresters are beginning to consider the adoption of these principles (Cairns, 2001). At least one district council, Franklin, has included a definition of CCF in its rural planning proposals.

* Sir David Hutchins was a British forester with a successful career in India, South Africa, East Africa, Australia, and New Zealand, and was the first British-born forester knighted for services to his profession.

1.3 CCF COMPARED WITH OTHER FOREST MANAGEMENT SYSTEMS

One of the most important advantages of CCF is that a much larger proportion of the growing stock is in large, high-value trees. Small trees occupy relatively little space in the system compared to plantation forestry. This is because, as far as possible, the size-class distribution is maintained vertically instead of horizontally, and so the site is utilised more efficiently (Figure 1.2) (Plate 1 No.1; Plate 2 No.7). What follows is that a greater volume of wood in any one stand is contained in large-diameter, high-quality saw and veneer logs than would be the case in clearfell systems. The silvicultural process periodically removes appropriate numbers of large trees, less vigorous trees, and poor-quality trees with minimal damage to the stand. This enables the bulk of volume increment to accrue on the best trees by giving them space to grow. Over time the standing volume of timber can be considerably higher than for plantation systems. For example, mature kauri stands can carry up to 3000 m^3 wood/ha, while regenerating stands can exceed 1500 m^3/ha (Silvester & Orchard, 1999). By comparison, *Pinus radiata* seldom exceeds 900 m^3/ha on a 40-year rotation (Weston,1957), although Wardle (see Appendix 3a) expects to produce up to 1200 m^3 from his original crop of *P. radiata*. However, it may not be possible to achieve high volumes of timber per hectare from New Zealand podocarp/broadleaved forests because of the relatively high number of non-productive species found within these forests. Removal of this non-productive wood (e.g., scrub hardwoods and tree ferns) could mean that the composition and structure of the forest are considerably modified, which is in conflict with the third CCF principle (I. Platt, pers. comm.).

Continuous cover provides continuous and high-quality soil protection, especially on steep slopes. The constant forest cover reduces both soil exposure and loss from erosion. Such conditions provide a good germination medium for the seed of many forest species and the soil surface conditions, along with ground and shrub strata plants, provide protection from sunlight and drying winds. While conditions such as these are ideal for species such as tawa, kohekohe, and puriri, other species are adapted to regenerate on bared ground — the beeches are an example. They are thus more suited to a shelter-wood system. A further group of species (e.g., kauri, totara, rimu) are intermediate. While they will germinate under low light conditions, they require the increased light levels occasioned by the removal of canopy trees to grow at their full potential.

In CCF there is better retention of natural biodiversity, species composition, and a tiered stand structure. A much wider range of biodiversity can be accommodated in the varied habitat of the forest strata than in monocultural clearfell systems. This diversity is also considered to make the forests more disease resistant (OECD, 1996; Kneebone, 2000; PCE, 2002; Patterson & Cole, 1999).

As far as the landscape is concerned, CCF systems have little visual impact because, to the casual observer, the forests never seem to change. In fact, it is considered that well-managed selection forests can be more attractive than unmanaged forest or monocultures and this can bring benefits to the owner, the region, and the general public. This is largely because within the forest the landscape is usually more varied in appearance with a mosaic of thickets and tall trees which is attractive to walkers and riders.

The main disadvantages with CCF are higher cost and the need for a high level of skill and experience. In effect the process involves higher costs and lower yields at each harvest than even-aged forestry. More complex management requires skilled personnel who would be paid at a higher rate than most workers in even-aged forests. This is especially important in the selection of trees to remain, the selection and marking of trees for removal, felling those trees, and extracting them with minimal damage to the forest. Associated with this are the higher costs and skill levels required to carry out planning and inventory, and harvesting costs which are increased by the scattered distribution of trees to be harvested and cost of access construction and maintenance. If helicopters are used for extraction, costs are usually higher than for ground operations although roading costs should be less. It should be noted, however, that higher energy costs in the future may result in helicopter harvesting becoming uneconomic.

Because many of the species which can be used in CCF systems have high quality and high-value timber, the higher costs and lower yields of each harvest event are offset by the higher value of the wood being harvested. It is expected that, over time, the value of the wood extracted will be higher than for even-aged forestry (Benecke, 1996). However when indigenous forests, especially those dominated by beech or tawa, are brought under management, the yield of high-quality wood at the first harvest is likely to be low because of the higher proportion of poor-quality logs and heart rot (I. Platt, pers. comm.).

The differences between CCF management systems and clearfell forestry are many and varied. The advantages that CCF has are mainly related to timber quality and better environmental outcomes, while the disadvantages are concerned with higher operational costs and the need for much higher skill levels. A full coverage of advantages and disadvantages is set out in Appendix 1.

Finally, consideration needs to be given to the potential problems caused by changing ownership over an extended time span. These may require land use planning or forest laws which take account of longer growth cycles. This matter is dealt with in detail in Chapter 4.

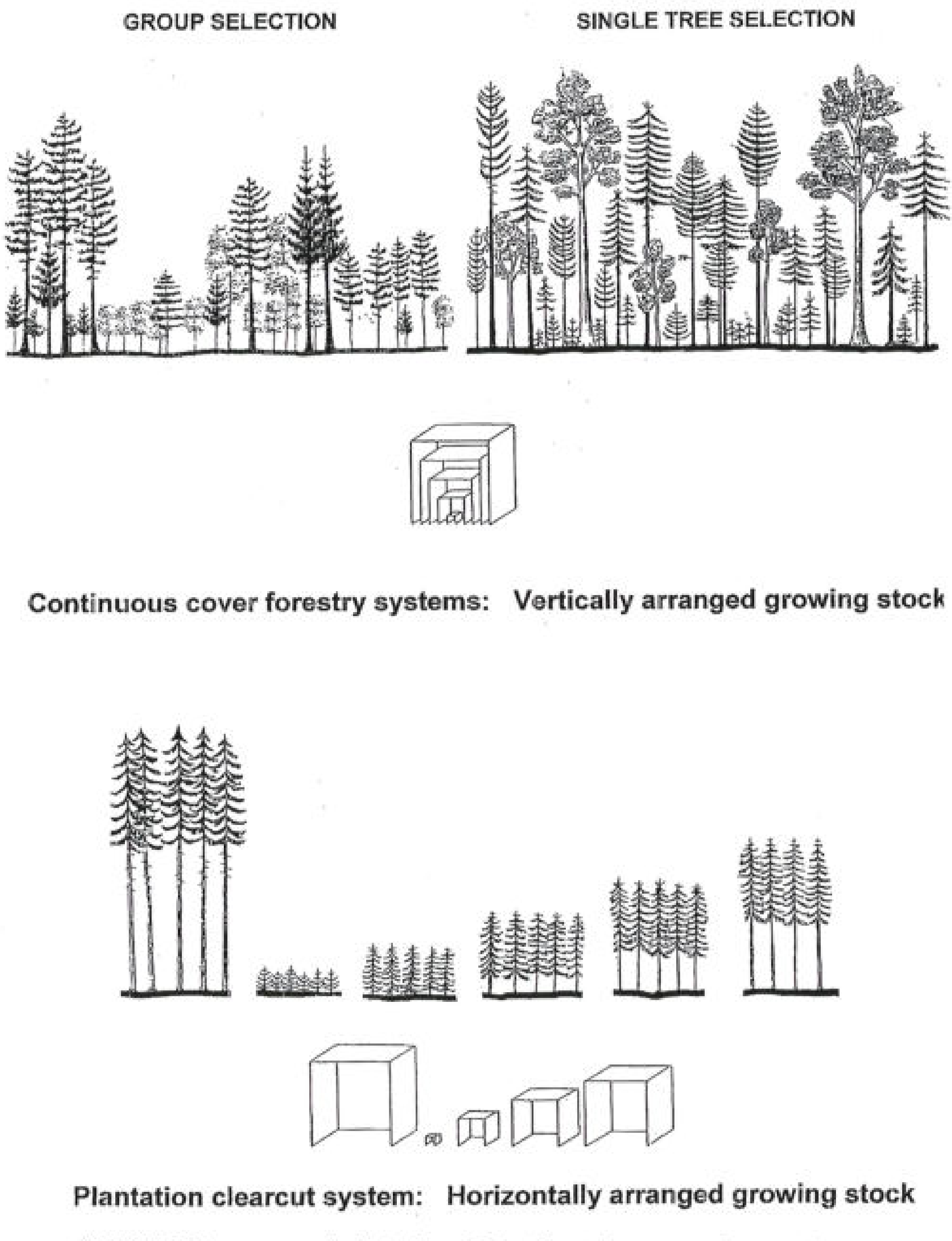


FIGURE 1.2: Uneven-structured selection forest (CCF) with vertical integration of species and size-classes, compared with horizontally arranged growing stock of the plantation clearcut system (adapted from Benecke 1996 and Matthews 1989)

CHAPTER 2: CREATING THE CONTINUOUS COVER FOREST

Depending upon the age and condition of the existing vegetation there are five possible courses of action when establishing a continuous cover forest.

(1) Establish a new forest on bare land or grassland;

(2) Convert a young, even-aged forest or scrubland to CCF;

(3) Convert cutover indigenous or under-stocked exotic forest to CCF;

(4) Convert a mature, even-aged plantation to CCF;

(5) Commence production from an indigenous forest reasonably stocked with mature trees.

The first option, creating a new forest from bare ground, initially requires determination of desired stand structure followed by site and species selection, tree establishment, and animal control.

The other four options involve the treatment of existing vegetation and fall under the heading of conversion. This means changing from one management system to another, or the upgrading of a poor quality forest or scrubland area. These situations are considered later, and require a detailed inventory of the stand which is to be converted. Mason & Kerr (2004) propose that conversion be done in three stages and, while proposals described here follow their outline, they have been adapted for New Zealand conditions.

2.1 PLANTING A NEW FOREST

This approach, similar to that employed in establishing an even-aged forest, would be used on sites from which a forest crop has recently been removed by clearfelling, or which are currently in grass or other low non-brushwood vegetation. The former, depending upon which understorey species were present in the original forest and whether the removed crop or its understorey is able to regenerate from seed, may rapidly grow a plant cover. If it does then it should be treated as for scrubland conversion.

Treatment required will vary, depending upon species and the type of continuous cover forest proposed. Four major aspects must be considered before any work is done (*see* box).

> CCF Establishment — Initial Considerations
>
> **(1) Site conditions:** These are factors such as soil moisture, light requirements, wind, temperature (both means and extremes able to be tolerated). It may be possible to modify these to some extent (e.g., the effect of wind can be reduced by planting shelterbelts) but modification is usually expensive and often difficult.
>
> **(2) Forest composition:** This will depend upon what is required and able to be achieved but care needs to be taken to locate species according to their individual needs. If the site to be planted is sub-optimal for the species to be used, then nurse species should be chosen to ameliorate the growing environment (e.g., use *Acacia melanoxylon*, *Chamaecytisus palmensis* (tagasaste), or *Alnus* species as a nurse species to provide nitrogen).
>
> **(3) Growth conditions:** These are aspects such as competition from weeds and adjacent trees, the presence or absence of essential mycorrhizas, and the nutrient levels of the soil. Most such factors are reasonably easy to control or adjust and not too expensive.
>
> **(4) Cost:** The seedlings of some species are quite costly, and effective establishment may require close spacing. Using cheap filler plants which can also perform a nurse function can offset cost. However, with some species wide spacing may be possible. It is necessary to thoroughly understand the requirements of the species to be used; for example does it require the competition of adjacent plants to encourage straight, lightly branched, stems?

Once a decision has been made about the form of the new forest, the following general principles will need to be adapted as required.

Tree species

In selecting suitable species to establish new forests or upgrade existing ones, it is necessary to have a good knowledge of the requirements of those species — in particular, their shade tolerance and their tolerance of other species. For example, *Pinus radiata* is a light-demanding pioneer species which cannot usually be grown under other species, nor is it generally a good nurse because of the heavy shade cast and aggressive moisture uptake (however, *P. radiata* can be managed using CCF principles, the main determining factors being the size of the felling coupes and the overall stocking — see Appendix 3a). Another species, black walnut (*Juglans nigra*) has allelopathic tendencies in that the secretion of the chemical juglone from its roots will prevent other species from growing under its canopy or close by (Johnson, 1973).

As a general rule species best suited to CCF are those that are more shade-tolerant and the management systems adopted will depend on the shade tolerance of particular species. For example, more light-demanding species such as Douglas fir or totara might best be managed under a shelterwood system while those that are more shade-tolerant (e.g., blackwood or kauri) could be managed with single-tree or small-group selection. Exceptions to this rule are those species which, while strongly light-demanding, can be used as short-term nurse plants when a new forest is being established, those which will function as scattered dominants over shorter species, or those which are deciduous and will associate easily with shade-tolerant species. Examples of short-term nurse species are the many short-lived leguminous plants like tagasaste (*Chamaecytisus palmensis*), mycorrhizal species such as *Pinus elliottii* which has a beneficial relationship when planted with kauri, and species like *Betula pendula* which is a common nurse plant in the Northern Hemisphere.

Species most likely to be suited for CCF in New Zealand are listed in Table 2.1 and grouped according to their light and shade tolerances as currently understood. This table is a simplification because many intermediate species grow well in full light while light-demanding species require protection from strong winds. Detailed information on each of these species is contained in Appendix 2A; Appendix 2B lists limited information on a range of other species which could be considered for CCF.

Indigenous species appear to offer very good potential for CCF. This is because their growth processes mean that many of them, e.g., kauri, are shade tolerant when juveniles (and will in fact survive at very low light levels for many years) but become light demanders as they grow older, and need high light levels in order to grow and mature. It should be possible to plant new forests of single or mixed indigenous species, and manage them as continuous cover forests. Alternatively, mixtures of exotic and indigenous species could be used, with the exotic sometimes being used as a nurse (and possibly first harvested crop plant) enabling the indigenous species to become established more rapidly. With further research it is predicted that mixed exotic and indigenous continuous cover forests will be possible. However, if exotics are to be used for CCF in New Zealand, cognisance should be taken of the guidelines below, as set out by Pro Silva, to be applied when using exotic species in a CCF situation with indigenous ones (Helliwell,1999).

i Do not introduce exotics which will reduce or prevent growth of appropriate indigenous species;

ii Exotic species should not be so aggressive that they suppress or eliminate indigenous species;

iii Exotic species should be suited to the local climate and soils;

iv Exotics must not spread disease or destabilise ecosystems;

v Exotics must not run the risk of being seriously affected by pests, disease, or climate;

vi Exotic species should be able to merge reasonably with indigenous species without excluding indigenous flora and fauna.

When developing a continuous cover forest using a range of species, and especially when mixing exotic with indigenous species, the overall rule is "Be pragmatic but be careful." That is, learn what you can about the species beforehand and avoid using species which might be considered aggressive in the particular situation. For

TABLE 2.1 Provisional grouping of species by shade tolerance

Light-demanding species suitable as dominant emergents.	radiata pine (*Pinus radiata*)
Light-demanding but will grow as co-dominants in association with other species	Chinese fir (*Cunninghamia lanceolata*) Douglas fir (*Pseudotsuga menziesii*) puriri (*Vitex lucens*) red alder (*Alnus rubra*) rimu (*Dacrydium cupressinum*) tallow wood (*Eucalyptus microcorys*) tanekaha (*Phyllocladus trichomanoides*) totara (*Podocarpus totara*)
Intermediate species which tolerate shade as juveniles but generally require full light for maximum growth	black beech (*Nothofagus solandri*) eastern white pine (*Pinus strobus*) Japanese cedar (*Cryptomeria japonica*) kahikatea (*Dacrycarpus dacrydioides*) kauri (*Agathis australis*) Mexican cypress (*Cupressus lusitanica*) Ovens cypress (× *Chamaecyparis ovensii*) red beech (*Nothofagus fusca*) redwood (*Sequoia sempervirens*)
Shade-tolerant but will grow in full light	blackwood (*Acacia melanoxylon*) gean (*Prunus avium*) silver beech (*Nothofagus menziesii*)
Shade species which do not grow well in full light	tawa (*Beilschmiedia tawa*) western red cedar (*Thuja plicata*)

example, some pines and other conifers can aggressively invade indigenous vegetation types because they produce copious seed at a very early age, and Robinia, potentially a very useful nurse species as well as timber producer, has a widespread root system which can sucker many metres from the parent plant.

Nurse plants

Nurse crops can be either native or exotic and have a range of functions (Anon, 1998). The ideal nurse species should preferably be short lived but initially grow faster than the crop species although not so fast as to suppress it.

If a short-term nurse species is to be used it should (depending upon rate of growth) be planted 1 to 3 years ahead of the crop species. If all of the species to be used grow at a reasonably similar rate, then they can be planted at the same time. Information on possible nurse species is given in Appendix 2C.

Much more research into the use of nurse plants is required; e.g., further trials should be conducted with kauri, using *P. elliottii*, *A. melanoxylon*, and *Alnus* species to determine viable procedures. With *P. elliottii* this should include total removal of the pines when they are quite young — probably not more than 9 years old (see side bar) (Plate 3 No. 10).

Trials with other nurse plants are also required, especially using native species with which indigenous timber trees are naturally associated. Also needed are trials with other exotic leguminous trees and shrubs, using a wide range of mixtures to ascertain the compatibility of nurse and nursed species.

Nurse species may provide some or all of the following values:

- Shelter and enhanced stem form.
- Help with weed suppression.
- Especially if broadleaf, should hasten the formation and breakdown of litter.
- Can be used to provide nitrogen.
- Some can provide an intermediate timber or firewood crop.
- Fruiting and flowering nurse plants should encourage native birds.
- Using a cheap nurse will reduce tree costs.
- Can reduce frost damage to the seedlings of susceptible species such as kauri and puriri, or winter desiccation, wind damage, and cambium scald in beech species.
- With nurse species, it may be possible to use smaller-grade crop tree seedlings.

Results from a kauri nurse plant trial

A trial involving a range of nurse plants for kauri was established in the Hunua Ranges in 1974. This involved the planting of 10 × 10-m plots with 36 nurse plants at 1-m spacing. When these had established (over 2–3 years) 25 kauri seedlings were planted between the nurse plants in each plot. Although not adequately maintained in later years, the trial provided sufficient data to enable useful conclusions to be drawn. After 28 years mean survival and height growth of kauri with the various nurse species were as follows.

Mean survival

Acacia melanoxylon / Pinus elliottii mixture	71%
Alnus incana	64%
Pinus elliottii	58%
Acacia melanoxylon	55%
Pinus patula	52%
Control (no nurse)	46%
Robinia pseudoacacia	45%
Alnus glutinosa	43%
Kanuka	40%
Pinus radiata	25%

Mean height growth

Control (no nurse, open planting)	5.0 m (max. 10.0 m)
Alnus incana	4.3 m (max. 7.9 m)
Robinia pseudoacacia	4.2 m (max. 8.3 m)
Alnus glutinosa	4.1 m (max. 8.3 m)
Pinus elliottii	4.1 m (max. 11.0 m)
Acacia melanoxylon	3.5 m (max. 8.2 m)
Acacia melanoxylon / Pinus elliottii	2.9 m (max. 6.8 m)
Kanuka	2.8 m (max. 7.5 m)
Pinus patula	2.7 m (max. 4.8 m)
Pinus radiata	1.7 m (max. 2.6 m)

Growth in the control plots was best because the nurse plants in adjacent plots gave side shelter but full light was able to penetrate from above, probably the ideal situation for kauri growth.

Forking of the main stem of kauri was bad in the control, *Alnus*, and Robinia plots. This was almost certainly due to frost damage as the site in an enclosed valley is subject to quite heavy frosts and these species are deciduous. It was obvious that *P. elliottii*, the *Alnus* species, *Acacia melanoxylon*, and Robinia had some effect on kauri growth but kanuka, usually accepted as the natural nurse for kauri, performed poorly.

As a nurse *P. radiata* was a significant failure, probably because it extracts so much moisture from the upper soil layers. This factor may also have caused the poor response under kanuka.

Robinia should not be used in future because it has a very high propensity to sucker long distances from the parent plant.

Site preparation

Some basic operations may be required.

- Cultivation loosens the soil to permit easier planting, breaks up hard layers to allow deep penetration of roots, controls weed regrowth, and releases soil nutrients to plants. Cultivation can be done by hand or machine, and may be shallow or deep depending upon both soil structure and the requirements of the trees to be planted. Root penetration into compacted soil can be achieved by deep ripping of the soil, down to at least 1 m if possible. Criss-cross ripping with two or three tines about 0.5 m apart is best in most situations. Ripping of clay soils should be done only when the site is dry. Do not rip parallel to the direction of strong winds.
- Weed control can be achieved by cultivation (e.g., discing and harrowing of bracken sites when the fern is dormant, and after it is burnt off, prevents rapid regrowth for up to 2 years), by pre-plant spraying with a suitable herbicide — e.g., Glyphosate, Terbuthylazine, or Gallant NF (grasses only), or by the use of a mulch in the form of chipped bark or weed mats around trees. Hand weeding is not recommended as it is costly, time consuming, and not very effective. In some areas blackberry and pampas grass can be major weeds and must be controlled with appropriate chemicals. So too gorse and broom — note, however, that they can be managed as effective nurse species.
- Soil improvement — for example, the addition of lime will raise pH; application of gypsum to hard compacted clay soils will improve texture, drainage, and aeration; and trace elements or major elements may be required. However, it is important to ascertain the nutrient requirements of the species being planted before applying fertilizer. Many species, for example, thrive better in acid soils.
- Animal control — control of any animals which will injure young seedlings is imperative and can be done pre- or post-planting. Methods include shooting, poisoning, spraying seedlings with animal repellents, or protecting seedlings with physical structures. On some sites insects (e.g., grass grub) could be a problem.

Planting

In areas of milder climate the planting of most species is best done in the autumn, as soon as the ground is moist enough. Early planting gives seedlings a chance to establish before the ground becomes too dry the following summer. Losses from drought* can be quite severe if seedlings are planted late in winter and have not properly established before the next summer. However, best planting times will vary in different parts of the country; for example, heavy winter frosts will kill newly planted seedings and spring planting is preferred in this situation. The best approach is to plant when seedlings are well hardened off and at the time when they will get the longest possible period with reasonable soil moisture levels and lowest risk of damaging frost.

In most soils a hole one spade deep and one spade wide should be dug and well cultivated before the tree is planted. However, when planting in poor or compacted soils a pit at least 30 cm square and deep should be dug and filled with cultivated soil. A useful tip is to make a slight depression in the soil around the tree base so that when rain does fall moisture will collect around the tree; the reverse may apply in areas of poor soil drainage.

Releasing

It is vital to ensure that seedlings do not have to compete with weed growth, especially during the first 2 years. If a pre-plant herbicide spray has been done, sites should be checked again in late November and sprayed again if regrowth appears. If pre-plant weed control is not done, treatment will be required early in spring before the weeds overtop the tree. Even if mulches and weed mats are used, there can be regrowth and this is best controlled by spraying with the appropriate herbicide. Apply carefully to grass and weeds without damaging the seedlings by using a guard on the tip of the spray wand. It is important to spray a good area around each seedling, at least 1 m in diameter and preferably 1.5 m, in order to ensure that no moisture is taken from the seedling by grass and weed regrowth. The same distances also apply to mulch and weed mats. Respray as required for up to 2 years or until the plant begins to shade the area beneath it and so gain control of its site.

Moisture

To ensure good seedling establishment, for both CCF and even-aged plantings, the single most important factor is adequate moisture. In high rainfall areas this should not be a problem but in many parts of the country periodic water deficits will slow plant growth. Keeping weeds clear of plants and leaving a depression around seedlings at planting will help minimise this but in some places it may be necessary to consider irrigation or the use of water-retaining crystals.

* A drought should be assumed to exist when there is insufficient soil moisture to sustain plant growth. This could be after as short a period as 15 days without rain. However, the length of the period of drought before irrigation is required should also take into account soil type, wind, and sunshine levels.

2.2 CONVERSION OF AN EXISTING FOREST

When converting a plantation or land covered in any sort of forest to CCF the work required falls into three stages:

(1) Appraisal.

(2) Deciding the structure, silvicultural system, and species to be used. But note that for natural indigenous forest the process must comply with Part III A of the Forests Act (Anon, 2007) and some of the points outlined below may not be required.

(3) Conversion process.

Stage 1: Appraisal of the existing stand

Preliminary work

1. Species choice

Throughout the appraisal process, the species to be grown in the new forest must be considered. The choice of species could be sparked by some which are already regenerating; or it may come later when the removal of unwanted stems triggers regeneration. But it may also require the planting of some completely different species. The final decision must be made at the end of the appraisal process.

2. Site appraisal

Soil and site information is essential for areas under consideration for transformation to CCF, because many of the species which might be used are sensitive to micro-site conditions. For some areas, forest type maps and detailed soil maps may be available but, if site-specific information is not obtainable, the best guidance at present is from the New Zealand Land Resource Inventory Worksheets which are based upon standard topographical maps (Anon, 1970s). In addition to soil data, these contain information on geology, slope, erosion types and degree, and vegetation.

3. Risk of windthrow

Wind creates problems for forestry in New Zealand causing windthrow, desiccation, physical damage, and salt burn. However, it has not been recorded in a way which is useful in determining a site's vulnerability.Some data on wind are available on www.metservice.co.nz/default/index.php, select "Learning centre" : "climate data" : "summary of climate observations". As a rule, because New Zealand terrain is very variable, wind data of use to foresters and landowners are not available (S. Reid, NIWA, pers. comm.) and people need to make their own assessments based upon local knowledge. Some evidence of wind impact may be available from observation of existing forests, by noting the direction indicated by overthrown trees or by wind shear. If wind is likely to be a problem, choose species that are known to be wind-firm or, as indicated in Table 2.2, do not convert to CCF.

4. Climate data

Reasonably good data are available in New Zealand for other climatic factors and can be found by consulting the National Institute of Water and Atmospheric Research (NIWA) or earlier publications of the Meteorological Service (Hickman, 1980: Anon, 1983, 1984a,b, 1985a,b, 1986). More up-to-date but more generalized data can be found on the NIWA website www.niwa.cri.nz.

5. Soil fertility and potential vegetation competition

Since natural regeneration will generally be the preferred method of restocking CCF stands, sites must be chosen where conditions for this are favourable. Achieving successful natural regeneration is sometimes more difficult on fertile than on infertile soils because of greater vegetation competition, and because very fertile soils sometimes produce unwanted growth characteristics in some tree species. Adequate fertility levels for individual species may vary and some information about this can be found in the species sheets (Appendix 2). In general, the best forest soils will be those in the medium fertility range.

6. Suitability for conversion

The current vegetation on the site has to be suited to conversion. It should also be realised that on many sites species from neighbouring stands may also regenerate, seed being bird or wind-distributed.

7. Preliminary site ranking

Windthrow risk and site fertility are the two most important factors to consider at the beginning of site assessment. When combined as outlined in Table 2.2, they can be used to rule out obviously unsuitable sites and to assist with preliminary assessment of others. This assessment is not precise because it is usually only able to be derived from the owner's knowledge of the site, although some soil information is available for individual areas from published sources.

Detailed stand appraisal

Once the initial selection has been completed, the potential CCF stands should be inspected in the field, with particular attention to the following features.

1. Stand structure and quality

Examine the structure and composition of the candidate stand. Points to consider include:

- ➢ Are those tree species to be retained clearly suited to the site and of good genetic quality?
- ➢ Are there sufficient trees with well-developed crowns that can act as potential frame trees, seed bearers, and nurse plants for the new crop; or, when poor trees are felled, is there potential for coppice regrowth which can be retained and managed to form a new crop?

TABLE 2.2: Suitability of existing forest types for conversion to continuous cover

Score	Windthrow Risk of site	Soil fertility and depth
1	Low wind risk areas	Medium fertility, deep soils
2	Moderate wind risk areas	High fertility and / or shallow soils
3	High wind risk areas	Low fertility & Shallow soils

FOREST TYPE PRIOR TO CONVERSION
Good quality indigenous forest
Degraded indigenous forest
Mixed exotic forest
Mixed exotic/indigenous forest
Reverting indigenous or exotic scrubland
Exotic monoculture

Wind score	Soil fertility & depth score	
1	1	All forest types very well suited for conversion to CCF
1	2 & 3	All forest types moderately suited to conversion to CCF
2	1 & 2	All forest types poorly to moderately suited for conversion to CCF
3	1 & 2	Exotic monocultures not suited for conversion to CCF. Other forest types low suitability for conversion
3	3	No forest types suited for conversion to CCF

(Based upon Mason & Kerr, 2004)

- Is there evidence of recent windthrow to suggest that stand stability may already be at risk? If windthrow has occurred, is it confined to small wet areas of inherently low stability or exposed edges which do not compromise the rest of the stand?
- Are the stems to be retained of adequate quality? For example, stems damaged by bark stripping may be at risk of timber degrade if retained.
- Are you confident of obtaining natural regeneration or coppice regrowth of the desired species, or will planting be required?

2. Advance regeneration

The presence of advance regeneration (i.e., seedlings and saplings present beneath the canopy) is a good indicator of the success of natural regeneration because it shows that conditions within the stand are favourable for seedling germination and growth. If it is present, is it acceptable — consider the density and size of seedlings present, as well as the species concerned and their form? (Table 2.3) A low to moderate, even a high density of small seedlings does not guarantee likely regeneration success since these seedlings may be lost through browsing, insufficient light, moisture stress, or physical damage when the stand is opened up. In many cases, further seedling recruitment during the transformation period will be necessary to ensure adequate stocking.

TABLE 2.3: Criteria for assessment of stocking and size of advance regeneration

Mean height	Stocking (seedlings/ha) Low (1)	Moderate (2)	High (3)
< 20 cm	Unacceptable	Unacceptable	Marginal
>20 cm	Unacceptable	Marginal	Acceptable

1 < 100 seedlings/ha
2 In range 100–1000 seedlings/ha depending upon age of stand, site, desired future structure, and spacing of seedlings.
3 In range 1000–2000 seedlings/ha depending upon age of stand, site, desired future structure, and spacing of seedlings.

If there is no advance regeneration, try to assess what factors are responsible. These may include the age of the stand (because stands less than 20–25 years of age may have low seed production and limited potential for regeneration), the regeneration processes of the species concerned, the light environment within the stand, the degree of browsing pressure and vegetation competition. These factors can change over time and may respond to appropriate management so that conditions become more favourable. Consider also whether coppice regrowth is possible and can be utilized, or whether some planting may be required.

3. Ground and shrub flora

The type and quantity of ground vegetation present vary with site and depend on factors such as soil structure and fertility, moisture availability, tree species, and canopy cover. Natural regeneration will be favoured where competitive weeds such as bracken, blackberry, grasses, or native ground and shrub species such as kiokio (*Blechnum novae-zealandiae*), tree ferns, and dense broadleaved shrubs, are either absent or sparse. Where such vegetation dominates the site, cultivation combined with weed control will be essential for any chance of natural regeneration. In such situations, it may be more sensible to consider planting, especially on moist fertile sites.

4. Litter

A deep litter layer (>5 cm thick) can present a barrier to regeneration. Seed, especially if small, will often germinate in such material but is unlikely to survive unless roots can quickly penetrate into mineral soil to access the water and nutrients required for growth. A thick litter layer will require disruption through scarification for regeneration to occur.

5. Animals

Deer, goats, rabbits, hares, and possums will all browse advance regeneration, while possums, rats, mice, and birds will eat seed on the tree and/or on the ground. Each of these factors must be carefully assessed by observation and inspection. As a general rule in Europe, ungulate densities are acceptable when there are fewer than 5–10 animals per 100 ha otherwise they must be excluded from areas by fencing. Even lower animal densities will be necessary if the tree species being used are preferentially browsed (e.g., Douglas fir, most broadleaves, and natives). Other factors affecting the impact of animals are having preferred non-timber species (e.g., mahoe) to attract animals away from trees, or the preferences of some animals for particular sites, e.g., sunny aspects.

6. Access and topography

Access to the stand for harvesting and ongoing management must be considered. In general, CCF stands require a regular network of within-stand tracks linked to extraction roads so that damage to regenerating seedlings by harvesting machinery is limited. These tracks need to be robust and well constructed to ensure long-term machinery access to the stands. The layout of this extraction network must be considered before any stand management to favour CCF.

7. Summary

Use the above features to adjust the initial ranking of the site and decide on the likelihood of success with CCF. Although varying with the silvicultural system used, the most suitable sites are likely to be those with little or no browsing, the presence of desirable advance regeneration, an appropriate stand structure (i.e., adequate numbers of desirable trees in each stratum), and ground flora and litter conditions conducive to seed germination and seedling survival. The topography must be amenable to easy access unless helicopters can be used. If any of these conditions are not met, then the decision to proceed must be influenced by the remedial actions required, as well as feasibility and likely cost.

Stage 2: Structure and Silviculture

The next issue to decide is an appropriate silvicultural system, based upon the presence or absence of suitable cover-building or frame trees, the shade tolerance of the species concerned, and a stand structure that will achieve the management objectives (however, refer to Section 2.2 for comments on natural indigenous forest). In essence, a decision must be made between:

(1) A simple structure in which there will be at least two strata, and no more than three species in total.

(2) A complex structure with three or more strata comprising several species.

The decision will also depend to some extent on the species involved and the intended harvest method. Group shelterwood systems are generally more appropriate to simple structures with one or two species involved (e.g., *Picea* species and *P. radiata*). Complex systems, like kauri with associated podocarps, are probably better managed using single-tree selection.

If possible, find stands within the forest, or on neighbouring properties, that embody the desired structure. These can be used as reference points for future management. It may be that, at a landscape scale, more than one structure is needed to promote greater visual and habitat diversity. Once the target structure for a given stand has been decided, choose the most appropriate silvicultural system. Figure 1.1 (adapted from Mason *et al.*, 1999) illustrates the differences between the main silvicultural systems, and more detail may be found in the glossary. Note, however, that a forest area containing several different stands may require more than one silvicultural system. A simple structure is produced by the uniform and group shelterwood systems, whereas a complex structure will result from an irregular shelterwood or a selection system. The chosen system can be modified to allow for the shade tolerance of the species concerned (Mason *et al.*, 1999). For example, use of group shelterwood with larger gap sizes (up to 0.2 ha) will be more suitable for light-demanding species.

Stage 3: Beginning the Transformation

Once the desired structure and silvicultural system have been determined, decide how to begin transforming the chosen forest area. The course of action will depend upon the current age of the forest and its life expectancy, but it must be accepted that it may not be possible to complete the transformation process within the life of the existing trees in the forest. For example, if a complex structure is desired but the trees now present are mature, the best that can be anticipated within 30 years is for a simple structure to develop, with regeneration establishing under a few surviving overstorey trees. Further development toward a complex structure would be accomplished by the management of the regenerated successor stand.

The presumption is always that natural regeneration will be favoured wherever possible in order to minimise establishment costs. However, under-planting can also be used if it is necessary to introduce desired species that are absent from the site, or to introduce improved genotypes, or to speed the process. For example, the planting of kauri into a scrubland site which would eventually have regenerated naturally to kauri will shorten the time to harvest size by at least 20 years. Alternatively, planting a smaller number of trees from selected parents and allowing natural regeneration to provide the bulk of the trees in the stand can reduce the costs of introducing improved stock.

As outlined at the beginning of this chapter, there are four possible courses of action, the choice depending upon the origin, age, and complexity of the forest.

CONVERSION OF YOUNG, EVEN-AGED FOREST OR SCRUBLAND TO CCF

Here there is already a vegetation cover of young, usually even-aged plants which can be in one of three sub-categories:

- Indigenous scrubland regenerating after clearance, usually by fire and perhaps with an intervening grassland cover; there could be some incipient indigenous tree regeneration.
- Exotic scrubland regenerating from grassland or cleared exotic forest. Gorse and broom are the usual species but this category can also include species such as willow or woolly nightshade.
- Plantation of exotic species less than 10 years old.

As a general rule an initial inventory of the site will not be required unless there is marked variation in cover type, or parts of the area already have regeneration present.

An example of the first category, from northern New Zealand, would be a site which has been cleared of bush, probably by fire, and which has regenerated to kanuka. Scattered through this are small kauri poles, which became established fairly early in the kanuka succession. These are now seeding out into the kanuka but development is slow because the kanuka is too dense, and the site probably too dry, for the rapid regeneration of kauri (Plate 3 No.9; Plate 4 No. 15 & 16).

A second category example could be a stand of gorse which can be used as a nurse to enable successful establishment of a species like totara which, unless there are seed trees present, would have to be planted.

Into the third category falls the conversion of a young *Pinus radiata* stand to another species. Opening gaps in the pine, underplanting with the desired species in groups, and then thinning out the *P. radiata* nurse in stages would be the best method to follow.

The choice of silvicultural system for these stands depends upon whether one or several species will be involved, and on the pattern of any natural regeneration. If the resultant crop of desired seedlings is regular, abundant, and consistent then a uniform shelterwood may be appropriate (e.g., *Nothofagus* species). If sporadic and in groups, such as patches of young kauri, then the single tree or small group selection approach could be more appropriate. If several species are planted or regenerating, single-tree selection or group shelterwood is the preferred silvicultural method. During this phase thinning is done to release advance regeneration but does not usually take place in anticipation of regeneration. If natural regeneration is not successful, planting may be required, using the overstorey to shelter the newly planted trees.

Thinning practice is based upon that used in conventional even-aged forests but done lightly and frequently to encourage the gradual development of the crowns of trees selected as frame and seed trees. It will be helpful to mark these trees so that there is continuity in the pattern of thinning. Depending upon species, natural regeneration could occur as early as 10 years of age which is about the time it takes for a fast-growing native tree to begin seed production.

CONVERSION OF CUTOVER INDIGENOUS OR UNDER-STOCKED EXOTIC FOREST TO CCF (PLATE 7 NO. 24 & 25)

Because forest areas of this type will be quite varied, an inventory is the first requirement. Two inventory methods, fixed area plots and variable area plots, are outlined in Appendices 3b and 3c, although more trials are required before either system is perfected for New Zealand conditions. Their main advantages are ease and speed of establishment. During the inventory, frame and seed trees located on plots should be selected and marked and a plan prepared showing their location as well as the locations of different stands of trees.

In cutover indigenous forest, Section IIIA of the Forests Act 1949 will apply but it is likely that the area can be demarcated into different stand types, for example:

- Stands of larger, mature and semi-mature trees;
- Stands of advanced regeneration;
- Stands with advanced seedling regeneration or where planting is desired;
- Stands where desired regeneration is limited by factors which can be controlled — e.g., the grubbing of ground ferns in a beech forest;
- Stands containing tree ferns and woody shrubs with no potential commercial value.

However, if the forest is a degenerated exotic area, regeneration is likely to be poor or non-existent and planting will be needed. If a species such as blackwood is present, coppice regrowth can be utilized.

The first step is to devise the appropriate treatment for each stand type, with the encouragement of regeneration as the main objective. An important task is the removal of poor quality trees, unless they are required as nurse trees to reduce potential wind damage or for animal habitat, and the clearing of such sites to allow for regeneration and the faster growth of any seedlings already established. If regeneration is not possible or it is desired to introduce species not currently growing in the stands, planting will be required, as will effective weed control. The latter aspect is one of the most important tasks and one most frequently overlooked. To ensure that does not happen, a programme should be implemented which provides for releasing over a 5-year period. In kauri and podocarp / broadleaved forest areas the control of tree ferns is probably the most important aspect of this; in beech forest it is the control of ground ferns.

The initial aim should be the development of at least three forest strata: the canopy of dominant residual forest trees, the establishment of a well-distributed sapling strata, and seedlings becoming established on the forest floor. As some of the saplings grow to sub-dominant status, a process that could take up to 50 years, a full forest structure will be in place. At this stage, the forest has completed its transformation and will have developed the reverse "J"structure traditionally identified with classical selection systems.

CONVERSION OF A MATURE, EVEN-AGED PLANTATION TO CCF:

One method is gradual thinning from above (i.e., by removing larger trees — see Appendix 3a) thus creating a shelterwood until light conditions increase sufficiently to allow regeneration. Another method would be to divide the block into equal areas (group or strip) and fell one area every year or so, replacing the trees with an appropriate mixture of species for CCF. If the species being felled is to be the only one in the new forest, the felling coupes should be as large as required to encourage regeneration (Plate 2 No.8) and care must be taken to select and retain suitable frame trees. If it is to be only one of several species, then it should be allowed to regenerate with the other species in the mixture planted as required. If the original species is to be completely replaced with others, then it must be prevented from regenerating.

Helliwell (1999) quotes the example of the conversion of a Douglas fir plantation 10 ha in area and 35 years old. The conversion process envisaged regenerating small groups every five years for 35 years, i.e., 12.5% of the area to be felled each time. If the average group size were set at 1500 m^2, then eight of these groups would be felled every 5 years.

COMMENCE PRODUCTION FROM A MIXED INDIGENOUS FOREST REASONABLY STOCKED WITH MATURE TREES:

(Note that this is usually the situation for those who wish to manage their existing indigenous forest, and Section IIIA of the Forests Act 1949 will apply — Anon, 2007.)

As with cutover conversion the first requirement here is for an inventory. Once this is done, a plan showing the different stand types is prepared. From this point the steps are very similar to those dealing with the cutover forest described above. The bulk of the stands should contain large, mature trees with the next largest stand category likely to be non-productive areas of tree ferns and woody shrubs. Stands of advanced regeneration and seedling regeneration will be less common.

Forest work does not involve just removing trees. Thought and planning must be put in to decide how individual stands will be manipulated to achieve the best results. For example, to induce the regeneration of silver beech only limited canopy removal (one or two trees) is required. However, red beech will only regenerate when a reasonably large coupe size — up to 0.25 ha — is used. On the other hand, kauri regeneration is continual throughout kauri stands but seedlings will not grow without removal of overhead canopy. This means removal of heavy shade plants like tree ferns as well as the felling of selected timber trees to provide small gaps (Plate 3 No.11). With beech, kauri, and most other regenerating timber species, periodic thinning of young plants is vital to ensure continuous even growth. As a rule of thumb, the crowns of saplings and poles must be free of competition from other plants, both to the side and above, and the creation of light wells is vital in this respect. Note also that where species are mixed (e.g., red and silver beech) the size of the gap will favour one species over the other — larger gaps favour red beech.

Management will consist of harvesting the appropriate volume of timber from the stands as large trees and encouraging regeneration after tree removal. Again, the selection and retention of suitable frame trees must be part of the process. First define the stands and determine their timber volumes and growth rates, as explained in Chapter 3. Harvesting to remove the assessed annual increment is then done on an annual or periodic basis, with regeneration encouragement and releasing following as required. At the same time, work in stands which have few or no timber trees to encourage regeneration where appropriate.

Stands are scheduled for harvest over a predetermined period of time. For example, if the total area of forest being managed is 100 ha and the work is to be done on an annual basis over a 25-year period, then 4.0 ha will be treated each year (as individual stands will almost certainly vary in area and volume, this will be an annual average area).

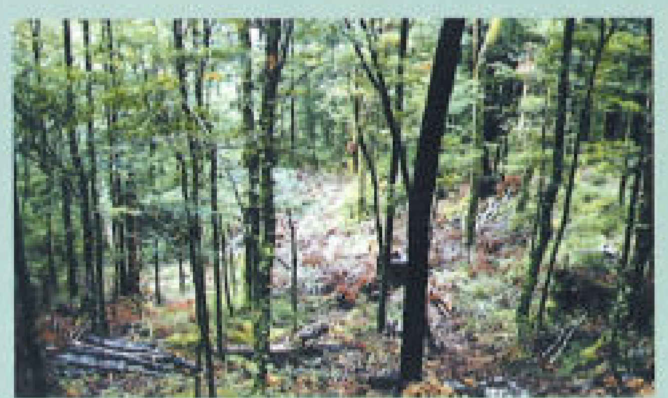
Where harvesting is by group selection the diameters of individual coupes should not be greater than two tree heights; in practice, the maximum size should not exceed 2500 m^2 for most species, and preferably should be less than this. Again, coupe size is dictated by the ecology of the species, with most podocarps, silver beech, kauri, and tawa being managed in single or two to three tree groups (i.e., very small coupes) and red beech in large coupes. Determining the optimal requirements for each species does need more research.

Individual tree selection, group selection, or irregular shelterwood systems can be used, depending upon relative shade tolerance of the species concerned. The aim is to develop greater structural diversity within the forest by encouraging the growth of better-quality trees using the criteria of root stability, good form and vigour, and appropriate spacing. At the point where these trees emerge through the scrub canopy there should be 200 to 300 dominant and sub-dominant trees per hectare for narrow-crowned trees like kauri and totara, fewer for those with spreading crowns. Higher stockings than this, risk reducing the quantity and quality of following regeneration and long-term productivity (see Table 3.0).

As the forest ages, natural regeneration (seedlings grown from seed off the crop trees or brought in by birds, wind, etc.) will begin to colonise the understorey. Thinning the canopy of nurse or non-crop species, progressively opens up gaps to favour the more rapid growth of regenerating seedlings. Because of the differing light levels within the stand, these seedlings will have variable height growth, with more favoured trees beginning to grow towards the canopy and so establishing the two- to three-tiered canopy structure. Up to 50 years may be required to reach this point (Plate 1 No.4).

An example of Option 4 conversion is given in Appendix 3C. This involved a kauri area which was partially logged about 1910, and then left unattended until 1982 when a single harvest of dominant and sub-dominant trees was undertaken over part of it and unstocked areas were planted with seedlings or naturally regenerated. It is now part of a regional reserve.

1: Forest of oak trees up to 60 cm dbh managed under CCF at Alice Holt, Surrey. Regenerating are sycamore, silver birch, oak and Scots pine.



2: Small felling coupe in silver beech at Nelson.

3: Pole kauri being felled to create a small gap prior to a helicopter harvesting trial at Mangatangi in the Hunua Ranges.

4: A natural windthrow gap being colonized by grand fir, Douglas fir, Norway spruce and Sitka spruce at Bowhill Forest, Border Country, Scotland.

Plate 1

5: Example of clear-cutting on steep forest land. Fairly well done, but areas like this have the potential for erosion. If access is reasonable, such a site would be better managed under CCF.

6: A natural gap in eastern hemlock in virgin forest on Wachusett Mountain, Massachusetts, contains regeneration of hemlock and black birch.

7: Faskally Forest, Central Scotland. Sitka spruce and Scots pine regenerating in an all-aged forest.

8: Small patch cuttings mainly in Sitka spruce and Scots pine above Lock Tay, near Ardeonaig, Central Scotland.

9: Lines cut in kanuka prior to planting. Centre and right lines are too wide and open to the sun, resulting in seedling mortality. At left the narrow lines with small gaps gave good results.

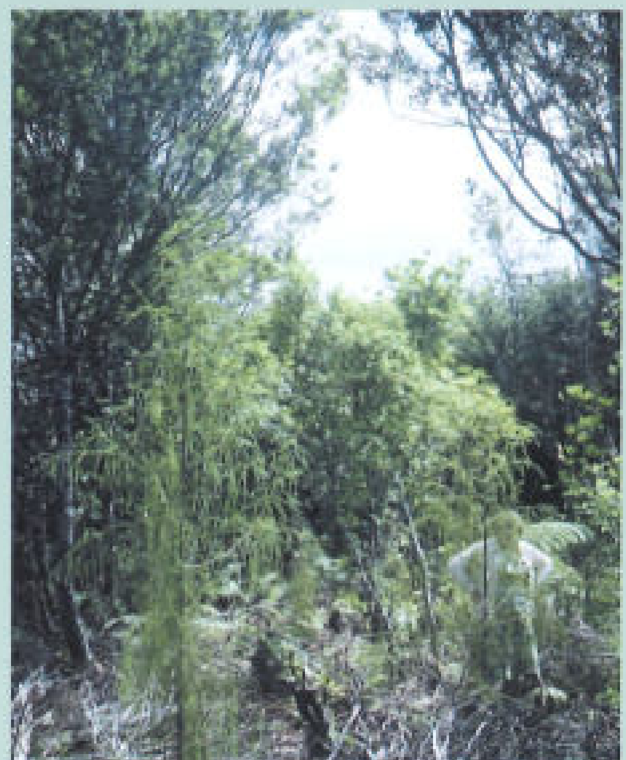
11: Extracting a kauri log from a small gap in the Mangatangi helicopter harvesting trial.

10: Kauri, age 26, originally planted under a blackwood nurse which is now 28 years old.

12: Sustainable harvesting of beech (single tree selection) in Westerwold Forest near Frankfurt, Germany (Photo Mark Dean)

13: CCF in Westerwold Forest near Frankfurt, Germany, showing logs awaiting remival, and regeneration in the background (Photo Mark Dean)

14: A hardwood/softwood mixture planted on a very dry site at Jolendale, near Alexandra (rainfall 340 mm per annum).



15:. Rimu, planted in cut lines 10 years ago, just released from scrub hardwoods and tree ferns by felling 75% of the nurse cover.

16: Kauri, age 20, originally planted in line gaps cut in 5-m-tall kanuka.

CHAPTER 3: MANAGING THE CONTINUOUS COVER FOREST

Continuous cover forest management systems are patterned on natural forest processes, sometimes referred to as mimicking. Silvicultural work essentially involves the speeding up of natural processes by the removal of some of the plants that are present, but not essential to the process, so that the desired species will grow faster. At any one time different parts of the forest will be at different stages which means that a number of silvicultural treatments may be undertaken simultaneously.

3.1 SILVICULTURE

Inventory

Effective inventory is essential, for in each part of a true continuous cover forest there must be a continuous series of size classes from seedling to tree, and continual addition to the growing stock by natural regeneration (or planting). The best way to determine size class distribution is to calculate the reverse "J" curve for the stand or compartment of the forest (see Glossary). Also important are the selection and maintenance of frame trees around which the stands are built. As well as ensuring the appropriate size-class distribution of trees, selection will concentrate upon favouring the better timber species, better quality trees, and those more suited to CCF practice; the reverse "J" curve is a guide to achieving this (Halkett, 1984). Inventories should initially be done every 5 years but the timing and intensity can be varied as the desired system of management evolves.

Currently there is no "best" monitoring inventory system for New Zealand indigenous forest although two methods are used, mainly in more southern forests (Allan, 1992; Handford, 2000). What is needed is a rapid, low cost, system. One of the earliest and best methods devised for inventory and yield checking is that of Biolley, who set out to obtain maximum increment from the smallest possible growing stock (see next Section). The concept is to have quite small stands and to undertake an inventory every 5 to 10 years, just before each felling cycle.

The British Forestry Commission has recently developed software to support an inventory system to monitor the change from even-aged to continuous cover stands (Kerr *et al.*, 2002). This system is now being trialled in New Zealand and, if modified for our conditions, could prove to be a useful monitoring and rapid inventory process (see Appendix 3b). Also under test is a method for indigenous forests, devised over many years by the author of this handbook (Appendix 3c).

Yield control

Inventory, which is used to determine the basic structure of the forest or stand, must be done at least every 5 years; yield control can be less frequent but more information on potential crop trees must be obtained. Yield regulation in selection forests can be undertaken by using Biolley's check method (Biolley, 1920; Matthews, 1989; Benecke, 1998b). J. D. Matthews explains the basic principle as applying the principle of gaining maximum increment from the smallest possible growing stock, and Knuchel (1953) and Spurr (1952) describe the method in detail. The forest needs to be divided into stands and measurements are made of the growing stock in three size classes (large, medium, small, commencing from about 10 cm dbh) every 10 years. This enables the forest manager to determine the growth rates of species by size class, fix the yield for the next period, and plan fellings in order to work toward a normal distribution of size classes. As an alternative to the check method, one of the monitoring systems currently being tested might also be modified to give the volumetric data required.

> Using the data obtained from forest inventory the following rules should be followed:
>
> - Try to maintain the various tree size classes at the correct levels (reverse "J" curve). This is best done by forest compartment or sub-compartment since stands are too small and do not always contain trees in all size classes.
> - If the continuous cover forest is a mixture of tree species, try to maintain an appropriate percentage mix of species in each size class (see below).
> - Free young saplings from suppression.
> - Remove defective stems of any size whenever they hamper better ones, unless they are important for habitat or protection of regenerating stock (Matthews, 1989), or are required to provide stability on sites affected by wind and snow, or to protect crop trees (beech) against winter desiccation (J. Wardle, pers. comm.).

To calculate annual increment the following formula is used (Helliwell, 1999).

$$\text{Increment } (m^3/ha) = \frac{\text{Current volume + volume removed in thinnings* + volume of trees which have died} - \text{previous volume}}{\text{Number of years between measurements}}$$

* Thinnings = any stems removed between measurements

In determining yield the focus should be on size rather than age, although occasionally the latter may have a bearing (Mason *et al.*, 1999). Target diameters should be adopted for the forest; in Europe these are sometimes as high as 60–70 cm but for New Zealand they have yet to be determined and will probably vary by species. However, note that for indigenous species, Section IIIA of the Forests Act 1949 requires that the forest structure be maintained so individual sites will determine ultimate diameters and it is likely that there will be a range of these from different size classes (see Figure 3c.2 where the curve indicates the need for removal of some stems between 20 and 40 cm dbh).

Determination of target diameters is based upon several factors, including the following:

- The requirements of Section III A of the Forests Act;
- Economic considerations, i.e., the size of log giving maximum return or the size at which volume m.a.i begins to decrease;
- Maximum size acceptable to sawmills or cut by portable mill;
- Size restrictions imposed by harvesting, i.e., helicopters are more efficient if lifting logs close to their lift capacity;
- Climatic or susceptibility factors such as the onset of heart rot over 45 cm diameter in the beeches.

Other parameters used are quality and distribution of frame trees, residual basal area, stem size distribution, and reverse "J" curve. Using the latter as a guide the objective is, over time, to bring the seedling and tree size distribution curve of individual compartments as near as possible to the ideal one.

The mix of species and size classes will vary with species and this information is not yet available for most species, becoming more apparent as stands mature and as managers become more skilled. The provisional figures in Table 3 (based upon the work of David Bergin and Ian Barton) are suggested for totara and kauri and must suffice until better data become available.

TABLE 3.0: Preliminary stocking levels for two indigenous species

Size class	Totara	Kauri
Seedlings and saplings	1500	1460
Small poles (15–25 cm dbh)	500	480
Large poles (26–45 cm dbh)	200	170
Small trees (46– 60 cm dbh)	70	50
Large trees (>60 cm dbh)	30	25
TOTALS (stems/ha)	2300	2185

Frame trees

Frame trees (Mason & Kerr, 2004) or future trees (Platt, 2002) provide the framework upon which the forest is constructed (see Glossary). A good continuous cover forest will have 40 to 80 dominant trees per hectare which are selected as frame trees because they are well formed, vigorous, stable, have high timber value, and are reasonably evenly distributed. The number of frame trees per hectare may vary with species and has yet to be determined (for example, species with spreading crowns like beech will have fewer frame trees per hectare than more conical trees like kauri). They should be identified at a relatively early stage, (about 12 m top height) as trees which show a natural ability to dominate the stands where they occur.

Tree removal in the harvest process is undertaken by thinning from above, with competing trees being removed from around the selected frame trees. In the United States a system called crop tree management achieves much the same purpose (McEvoy, 2004). Frame trees will tend to remain and should ideally do so until they reach a predetermined target diameter. When their time comes for removal a nearby subdominant is chosen to take their place. During early thinning (about once every 5 years) and later harvesting, attention must be paid to the removal of unwanted competition in order to encourage growth on the frame trees and to open the stand for regeneration to begin. Irrespective of the management system used, the principle of frame trees should be applied, with the frame trees being the last ones felled.

Silvicultural processes

In managing indigenous forests using CCF principles, silviculture is based upon the ecology of the natural indigenous forest (Matthews, 1989). This means that the process will not be confined to certain parts of the forest but will be taking place over all of the forest at the same time*. Harvesting will normally be by single-tree or group selection depending upon the shade tolerance and seedling regeneration characteristics of the tree (Benecke, 1996). Other methods might be employed in certain situations — for example, beech forest often naturally follows what is virtually a shelterwood pattern and harvesting should be based upon that (J. Wardle, pers. comm.). Felling will not always be confined to older trees because frame trees are left to grow to their fullest potential while others are left for habitat purposes (Peterkin, 1997). However, the main selection criteria should be to (a) remove trees with impaired health and vigour or which are malformed or damaged, and (b) thin to reduce density. The removal of dominant trees and eventually frame trees will allow subdominants to increase their growth rate.

Because continuous cover forests are not completely natural forests there may be some diversion from normal natural processes. For example, they may be single-species forests (e.g., *Nothofagus*) or could be mixtures of species from New Zealand and overseas. If species which are infertile (e.g., ×*Cupressocyparis ovensii*) are used, the planting of replacement stock will be required. In this situation the ecological requirements of the various species used will

* For example, with kauri, an alternative to returning to each compartment every 20–30 years could be to divide the forest into very small stands averaging say 1000 m^2. Each stand would be revisited at approximately 10-yearly intervals so that at the same as time as harvestable trees were removed, new scarification, planting, releasing, thinning, fertiliser aplication, etc. could be done. It is necessary to have at least one intermediate visit to release tiny seedlings. Stand centres can be defined by a Global Positioning System (GPS).

need to be compatible and it is likely that a good deal of trial and error will be needed before a suitable silvicultural process can be devised (Plate 4 No. 14). However, before species are included in a mixture it is necessary to understand something of their ecology, in particular their light requirements. Depending upon the requirements of their seedlings for light, trees fall along a gradient but can be grouped into three broad classes (Mason *et al.*, 1999) — light-demanding, intermediate, and shade-tolerant. Thus a suitable mixture might include red alder as light-demanding, *Cupressus lusitanica* and × *C. ovensii* as intermediate species, and *Acacia melanoxylon* as relatively shade-tolerant.

Following harvesting of individual trees or groups, growth at all levels in the continuous cover forest needs to be encouraged. New tree establishment can be obtained by encouraging seed germination and coppice regrowth but if these are not possible planting will be required. Existing seedlings and saplings will require releasing from competition and excessive numbers will need to be thinned out. Depending upon species, it is likely that repeat releasing will be needed, in particular newly planted or germinated seedlings may need to be freed from competition several times during the first 5 years after establishment. To encourage regeneration it is important to take advantage of seasonal seed supply by manipulating light levels, competition, and predation of both seed and small seedlings (Helliwell, 1999).

Rotation

The concept of crop rotation has no place in CCF because an ideal forest will have trees of all ages and size classes growing in an intimate mixture (Matthews, 1989). However, there is likely to be an average age which trees will attain when reaching minimum harvest size.

Management plans

The essence of management is yield control — that is, aiming to keep the annual harvest volume at the same level as new growth: the annual increment. The forest must therefore be managed with a good knowledge of the dynamics of the system based on sound ecological principles. To achieve this, regular inventory surveys need to be made, usually every 5 years.

It is necessary to have a good operating plan, the basics of which are contained in Schedule 2 of the Forests Act 1949 which clearly specifies the requirements for existing indigenous forest (see box in next section for summary) (Anon, 2007). Of course it is not mandatory to follow this for planted indigenous or exotic forest but the basic principles remain the same. Where ground-hauling methods are to be used, a well-planned network of skidder tracks spaced according to the harvest system being used must be specified (Plate 5 No. 19& 20). To achieve this, all main ridge and valley systems should be accurately mapped and contour plans should be drawn.

Initially the forest needs to be mapped by forest type (normally dictated by the dominant species) and this will be required whether the forest is natural or planted, exotic or indigenous. This is the first step in making the inventory and the forest plan becomes more refined as more data are obtained.

The level of inventory will depend upon the economic viability of the forest. Ideally enumeration of the entire stand should be carried out, as was formerly done in some European countries, but is now often impractical for economic reasons. Realistically, sampling will be undertaken, the intensity of which will be determined by costs relative to benefits. In practice it is expected that management plans will have individual vegetation units, or stands, mapped by GPS and this arrangement will become the basis of the completed plan. Using GPS, individual stands can easily be relocated for silvicultural work, frame trees can be noted, and inventory points recorded and, if needed, shifted. In addition tracks and other infrastructure and landscape features can be plotted with reasonable accuracy.

Monitoring

Monitoring of the whole system has already been discussed in the sections on inventory and yield control, and it is essential that this be done effectively for allowable yield can be compromised if it is not. In addition, flora and fauna populations must be maintained at appropriate levels. It is very easy for the forest to become degraded through any of the following failures of procedure (Matthews, 1989).

- Uncontrolled fellings, especially removing only the best trees;
- Decline in value of the growing stock because of market changes;
- Severe damage by fire, wind, disease, or war;
- Uncontrolled grazing by domestic or feral animals;
- Outbreak of disease or explosion of insect populations;
- Agricultural practices such as litter removal.

All management plans must have good monitoring systems in place. At this stage it is recommended that one of the systems discussed under Inventory (page 17) be used.

Reserve areas

When indigenous forest is being managed using continuous cover principles it is important to have reserves of non-harvest forest to serve as reference points, particularly for the monitoring of ecological processes and biodiversity. This is especially so if the area being managed is natural forest (20% of the total forest area covered by the plan must be set aside and not logged — see Clause 10 of the second schedule of the Forests Act summarised on next page) but not so vital if the forest has been created by planting new areas on open ground. Reserve areas could and that sediment eroded from skid trails is directed, as far as is possible, away from all waterways. Location of skid trails should be planned and trails re-used wherever possible. Small branches used to corduroy skid trail and track surfaces act as shock absorbers and lessen ground impaction. When determining which harvest method will least damage the environment, access pattern is the first consideration. On steep or very wet sites, roading is difficult and may need to be avoided apart from the major access route. It is important that protection of environmental values is considered as well as the economics of the operation.

Land use consents

Prior to construction of roads over a certain length, or to the clearing of vegetation from an area above a certain size, a land use consent will be required from most Regional Councils. However, in some Council areas this will not apply providing trees felled do not exceed a certain height and industry standards are adhered to (J. Wardle pers. comm.). In most areas, because CCF should not require the felling of areas of trees exceeding 0.25 ha, a clearing permit should not be needed.

Rules vary between Councils but roading consent will be classified under one of the following: -

➢ Permitted activity	No consent needed.
➢ Controlled activity	Consent will be granted subject to specific conditions.
➢ Discretionary activity	Consent may be granted or refused. Conditions apply.
➢ Non-complying	Activity is contrary to plan but may be consented subject to conditions. Public notification required.
➢ Prohibited activity	Prohibited in plan and no consent may be applied for.

The above are covered by Sections 2 and 88 of the Resource Management Act, 1991.

When granting consent, the Council must take notice of Section 17 of the Resource Management Act which states that every person has a duty to avoid, remedy, or mitigate adverse effects on the environment.

Roading

Ground harvest methods will involve extraction of logs for short distances by hauling through the trees to the road. On steep country this method can be used if ridges and spurs are easily tracked; otherwise aerial extraction may be required. An alternative on steeper country is to construct roading following the site contours and use ground extraction methods. This technique was used by Rudolf Hohneck between 1930 and 1956 in his kauri forest at Mangatawhiri (Barton, 2007) (Plate 5 No.17). However, this practice is not recommended for country which is unstable. Today the techniques of digital terrain modelling and GPS mapping can replace the "rule of thumb" methods of the past and enable good road construction with minimal damage.

Continuous Cover forests on easy country generally require a denser track network than forests which are clearfelled, although the permanent roading system need be no more intensive than that required for the management of clearcut forests. The more intensive internal track system, at 80- to 100-m intervals, should be planned well in advance (Yorke, 2001). An effective road, track, and skid trail system will occupy between 6% and 8% of the total forest area.

Good access to and within the forest is a key factor in ensuring easy harvesting at minimal cost. However, because roads can be a major source of adverse environmental impacts they must be carefully designed. To do this it is necessary to understand the geology, soils, topography, and drainage patterns of the forest before construction begins. Areas of unstable soils, steep slopes, and poor drainage are more susceptible to damage and roading should avoid such areas. Where possible locate major roads on stable and well drained sites, with preference given to ridge and contour layouts (see Table 3.2 for details).

In new forest areas main roads and tracks should be formed before planting, if at all possible.

Harvest methods

It is not intended to write a definitive explanation of harvest methods and procedures here but rather to discuss the basic principles and the pros and cons of possible methods.

As a general rule, for flat and rolling country up to 20° slope, skidder extraction is possible. Tracked machines can operate up to 35° slope but on country steeper than this aerial extraction, although more costly, is better. Small haulers may also have a role in some places. Different methods are compared in Table 3.1 which shows that ground harvesting methods which have small impact on the environment (horse and mini skidder) also have low production potential. They will be applicable only in small-scale operations where the value of the timber is moderately high. Skidders will be applicable only on flat and easy country, although they can operate very well on steeper country off contour roads up to 100 m apart. Ground and hauler systems have high productivity but greater impact on the environment. Their use in CCF is therefore restricted. Haulers may not be possible at all because of the high cost of moving ropes and the resultant damage to the forest but, because they generally haul aerially, skyline systems may have a place. There is little doubt that helicopter extraction causes least damage to the forest, because it not only minimises damage to other plants and the soil but also greatly reduces the need for road

TABLE 3.2: Road construction

	Roads	Tracks	Landings
Roading length / Landing size	Keep road length to minimum consistent with efficient harvesting.	Track length as short as required to remove logs with minimal impact upon remaining vegetation. Where ground harvesting is used space tracks at 80–100 m intervals.	Minimize the number of landings required. Ensure that landings are large enough to allow the bucking, sorting, stacking, and loading of logs in safety
Construction timing	Construct roads during the dry season and avoid working in wet conditions.	Where construction is required do during dry weather.	Construct during dry weather.
Contours and ridges	Roads should follow ridges or contours wherever possible.	Tracks should follow ridges or contours wherever possible.	Where possible locate landings on ridges to permit effective drainage of water.
Streams – Crossing	Select natural crossings on straight sections of stream with easy approaches requiring minimal impact upon the stream bed. Always use bridges, culverts, or concrete pad crossings. Provide fish passages where necessary.	Keep to minimum. Consolidate entry and exit points to reduce scouring. Always cross at right angles. Repair damage to stream banks, etc., when job is complete.	
– Riparian strips	Set back from streams, with setback distance increasing with slope (about 10 m on flat to 30 m at 25° slope). Riparian areas may not be required where helicopter logging is used.	Set back 2 m on flat and 10 m on slope. Riparian areas may not be required where helicopter logging is used.	Should be at least 30 metres from permanent streams.
– Riparian vegetation	Take care not to damage riparian vegetation.	Take care not to damage riparian vegetation. Ensure that logs, branches and other debris are kept out of streams.	Areas should be dry and as flat as possible.
Wet areas	Avoid wet areas wherever possible	Avoid wet areas wherever possible	Avoid wherever possible.
Unstable Areas	Avoid wherever possible.	Avoid wherever possible.	
Slope	Avoid slopes of more than 26°.	Avoid slopes of more than 26°.	
Grade	Grades of 2–3° are ideal and up to 6° acceptable. Increasing grade to 10° is possible but requires additional care with drainage.	Keep grades to minimum by utilizing contours if required.	

Continued on page 24

TABLE 3.3: Portable sawmills available in New Zealand — Basic specifications at April 2007 [(1)]

Note: Where more than two models are available specifications are given for the smallest and the largest only

Mill type	Number of models	Model name	Weight (kg)	Max. log length cut (m)	Max. log diameter cut (cm)	Max. cut dimensions (mm)	Production rate (m^3 sawn per 8-hour day)	Blade type[(2)]	Kerf (mm)	Feed system	Engine power
Lucas	4	613	263	4.3 [(4)]	135	160 × 160	–	Circular 2	5	Manual	13 hp
		827 [(3)]	330	6.1 [(4)]		215 × 215 [(6)]	–	Circular 2	5.7	Manual	27 or 15 hp elec
Mahoe	3	Minimax		6	150	300 × 200	4–6	Circular 2	4.5–6	Friction	32–34.6 hp
		Super mill		6 [(5)]	150	300 × 150	15	Circular 2		Hydraulic winch	83 hp
Peterson	5	Skill Mill		4	80	101 × 203		Circular 2	3.5	Manual	16 amp elec or chainsaw
		ASM		6 [(5)]	180	260	6–10	Circular 2	5.0–5.5		20–27 hp
Rimu	5	Lightweight high track 10 × 6		5 [(5)]	170	250 × 150			4 +	Manual	22–25 hp
		Contractor deluxe 12 × 6		6.3 [(5)]	170	300 × 150			4 +	Computer control	25–50 hp
Wood-Mizer *	8	LT 15	428	3.3 [(5)]	71	600	1.5–2.5	Band	1	Hand crank	13–22 hp
		LT 70	2059	6.1 to 13	91	700	7.5–15	Band	1.4	12v electric Computer control	25–60 hp
Chainsaw mills	Various	Several types are available and full details are not given here. Normally used to reduce large logs in bush for easier removal.	Up to 155 kg	In theory any length	Limited by bar length		Cuts 0.3 to 2.5 lineal metres per minute, depending upon plank width and species.	Chain	>5	Manual	Depends upon chainsaw. Larger logs require higher cc rating. A 45-cm log requires 55 cc and a 90-cm log 120 cc.

(1) All data given are from information provided by manufacturers or converted to metric, etc., as required
(2) "2" after blade type means circular blades cutting at right angles
(3) Mill also available as electric
(4) 8-m length optional
(5) Can be extended
(6) Or double cut 215 × 430 mm

CHAPTER 4: FINANCIAL ASPECTS

4.1 ESTABLISHMENT AND MANAGEMENT

Economic considerations, at least in the more developed nations, are no longer the sole raison d'être driving forest management (Benecke, 1997). In fact many now challenge the concept that clearcut plantation systems are more economically viable than CCF because the latter's other advantages mean that this system is now becoming accepted as equally valid (Rooney, 2000). The reason for this is an increasing acceptance that the various multi-use activities associated with forestry also have economic values, even though these may at times be difficult to quantify using conventional economic analysis.

Research to clarify the direct costs of CCF, especially the cost of conversion from plantation forest to CCF, has been under way in Europe for some time. Management costs per unit area are higher, with a significant component of this being cost of inventory (Mason *et al.*, 1999). However, there are savings in the greatly reduced costs of planting and silviculture, although if seedling densities are very high — e.g., with beech and totara — thinning costs can be higher than planting. In 1996 the cost per hectare for regeneration and tending in Swiss CCF forests was NZ$21 (this increases if the size of areas being tended is small (Benecke,1996)) compared to NZ$152 for clearcut forests. In German forests the situation is similar (Fig. 4.1), but variation between individual forests is likely to be large.

4.2 HARVESTING

Costs of harvesting do vary widely but what does not change much is cost relativity between the different methods:

Horses<mini skidder<ground skidding<haulers< helicopter

It is also important to consider the hidden cost of each type of operation. The two cheapest options and helicopters have far less impact on the environment and do much less damage to the residual crop. The latter is particularly applicable to helicopters which also require much lower roading density and can be used when volumes per hectare are low.

Road construction costs vary enormously depending upon terrain, the length of road needed per hectare, and the roading standard required. On easy country, gravelled roads will cost from $15,000 to $20,000 per kilometre, which adds $0.80 to $10.00/m^3 to the cost of wood extracted — depending upon road length and wood volumes. On difficult country the cost rises considerably to between $4.00 and $30.00/m^3 (Murphy, 1993). On the benefit

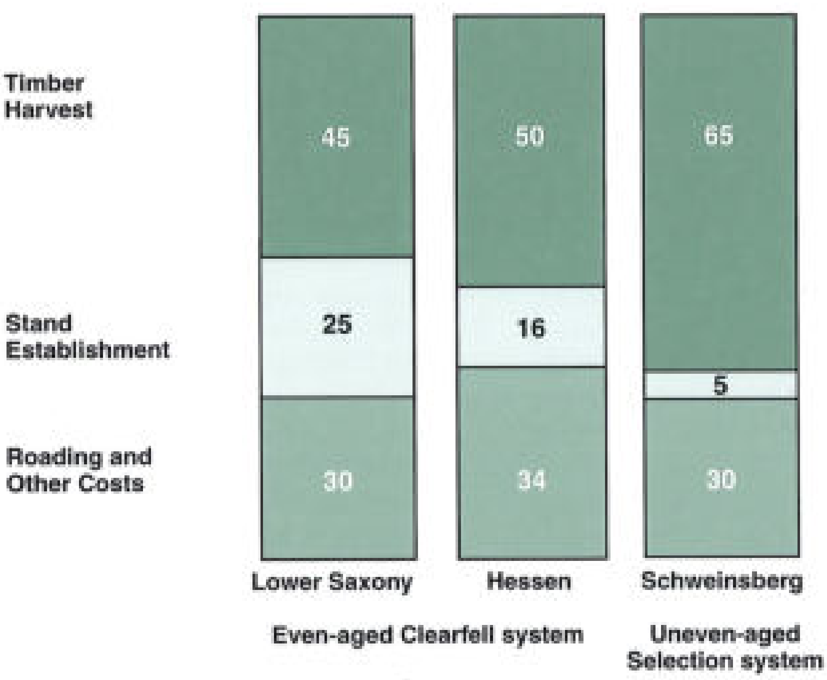


FIGURE 4.1: Relative management and production costs in even-aged plantation forest and uneven-aged "near natural" forest, over a 10-year period, in two German provinces (from Beneke, 1996)

side, once a road is built it can be maintained at fairly low cost, provided there is no non-production heavy usage, and it will be available for subsequent tending and harvest operations. The cost of maintaining such a road should be less than \$500/km annually. Although difficult to quantify, the cost of wood extracted in subsequent harvests should be under \$5.00/m³, even on the most difficult country.

Helicopter costs do not vary to the same extent, ranging from \$35.00 to \$50.00/m³ depending upon haul distance and piece size. These costs will be relatively constant from harvest to harvest; however, possible fuel shortages in the future may result in helicopter harvesting becoming less economic.

Depending upon circumstances at each site, including silvicultural systems and timber piece sizes, it may be that when all costs are considered helicopters will deliver the best service if large volumes of logs have to be moved, especially in difficult terrain, and horses or mini skidders the best with low-volume operations on easier country.

4.3 POTENTIAL AND COMPARATIVE TIMBER VALUES

Pre-1981 net returns for Switzerland's Couvet Forest, managed under continuous cover since 1881, were up to NZ\$150/m³ but they have dropped more recently averaging only \$38/m³ between 1984 and 1991. However, nearby clearcut regimes suffered even more because they had a high proportion of industrial wood and sawlogs of lower grade than Couvet, where virtually all trees felled yielded high-grade sawlogs (Benecke, 1996).

Few data are available for New Zealand. However, calculations based upon the best available information suggest that the nett return from a planted but self-regenerating kauri forest when the first harvest of approximately 300 m³ is made at age 80 would be about \$100,000/ha (discounted return <5%). If blackwood were used as a nurse crop and these trees were all harvested between 25 and 45 years of age, yielding about 390 m³, the return would be close to \$200,000/ha (discounted return 8%). Succeeding harvests of kauri, because of the low management costs incurred by not having to replant, will have a discounted return of about 18% (G.P.Horgan & I.Barton unpubl. data).

Another aspect affecting financial yield is the tax regime imposed. Helliwell reports (1999) that in Britain prior to 1985 the system of taxation favoured clearfelling but that the Budget of that year swung the balance in favour of CCF.

Many countries also provide Government grants to encourage tree planting. More recent grants in Britain have favoured CCF over clearcut forestry.

It should also be noted that a continuous cover forest of say 150 ha would be under more or less constant management (although harvesting might not be done annually). There would always be work going on such as scarifying; planting; releasing; non-productive thinning; fertilizing; weed and noxious animal control; fence, road and track maintenance; inventory; planning; etc. Harvesting could be intermittent; it may occur annually but during drier times with autumn and early winter preferred because the sap is down, or it could be biennially or even irregularly, selling mainly when prices are good. Note that periodic or intermittent harvesting enables income to be spread over previous non-income years for tax purposes.

4.4 ESTATE PLANNING AND MANAGEMENT

In New Zealand forest ownership is currently in a state of flux. Some 20 years ago the State owned most of the indigenous protection forest and about 60% of the production forest. Divestment of State assets saw most of the productive exotic forest land pass into private hands, since when it has often been re-sold and considerable areas have been converted to other uses. The State has also ceased production from Crown-owned indigenous forest while amending the Forests Act to control harvesting from private indigenous forest. These events and the ambivalent attitude of Government toward forestry, cause practitioners and investors to be very wary and the uncertain state of affairs works against the long time-periods required for CCF to prosper. Contrast this situation with the State of Baden Württemberg in Germany. Here 1.4 million ha of forest are 24% owned by the State, 39% by local government organizations, and 37% by private owners. Underpinning this is the requirement of both Federal and State forest law, that forested land must be retained as forest (Platt, 2002).

In New Zealand today, should any forest owner wish to practice CCF it is important that initial planning be accompanied by consideration of how the ownership of the forest is structured to ensure that CCF will continue long into the future. These long-term planning considerations must take three basic factors into account:

- Long-range planning must extend far beyond the 10- to 30-year planning cycles common to most current forest planning;
- Forest owners need to understand that truly sustainable forests are measured in terms of centuries and not decades (McEvoy, 2004);
- Subscribing to the concepts of CCF means being willing to forego some current income opportunities in order to create a lasting legacy for the future.

This section therefore deals with ownership vehicles appropriate to managing a forest which has a life of considerable length (probably 100 years minimum). The issue is to provide a mechanism which will ensure perpetuation of the forest rather than protect the rights of the owner. Thus individual private ownership is probably a poor vehicle because there is a high risk that if a forest is sold, especially if it is immature, the trees could be cleared to permit an alternative land use. It is assumed here that anyone who creates a continuous cover forest will seek an ownership vehicle which will enable the forest to operate for a long period. Described below are several mechanisms which could be considered. Anyone contemplating setting up an estate management system for CCF is advised to first put all of their requirements on paper and then seek legal advice.

Possible ownership types which could be used in New Zealand are:

- Private
- Trusts
- Company
- Maori customary title land
- Government and local government
- Use of the Forestry Rights Registration Act
- Use of land covenants
- Special legislation to protect forestry land use.

Private ownership

This implies ownership by a single individual, partnership, or family company and would be land held as freehold or very long-term leasehold. With no protective instruments in place the owners have no way of controlling future use of the land once it passes from their ownership unless some mechanism is devised to ensure future management of the trees (see Forestry Rights Registration Act 1983).

Trust ownership

There are many different types of Trust but only certain types may be suited to a long-term operation such as forestry. With the exception of charitable trusts which are not considered here, the maximum life of a Trust is 80 years (Brown, 2000). This length of time is probably not sufficient for a continuous cover forest operation, so being able to resettle a Trust is vital. Since resettlement of a Trust cannot breach the rule against perpetuities it is not possible to do this by simply creating a new Trust; however, distribution of the Trust assets to a beneficiary which is a company, with shares in that company held by a Trust is a possible alternative. Essentially four types of Trust could be considered and these are covered briefly below.

With a discretionary trust trustees have the discretion to dispose of the benefits as they see fit, although all beneficiaries have the right to impartial consideration by trustees and have their rights protected by the courts. The trust deed would need to be set up to clearly define the CCF objectives and outcomes required.

A fixed trust sees the rights of beneficiaries fixed by the trust deed, and trust income must be distributed according to this specification. This type of trust will probably only work in the long term if the beneficiaries are also Trusts since it is not possible to specify individual beneficiaries 50 or 80 years ahead.

Unit trusts are principally used for investment where benefits are allocated according to predetermined fractions or "units". As with fixed trusts, they will probably only be effective in the long term if the beneficiaries are also Trusts. For tax purposes unit trusts are deemed to be companies.

The purpose of a trading trust is to use Trust assets to carry on a business and such Trusts have tax advantages. Once again it will function better in the long term if the beneficiaries are also trusts.

Company ownership

Unlike Trusts, companies have an indefinite life span so could be an ideal mechanism for retaining land ownership providing the company objectives are specifically CCF and clearly outlined in the operating agreement of the company, so that although shareholders might change the objectives would not (McEvoy, 2004). However, companies have several disadvantages as estate management structures, especially:

- fragmentation of share holding amongst succeeding generations,
- are more disadvantageous than Trusts as regards taxation,
- and are less flexible because of greater regulation and control.

Maori customary title land

Although Maori land can be freeholded and sold, this is a difficult process due firstly to the provisions in the Te Ture Whenua Act, which prevent alienation of Maori land, and secondly the constraints of multiple ownership. Equally, the Maori way of thinking about land is a factor which restricts easy sale, it being regarded by them as an important component of whanau, hapu, and iwi identity. Most Maori land therefore is held in group ownership, sometimes in a whanau trust, and is likely to remain so. Activity on that land is decided by group consensus and management is usually entrusted to a Trust or Incorporation. It should be noted that Trusts under Te Turi Whenua Act are not subject to the rule against perpetuities and can therefore exist in perpetuity. Because Maori land ownership is continuous it is an ideal vehicle for CCF.

Public ownership by Government and local government

As discussed above, this type of ownership would once have been regarded as especially secure in New Zealand, and much forest land was owned by Governmental agencies. Although this remains the case in many parts of the world, recent New Zealand Governments have seen fit to divest ownership of the trees on their productive forest lands to private enterprise with the inevitable result that management is now dictated by the bottom line. Such a situation is inimical to CCF until the forest becomes fully productive so, at least for the foreseeable future, publicly owned land would not be suitable for CCF unless the long-term objectives are clearly fixed. A process for this might be establishment of such forests under the protection of the Forestry Rights Registration Act 1983.

Use of the Forestry Rights Registration Act (1983)

Under this legislation the landowner enters into an agreement, registered by transfer under the Land Transfer Act, 1952, with another person or entity which allows the second party, sometimes in conjunction with the landowner, to establish forestry on the land (Ministry of Forestry, 1994). The entity could for example be a Trust set up by the land owner so that the forest was protected in the event of him/her selling the property. Once the transfer (which is binding on the heirs, executors, administrators, and assignees of the landowner) is established, the forestry right may specify the management system, in this case continuous cover, to be used. The time period of the Forestry Right is often set at only one or two rotations but may exist in perpetuity.

Land covenants

In New Zealand these are already in use to protect forested land; that is, the Queen Elizabeth II National Trust which enables rural landowners to protect areas of bush and wetland using the provisions of a QE II covenant. The use of a similar covenant registered by the owner to provide protection for a continuous cover forest is therefore possible, being an alternative approach to both a Queen Elizabeth II covenant and the Forestry Rights Registration Act. However, the latter Act, being a precise legal tool designed for forestry, probably provides better protection.

Special legislation to protect forestry land use

In the long term it is possible that better protective processes than those described above will be required to protect the practice of CCF in New Zealand. Most countries that are longer established than New Zealand have laws which specifically protect forest land as part of the natural environment and laws clearly prescribe what activities are possible on forest land. For example, in Switzerland CCF is encouraged by a ban on clearcutting ,which is permitted only in exceptional circumstances (Herman *et al.*, 2000). New Zealand by comparison has no national restrictions, although some local councils protect indigenous forest areas through their district plans. Here, as land use pressure grows and environmental protection becomes increasingly important, it is expected that law to prevent deforestation (both exotic and indigenous) and enhance the impact of forests and forest practice on the environment will be required.

Processes to protect forests, especially those managed under continuous cover, are available, with a combination of Trust and/or Company with the Forestry Rights Registration Act being currently the best option. In the future the legislative process might give simpler and more robust possibilities.

CHAPTER 5: LEGISLATION WHICH IMPACTS UPON CONTINUOUS COVER FORESTRY

Several Acts of Parliament, and their associated regulations, have implications for CCF. Several of these impact on District, Regional, and National Plans, and the major impacts are listed below (see also Sections 3.2)

5.1 ENVIRONMENT ACT 1986

Section 17 requires the Government to be involved in the maintenance and restoration of ecosystems and habitats. Activities to be taken into account at this level fall into the following categories. These activities, especially 3 and 4, could have an impact upon the practice of CCF.

1. Increase of pollution
2. Increase of natural hazards or substances
3. Introduction of species not previously present in New Zealand
4. Features with unknown environmental effects
5. Causing depletion of natural resources.

5.2 THE FORESTS ACT 1949

This Act, which has been considerably modified since 1949 (especially in 1993 by part IIIA which created a framework for the sustainable management of indigenous forests), has several deficiencies. It does not cover the management of planted indigenous forest and applies only peripherally to forests managed by the Department of Conservation and forests allocated under the South Island Landless Natives Act 1906.

The Act also tends to be over-prescriptive, not allowing for sufficient variation in management which would permit a better fit with the specific ecological requirements of a particular species. For example, single-tree selection in podocarp/tawa forest favours the replacement of podocarps with tawa, which is very shade-tolerant. If the podocarps are to regenerate, greater levels of disturbance are required, i.e., larger coupe sizes, which are not currently allowed by the Act (see side bar page 20).

The essence of the Act is that natural forests used for timber production must be managed under the provisions laid down in Sections 64 and 67a–67v which cover the use of Sustainable Forest Management permits and Sustainable Forest Management plans.

Eventually the Act will require amendment to allow better operation of CCF. A recent regulation (February 2007), which will benefit planted indigenous forestry by providing for the registration of planted indigenous forest, is a move in the right direction. It should be noted, however, that because Sustainable Forest Management Plans under Part 3A of the Forests Act are subjected to a rigorous audit process by DoC for conservation/historic/ecological issues, there is a measure of quality control and assurance to the general public which is purported to be driving the move to better environmental management of all natural resources (I.Platt pers. comm.)

It is also important to note Sections 70 (1 and 2c) and 70a of the Act which state that regulations must be made to prevent the spread of or eradicate disease which may affect forests, or forest products, on both public and private land. Such regulations also restrict the movement of plant material, which may be infected, from one area of New Zealand to another. Compensation may be paid to the owners of trees that are destroyed. This act may prevent the importation into New Zealand of plant material required for propagation (e.g., oak species, or the movement within the country of plant material (e.g., elm species).

5.3 FOREST AND RURAL FIRES ACT 1977 & REGULATIONS 1979

Section 10 states that territorial local authorities are responsible for fire control in their areas unless a specific Rural Fire Authority exists. Fire protection for forests managed under CCF principles is therefore usually the responsibility of the District Council where the forest is located.

In high risk areas the provisions of Section 18 of the regulations, Application for Forest Areas to be registered, should be followed. However, it should be noted that CCF systems using indigenous trees and comprising a range of species and mixtures, will usually be less prone to destruction by fire than even-aged monocultures.

5.4 FORESTRY RIGHTS REGISTRATION ACT

As indicated in Chapter 4.3, covenants under this Act could be entered into in order to undertake CCF with indigenous or exotic species or a mixture of both.

5.5 RESERVES ACT 1977

This Act covers publicly owned land, which is designated as a reserve. Section 75 of the Act specifies that recreation and local purpose reserves may be used for afforestation if they are not for the time being required for the purpose for which they are intended (usually for physical activity or similar). The local body will usually enter into a contract to afforest the area and the proposed activity must be publicly notified. The public normally continue to have the right to enter the reserve.

5.6 RESOURCE MANAGEMENT ACT 1991

Section 9: (1 & 3) Restrictions on the use of land: States that no land may be used in a manner which contravenes a rule in a District Plan or Regional Plan unless the activity is expressly allowed. Therefore anyone who wishes to undertake CCF needs first to check if the local District Plan contains anything which may inhibit planting and managing a forest. Such restrictions may apply more to indigenous than exotic species. For example some Plans, mainly urban, prohibit the felling of indigenous trees. This rule is already impacting on people wishing to plant native trees for future timber supply in the rural parts of some cities. Previously the only way to overcome this was to apply to the Council concerned to register the property as a production forest. The recent regulation in the Forests Act (Section 5.2) provides for registration of plantings of native trees on non-forest land and will go part way toward addressing this problem.

Section 9(4c): States that no land may be used in a way which would cause damage or disturbance of the habitats of plants or animals in, on or under the land concerned.

Section 17: States that every person has a duty to avoid, remedy, or mitigate adverse effects on the environment. As the planting of trees, especially indigenous species, will have a beneficial effect on the land there should be no restrictions under the Act. However, the harvesting of trees could have an adverse effect, especially if felling coupes are large. The clearing of an area larger than about 0.5 ha usually requires a permit from the Regional Council but continuous cover harvesting should not be affected because coupes will almost always be smaller than this; if in doubt a check should be made with the local Regional Council.

Section 30 Functions of Regional Councils under the Act: Listed here are soil conservation (1c) and the introduction of plants for soil conservation, which may have an impact on the bed of any water body (1 g).

Section 31 Functions of territorial local authorities under the Act: Requires that Councils shall be involved in the establishment, implementation and review of objectives, policies, and methods to manage the effects of use, development, and protection of land. This ties in closely with the functions of Regional Councils in controlling impacts on soil and water.

Section 87 Types of resource consents: This section lists those previous clauses which require a resource consent before any activity is undertaken which might contravene the contents of that section. These are:

Section 9 Restrictions on use of land — see Section 9 above.

Section 11 Restrictions on subdivision of land.

Section 12 Restrictions on use of coastal marine areas.

Section 13 Restrictions on certain uses of beds of lakes and rivers.

Section 14 Restrictions relating to water

Section 15 Discharge of contaminants into the environment.

Care should be taken to obtain a resource consent if the activity is likely to contravene any of the above. In this context, Sections 9, 11, and 15 are the most important.

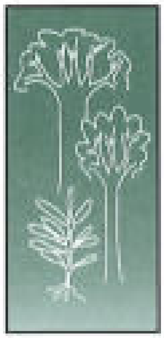
Regional and District Plans

These are the documents which will have the most immediate impact on people involved in CCF, especially if indigenous species are used. These plans are administered within the context of the Resource Management Act.

Regional Plans contain rules relating to the impact on soil, air, and water of various human activities. Of particular importance to foresters are restrictions on road construction and the area of vegetation that may be felled during harvest operations. Because the maximum coupe size required for CCF is usually small enough to fall within the requirements of Regional Plans, no problems should arise.

District Plans relate to the use and management of land. In rural areas some land may be zoned, or otherwise defined to place restrictions on the practice of forestry. However, most District Plans seek only to define indigenous and plantation forests, albeit in a variety of ways. Some plans are now taking account of CCF.

There are usually considerable differences between the plans of various local bodies. Because there are no national guidelines on most of the issues that have to be covered, individual councils make local rules to suit their districts. For example, the recent Rural Plan Change in Franklin District sees the District divided into Management Areas. All of these have as an objective, "To encourage the planting of indigenous forestry and sustainable farm forestry in appropriate locations". In return for a subdivision right, provision is also made for bush protection and the planting of both indigenous and exotic species on Class VIII land which is retired from farming. The plan is, however, silent as to the possibility of productively managing the latter using continuous cover. Finally, the Plan provides definitions for "production forestry", "conservation forestry", and "CCF".



CHAPTER 6: THE FUTURE OF CONTINUOUS COVER FORESTRY IN NEW ZEALAND

Continuous Cover Forestry presents people involved in New Zealand forestry with a very different approach to that with which most are familiar — the growing of an even-aged monoculture which is harvested by clearfelling. For various reasons it is likely that in future years more and more of our timber will need to be grown and harvested by methods which do not require the baring of large areas of soil. These methods can be more costly and complicated than clearcut forestry so will probably be used for production of high-value timber rather than low-value wood fibre.

In the U.K a number of factors, including the Rio-Helsinki process, the requirements of certification, and an international movement favouring more natural forest management, have seen a shift from clearcutting towards continuous cover. In the early 1990s the U.K had about 5000 ha of forest under continuous cover management but since then there has been a steady move to convert more clearcut forests. The strongest movement has been in Wales where the Welsh woodland strategy aims to have 50% of public forest transformed to continuous cover by 2020. Similar moves are afoot in Scotland (Mason *et al.*, 2004).

What then is the future of CCF in New Zealand? Because it is a management system which offers considerable benefits over and above timber production it is predicted that it will become more common over time. Continuous cover produces not just timber but also the associated benefits of what used to be known as "multiple-use forestry". From forests managed in this way we can achieve a wide range of environmental and social benefits such as improved biodiversity, protection of soil and water values, landscape enhancement, and more effective carbon sequestration. Exotic continuous cover forests will be more "natural" than the plantation forests with which we are more familiar; but it is with indigenous forestry that the major gains will be made.

It is becoming increasingly evident that the management of most, if not all, indigenous species can be successfully undertaken only by using continuous cover principles, although the beeches and totara can be managed as even-aged stands. This approach, under a variety of names, has long been that of most New Zealand foresters involved with indigenous species and has evolved, with fits and starts over the past 100 years. Prior to 1979 it often came under attack from environmental groups because foresters usually attempted to implement it by commencing with the harvest of large, over-mature trees, especially kauri and the podocarps. While this is possible in some circumstances (for example with *Nothofagus* species) it may not be desirable and can only work if combined with a holistic approach to forest management. That is, all aspects of the forest environment must be considered by using an ecological approach to management — taking into account all parts of the forest, from mature trees down to the smallest living creatures.

The forest owner who practices CCF provides a number of services such as carbon sequestration, landscape enhancement, protection of soil and water values, and increased biodiversity, which are real contributions to the well-being and economics of the nation. This protection of other forest benefits is a distinct advantage that CCF has over clearcutting and perhaps the future will see in place a mechanism to materially compensate the providers of these public goods.

Much remains to be done to ensure that CCF will have a future place in New Zealand forestry and some of the issues are outlined in the following sections.

6.1 RESEARCH

One thing which will have become clear from the preceding chapters is that, in New Zealand, there is still a lot we do not know about CCF. First, and probably most important, is the lack in our depth of knowledge about the ecology of many of the species with which we wish to work, particularly so for our indigenous forests. Of the beech species and kauri we do have reasonable knowledge, information about totara is now much more advanced (Bergin, 2003), but of the others there is still a lot to learn. And knowledge of individual species is not the end of the issue. If we wish to establish and manage forests containing a range of species, a great deal of investigation is needed — in particular, about the ecological processes involved if we wish to have mixed stands of exotic and indigenous trees (refer to Appendix 2 for species details).

Also significant is the matter of biodiversity — not only of the plant population but also of associated animals and invertebrates. The latter are of considerable importance because invertebrates, with fungi, play a major role in the breakdown of forest litter and contribute considerably to the health of the forest (Peterkin, 1997).

The possibilities for contributing useful research are many and varied, and are grouped into main categories as follows:

Genetic and provenance studies

Apart from some work on the selection and grafting of superior kauri seed trees in the 1950s (Morrison, 1955; Morrison & Lloyd, 1972) there has been little if any research done in this area, yet it is one which would definitely result in important gains being made — if the early kauri results are any indication. A project being undertaken by Janssen "A pilot inventory of elite native timber trees as seed-sources for native afforestation silviculture from lowland environmental domains", should provide valuable data on a range of species (Janssen, 2006). However, care must be taken to ensure that we do not reduce genetic diversity.

Establishment

This is an important area requiring a significant research input because solving problems here will enable a major leap forward in the establishment of new indigenous forests. Much is already known about the production of seedlings through the work of Morrison with kauri, and several podocarp species by D.Preest. Although the latter did not publish any results his work was recorded in unpublished Forest Research reports and picked up and improved upon by a large number of nurseries currently producing native tree seedlings (A.E.Beveridge, pers. comm.).

Once seedlings are grown there are several areas where research is urgently needed — in particular the use of nurse species, site/species interactions, and the shade tolerance levels of key species. While some work has been done in these areas with kauri (Morrison & Lloyd, 1972; Barton, 1999), the surface has hardly been scratched for most other species.

The natural regeneration processes of many species is reasonably well understood, particularly for kauri and beech (Wardle, 1984; Morrison & Lloyd, 1972; Barton, 1999), and recent studies show that totara has great potential (Bergin, 2003). But more information is urgently needed, especially on the moisture requirements necessary to obtain rapid initial growth, scarification to induce regeneration, and releasing in the first few years of growth.

Silviculture and management

The references given show that there is reasonable information available relating to the silviculture of kauri, beech, and totara but little on other species. In particular, we need to apply the ecological knowledge that we have to devise methods to permit rapid establishment and growth over the first 10 years or so, since this is the key to reducing the time needed to produce utilizable trees.

Feral animals are more of a problem than in plantation forests and can cause serious damage to younger trees in particular, because of the very favourable habitat provided by continuous cover. Better control methods are required for most situations and species. The same applies to weed species because many (such as blackberry, woolly nightshade, and pampas) can flourish at lower light levels.

Research is needed on improved economics and methodology of ground extraction methods for harvesting in forests where the trees are often scattered. Felling and extraction must be done with minimal damage to the forest and this includes issues such as optimum log length and time of harvesting. On the utilization and management side, markets for timbers once routinely used need to be re-established and research into improved sawing, drying, and marketing is required.

Conversion to CCF

This handbook outlines the processes involved, but in many cases the approach is somewhat theoretical since, apart from specific trials with kauri and some podocarps and more extensive work with beech, this has not been previously done in New Zealand. It is essential to test the processes proposed to ensure that they will work in this country.

Inventory, monitoring, and yield control:

This handbook provides some information on monitoring and inventory systems and yield control, but considerable further development is required to perfect these systems for New Zealand conditions. The ideal inventory system will be rapid, easy to carry out and analyse, and provide accurate data.

Wind research

Surprisingly, for such a windy country we know little about the measurement of wind and the selection of planting sites suitable for species which are not as wind-resistant as *Pinus radiata*. We know that wind can cause serious losses of trees, both in native bush and plantations, yet, unlike the British who have a range of sophisticated wind-prediction models (Mason & Kerr, 2004), we have done little to try to understand the impact of wind on forestry practice, apart from some trials to ameliorate wind damage in naturally established beech forest (J.Wardle, pers. comm.).

6.2 PLANNING

To achieve success in establishing continuous cover as an important management tool in New Zealand forestry we must plan ahead by setting effective targets through the use of sustainable management plans and the monitoring of these plans in order to measure the degree of success in reaching the targets set. The minimum requirements of such plans are contained in Schedule 2 of the Forests Act 1949 (see page 19).

It can be argued that this will be achieved via the adoption of certification schemes such as that promoted by the Forest Stewardship Council (FSC). However, given the almost insurmountable difficulties being encountered by those currently involved in attempting to set up such a system in New Zealand, it may be that a simplified and pragmatic approach is more likely to succeed than one based on very specific rules and limitations. This can be done by working via ecologically based sustainable management plans, which are produced to a standard set by national or international guidelines and monitored by a Government-appointed organisation. Despite some limitations, Schedule 2 of the Forests Act 1949 already provides this service. In addition, it is felt by some that the FSC approach does not necessarily mean better planning and forest management, and is somewhat of a dead end; this is particularly so in view of its high cost relative to small individual forest areas.

It must be emphasised that having good monitoring and inventory systems in place is vital to successful planning. Until suitable methods for continuous cover forests are developed, existing procedures for exotic and indigenous species, or those described in Chapter 3, can be used.

6.3 FINANCE AND TAXATION ISSUES

The economics of indigenous forestry

Until quite recently indigenous forest management in New Zealand has been an extractive industry. That means that the forest owner paid for the extraction, transport, and milling of a product which cost him nothing to grow. However, to properly implement CCF, particularly if new forests are to be established, additional costs must obviously be met. Economic studies are essential to ascertain the viability of such operations, as are comparisons between management of natural forest and planted forests. The only such study so far undertaken is for kauri; this showed that kauri grown as a plantation species would not make even a 2% return on the investment (Barton & Horgan, 1980). A recent update of this (unpubl.), using *Acacia melanoxylon* as a nurse and intermediate crop, as well as better growth data, shows that the potential is much better than originally thought.

This situation with kauri highlights one of the main impediments to investment in non-rotational forests which can take up to 100 years to produce harvestable timber. This impediment is the whole area of forest valuation with its complete emphasis on plantation forestry. In New Zealand we are tied to various methods, all of which include the discounting of forest value to take account of time. This creates problems for the uneven-aged forest because discounting is not really feasible, although in some form it must be used when CCF forests are sold. The logical approach is to adopt the procedure of writing off all of the establishment and tending costs of a new forest (including naturally regenerating stands) and, once production begins, adopt the practice of balancing costs and returns in any one year. Then, if the forest is to be sold, it would be valued on its current stocking, wood volume, etc., without any application of discount rates.

Taxation and legislative impediments

Initial work done in this area (Barton *et al.*, 2005) has clearly shown that those wishing to grow native trees for productive purposes are not only discriminated against by the taxation laws but are also affected by the Resource Management Act. In the latter case it is mainly the interpretation of the Act by some units of Local Government which is the problem. Further research can help make a better case for growing native trees but the main issue here is persuading the Government and people generally that law changes to encourage the establishment of productive indigenous forests will be beneficial to New Zealand. However, the overriding issue is that all forests — exotic and indigenous, natural and planted — should be treated the same as regards taxation and environmental issues.

The non-timber values of continuous cover forests

There is good evidence suggesting that forests managed under continuous cover produce higher values for carbon sequestration, landscape, biodiversity, soil, and water than do clearcut forests or farmland. Apart from carbon there have only been minimal attempts to value these factors or to consider how such valuation might provide a benefit to the owner; there is good reason to undertake research in this area.

6.4 TRAINING

As outlined in Appendix, 1 the lack of skills in the area of CCF is a major impediment to its successful practice. Tāne's Tree Trust has begun running workshops which are aimed at improving the skills required to grow native trees. The intention is to upgrade and expand this training and put it on to a more formal basis. In addition to teaching the silvicultural and harvesting skills needed in the forest, the organizational and mensuration skills required to manage continuous cover will also need to be taught to tertiary level.

6.5 LEGISLATIVE

Taxation

As noted in 6.3 it does appear that some modification of the taxation law, especially in the I.R.D's approach to the lack of tax revenue over the long period from planting to first harvest, will be needed to ensure equal treatment for those managing indigenous as opposed to exotic forests. There may also be some taxation impediments which apply to continuous cover management but these are not immediately obvious.

Review of the Forests Act

The Forests Act 1949 and its 1993 amendment which is now Part IIIA of the Forests Act 1949 have been drafted to cover issues relating to exotic forests and the management of naturally established indigenous forest. The issue of planted indigenous forest is not dealt with except for the "Forests (Planted Indigenous Forest Certificate) Regulations 2007" which will enable people planting indigenous forests to register their forest with the Ministry of Agriculture and Forestry. Other aspects which would require attention, should CCF become more common, are the conflicts between prescriptive sections of the Act and the ecology of individual species (see 5.2), and problems which might arise with mixed planting of indigenous and exotic species. In fact, the major fault with the Forests Act is probably the existing dichotomy of indigenous and exotic species which, from both legal and management perspectives, is unnecessary and counterproductive.

However it will probably be necessary to allow problems associated with planted and managed forests, exotic and indigenous forests, and mixtures of the two, some time to become evident, before a thorough overhaul of the Act is undertaken.

Although the silvicultural systems upon which it is based have been known for considerable time, CCF in New Zealand is a very new concept, little understood by most except for the few involved in timber production from existing indigenous forests. There is no doubt that some parts of this manual will be out of date almost as soon as it is published but that is all to the good for, if it encourages some forest owners to make the leap to more economically and environmentally sustainable systems, it will have succeeded. Future publications on the subject will keep those foresters and the ones who follow them, up to date with the rapid growth of continuous cover procedures world wide.

APPENDIX 1

ADVANTAGES AND DISADVANTAGES OF CONTINUOUS COVER FORESTRY

	ADVANTAGES	DISADVANTAGES
Management, yield, and sustainability	CCF produces a greater percentage of wood as large-diameter, high-quality saw and veneer logs than clearfell systems do, so value per cubic metre is higher. The standing volume of timber can be considerably higher than plantation systems where trees are often felled before they reach economic size..	Often lower wood volume in hardwood and mixed stands.
	CCF requires long-term stategic objectives and flexible working plans with emphasis on forest ecology and dynamics.	Intensive management decision-making is required in the forest.
	Small trees occupy relatively little space in the system compared to plantation forestry, because the age-class distribution is maintained vertically instead of horizontally (see Fig 1.2).	
	Because crowns of dominant trees (i.e., those available for next harvest) are well developed and often emergent, increment continues at an even rate on all dominant trees.	Because crowns are free, upper logs often bear large branches and therefore large knots. There is also more taper.
	There is increased within-stand structural and species diversity.	
	The potential to undertake enrichment planting is available which means that the genetic quality of future crops can be improved by planting superior provenances and cultivars.	Forest managers need an holistic approach to forest management and must have in-depth understanding of the environmental and ecological requirements of the forest.
	It is often possible to widen the range of produce from the forest — for example, the production of handles from saplings and the use of small poles for a variety of purposes. With small stands it is often possible to mill and dry small quantities of wood on site.	
	Carbon sequestration is often higher in the mature coniferous continuous cover forest because the biomass can average 1000 tonnes compared with *P. radiata* at *ca* 600 tonnes/ha.	*Nothofagus* and other indigenous and exotic hardwoods may have lower carbon sequestration potential with biomass as low as 500 tonnes.
	Harvesting can be regular or intermittent because timing is not tied to rotation length.	Many species are more difficult to establish and manage than plantation species such as *Pinus radiata* and Douglas fir.
Protection of site values	Continuous and good soil protection, especially on steep slopes. The constant forest cover reduces both soil exposure and erosion.	During harvest there can be more damage on heavy soils because there is less slash to prevent soil compaction.
	The humus provides a good germination medium for many species and the soil surface conditions provide protection from sunlight and drying winds, therefore enhancing natural regeneration. (However this may not apply to all species; e.g., *Nothofagus* and rimu regenerate well on mineral soils.)	In group felling systems, if the soil dries out after extraction there will be heavy mortality of germinating seedlings. Shallow-rooted seedlings (e.g., kauri) are more vulnerable than deeper rooting ones (e.g., tawa).
	Damage by wind and snow is generally less than with even-aged monocultures.	
Flexibility of system	Flexibility of the system gives good scope to a skilled manager and the system is well suited to small forests where intensive working and close supervision are possible (e.g., the family forest situation.)	Unskilled managers can wreck the process.
	The best possible use can be made of each site and the productive capacity of the soil can be preserved.	

	ADVANTAGES	DISADVANTAGES
	Trees do not have to be felled merely because they have reached a certain age but good form trees can be retained for as long as they are making valuable increment.	
	It is possible to accommodate a wide range of species from the strong light-demanders through to very shade-tolerant.	
	Use of natural regeneration, direct seeding, coppicing, and enrichment planting mean that the establishment process is usually less costly than in plantation forests. Where planting is required, stock must be sturdy, vigorous, and uniform.	
	Where required, mixtures can be constructed to more closely match local site variations.	
	There are good prospects for the long-term sustainability of all forest values.	
Ecological and biodiversity aspects	Regeneration occurs under the shelter of the stand and, with parents being components of that stand, juveniles are well adapted to the site, the young crop developing in a more natural way. An over-abundance of seedlings from natural regeneration can form a seedling bank to be utilized in poor seed years.	
	The microclimate near the ground will be more favourable to the needs of newly germinated seedlings as there is less disturbance of the ecosystem guaranteeing shelter for regenerating seedlings. All seed years are available for regeneration.	The system tends to favour shade-bearers against light-demanders unless action is taken to encourage the latter. Depending upon the silvicultural system used, continuous cover is not usually suited to strong light-demanders (e.g., *P. radiata*). However, if gap sizes are larger some strong light-demanding species can be used in group systems.
	There is retention of natural biodiversity, species composition and a tiered stand structure. A wider range of biodiversity can be accommodated in the varied habitat of the forest strata.	
	Microclimates in continuous cover systems will usually be more humid and stable than with clearfell.	
	Plants and animals which thrive under forest conditions are conserved.	Species which are well adapted to a particular ecological niche may still be difficult to manage from a silvicultural perspective — e.g., the impact of harvesting upon indigenous fauna.
	Some invertebrate and fungal species increase in number because environmental conditions remain more constant, and some trees reach greater heights.	A preponderance of undesirable species can become established unless care is taken.
	It is easy to leave dead and fallen dead trees for wildlife enhancement.	
	Because there is less overall disturbance, biodiversity will be enhanced by the practice of CCF.	
Skill levels required	Higher pay and greater interest for skilled workers aid in skill retention.	More complex management requiring skilled personnel. This is especially so in the early selection of trees to remain, the most effective introduction of planted stock, the selection of trees for removal, felling those trees and extracting them with minimal damage to the forest.

	ADVANTAGES	DISADVANTAGES
	Better job satisfaction because of the higher skill levels required	Yield prediction and regulation are more difficult than for clearfelling, especially when regeneration centres are small and scattered. Greater skill required to open gaps to let in sufficient light (but not too much) for regeneration and growth and, where regeneration is insufficient, planting the right number of trees to ensure maximum future timber volume.
		There is currently a lack of contractors with sufficient skills in CCF.
		Complex harvesting systems with the need for accurately located access tracks.
Threats to the forest and failure of natural processes	Stands are more resistant to disease.	Animal control is difficult in forests with tiered understorey, and damage done by browsing animals can be severe because of the combination of easy access to young trees and abundant, dense cover. Wherever possible, destructive animals must be excluded from the forest.
	Structural diversity and enhanced stand stability provide resilience against windthrow.	There is risk of windthrow when transforming regular stands, particularly on unstable sites, and wind damage is possible especially on margins of small gaps.
	CCF stands are usually less susceptible to major weed invasion than clearfell systems.	Some weeds which are relatively shade-tolerant, e.g., blackberry and privet, have the potential to cause serious problems and the wide range of light conditions creates habitats for a wider variety of weeds.
		Weeds are a problem whenever they can establish, whereas with even-aged monocultures they are troublesome only during the establishment phase.
	Able to plant trees if that is required to improve proportions of more desirable species.	It is rare not to have to aid the process of natural regeneration by planting or direct seeding in order to reduce risk of failure, correct deficiencies in stocking, or shorten duration of individual operations.
	With small gaps, the young crop gains from side protection combined with overhead light.	Where gaps are too large and soil is a dry type, there can be heavy seedling mortality — especially on south side of gaps. Stem distortion, caused by plants growing toward the light, is likely at gap edges.
Landscape and recreation values	Less visual impact than clearfelling and no sudden or drastic changes to the landscape. Continuous cover forest is considered more attractive than monocultures and this can bring benefits to the owner, the region and the general public. The forest is usually varied and interesting in appearance and the mosaic of open glades, thickets, and tall trees is attractive to walkers and riders. Provides a subtly varied internal landscape in which to undertake a variety of recreational activities.	
Costs	If regeneration is successful, establishment costs are reduced.	Regeneration and felling are usually scattered and a dense system of extraction routes is required to offset the effect of scattered working. Harvesting costs are increased by scattered nature and cost of access for construction and maintenance.

	ADVANTAGES	DISADVANTAGES
		If helicopters used for extraction, costs are usually higher than for ground operations.
	Maintenance and tending costs can be reduced because stands are "self-tending" to a considerable degree.	Total management costs depend upon the initial condition of the forest. Enrichment planting can be expensive.
		Occasionally, as can happen with the beeches and some exotic conifers, regeneration is too successful, thus increasing thinning costs.
	Cost effective because average piece size is larger.	Costs of planning and inventory are high.
		There are higher costs to exclude animals — especially if fencing is required (e.g., deer).
		More costly on fertile sites because of increased weed competition and /or where there is heavy browsing pressure.
		Cost of skilled manpower is expensive.
	Because environmental benefits are higher, the benefit : cost ratio is usually better than for clearfell monocultures.	Overall costs likely to be higher than in a comparable area of clearfell forest.
	Access tracks can be narrower and constructed to a lower standard than those required for clearfell extraction.	Unless using a helicopter, extraction will require a higher density of of access tracks than for clearfell and these tracks will require on-going maintenance.
Marketing	Easier to get F.S.C or similar certification with CCF.	
	With mixtures there is more flexiblity in meeting market needs.	Difficulty marketing small quantities of a range of species.
	With high-value species the yield from thinnings of poles and saplings may find a market.	Unable to supply large quantities of low-grade fibre.
Forest ownership		Not suited to Trust ownership because of rule against perpetuities.
	CCF is better adapted to a political climate which has some form of State involvement and direction (i.e., Forest Law).	Possible ownership changes with private ownership, or rapid staff changes with State ownership can mean variable quality of management.
	People are likely to provide better management to forests which have good long-term potential.	Long period of time required for planted forests or forests converted from poor quality growth to reach management equilibrium.
		Long growth cycles of individual trees mean that several generations of foresters will be involved in management.

This table is based upon the work of the following:
Beneke (1996, 1998), Cairns (2001), Heath (2001), Helliwell (1999), Mason *et al.* (1999), Matthews (1989), Peterkin (1997).

APPENDIX 2a

SPECIES FOR CONTINUOUS COVER FORESTRY IN NEW ZEALAND

Details of the species included have been assembled from a wide range of references, supplemented from personal experience. Those considered to have greatest potential at this stage are described in more detail on the pages following. Other species, whose potential is lower or about which we have little knowledge, are listed in Appendix 2b; potential nurse species are listed in Appendix 2c.

Scores for each species included in Appendix 2b are relatively subjective and based on five major factors: timber quality, shade tolerance, growth rate, climate tolerance, and soil tolerance. The total scores, calculated in the same way, are also given for the species in Appendix 2a. Some 2b species score higher than 2a ones and the reasons for their non-inclusion in 2a are usually noted in 2b. As a general rule, species with lower scores but included in 2a are thought to be particularly suited to CCF, or they perform functions such as nitrogen fixation which are important for associated species.

The rankings given for shade tolerance should not be considered as the final word on the issue. They are contained in parentheses under "Shade Tolerance" on each species sheet. It is not possible to give good data on these factors at present and more research is needed for most of them. At this stage it is better to use them in a comparative fashion. For example *Thuja plicata* with a 2–3 rating is more tolerant of shade than *Cupressus lusitanica* with a 3–5 rating. The classification of shade tolerance into juvenile and mature is also a tentative one and if a species tolerance is given without division into juvenile and mature it is because at this time there appears to be little differentiation between the phases of growth.

SHADE TOLERANCE RANKINGS

1 Will establish and grow in dense shade
2 Will establish and grow in moderate shade
3 Will establish and grow in light shade
4 Grows on edges of stands and in gaps
5 Requires high light levels.

COMPETITION TOLERANCE LEVELS

These relate to competition from associated species and weed growth for light, soil moisture, and nutrients, as well as the competitive abilities of different species. There is much less information available on the subject of competition than on shade tolerance, although the two aspects are linked. There is not enough information to assign tolerance levels at this time.

The species for which full details are included in the following pages are listed below.

Acacia melanoxylon
Nothofagus menziesii
Agathis australis
Nothofagus solandri
Alnus rubra
Phyllocladus trichomanoides
Beilschmiedia tawa
Pinus strobus
Cryptomeria japonica
Podocarpus totara
Cunninghamia lanceolata
Prunus avium
Cupressus lusitanica
Pseudotsuga menziesii
Dacrycarpus dacrydioides
Sequoia sempervirens
Dacrydium cupressinum
Thuja plicata
Eucalyptus microcorys
Vitex lucens
Nothofagus fusca
× *Cupressocyparis ovensii*

The **Reference** number at the bottom of each species sheet refers to the number to the left of each publication in the list of references.

SPECIES: *Acacia melanoxylon*	COMMON NAME: **Blackwood**	SCORE: 28

Altitudinal limits: 0–1500 m
Latitudinal limits: 16° to 43° S
Indigenous location: East and SE coast of Australia. Queensland to Tasmania and South Australia
General site requirements: A tough and adaptable species surviving over a wide range of sites but only growing well when correctly sited; ideally sheltered valleys and lower valley slopes.

Climate:		**Soil:**	
Climate type:	Cool & warm humid zones	Optimum and extremes:	Fertile, moist, well-drained soils best. Tolerates clays and peats.
Rainfall:	High rainfall best, > 1300 mm. Will grow 800–1800 mm. Requires > 150 rain days.		
Temperature:	Mean hottest month 23–26°C Mean coldest month 1–10°C	Soil moisture:	Tolerant of wet conditions but will not grow in stagnant water. Moisture must be adequate through growing season
Frost / Snow:	Withstands frost but seedlings in open can be damaged. Some provenances more tolerant. Susceptible to snow damage.	pH:	?
Wind:	Moderate tolerance but poor form in exposed places. Early shelter essential for good form.	Fertility:	Reasonable soil fertility required
		Soil hardness:	Grows poorly on hard soils
Drought:	Withstands occasional drought		

Shade tolerance*: Reasonably tolerant (3–4) when young but less tolerant from pole size on (4–5)
Competition tolerance: Relatively low
Form, habit, and shape: Poor form unless there is strong side competition when trees are young
Epicormics: Minimal
Coppice ability: Coppices very well. Also root suckers.
Regeneration: More likely from coppice and suckers than seed.
Naturally associated species: *Eucalyptus regnans, E. obliqua, E. viminalis, Nothofagus cunninghamii, N. moorei, Dicksonia antarctica*
Nitrogen fixing: Yes
Nurse potential: Very good

Pests:		**Maximum Growth:**		**M.A.I. Range:**	
Animals:	Goats and deer	Height:	45 m	Height:	0.3–1.1 m
Insects:	Psyllids, blackwood tortoise beetle, lemon tree borer, painted apple moth	Diameter:	1.5 m	Diameter:	1.0–2.5 cm
		Volume:	5 m^3	Volume:	<1.0–21 m
Fungi:	Rust fungus				

Other:
Time to utilization: 25–40 years
Optimum log diameter: 60 cm

NOTES: Possibly the most useful exotic for CCF in New Zealand because it is one of the few which fits well into indigenous forest. Preliminary work suggests that indigenous species regenerate successfully under blackwood.

* Provisional shade tolerance rating in parentheses. See explanation on page 41.

References: 10, 26, 78, 92, 94, 95, 108, 113, 116

SPECIES: *Agathis australis*	COMMON NAME: Kauri	SCORE: 30

Altitudinal limits: 0–700 m

Latitudinal limits: 34° 30' to 38°

Indigenous location: North Cape to line from Kawhia to Te Puke

General site requirements: Will grow on all slopes with warm aspects. Not usually found in gullies because of competition from other plants.

Climate:		**Soil:**	
Climate type:	Warm humid summers and mild winters.	Optimum and extremes:	Grows on most soils but best on friable, deep, water retentive, organic, alluvial and loamy soils. Not good on hard clays and sands.
Rainfall:	1000–2000 mm Optimum 1300 mm		
Temperature: requirements	Best growth between 13° and 15°C mean annual temperature. Does not grow well below 11°C.	Soil moisture:	Medium to high moisture for optimum growth. Intolerant of poor drainage.
Frost / Snow:	Seedlings survive –2°C and small poles –7°C.	pH:	>5.5
Wind:	Moderate to high wind tolerance. Moderate tolerance of saline winds. Shelter is beneficial. Generally best where humidity is high.	Fertility:	Must have reasonable nitrogen levels Foliage N >1.5%
		Soil hardness:	Growth very slow on hard soils
Drought:	High tolerance.		

Shade tolerance*: Very tolerant as seedling and persistent at low light (2–3). Need overhead light to grow (5)

Competition tolerance: Survives moderate competition. Cannot establish in dense scrub hardwood / tree fern cover.

Form, habit, and shape: Single stemmed and pyramidal in pole stage. Adult has spreading crown atop cylindrical trunk.

Epicormics: Occasional on trees that have had trunks suddenly exposed to sunlight, especially if crowns are sparse.

Coppice ability: Very rare in pole stands only.

Regeneration: Not common in mature stands. Common in scrub and pole stands and stand edges.

Naturally associated species: tanekaha, hard beech, kanuka, rimu, totara

Nitrogen fixing: Nil. Has high N requirement because much of stand N is locked up in slowly decomposing litter.

Nurse potential: Low

Pests:		**Maximum Growth:**		**M.A.I. Range:**	
Animals:	Goats, deer, cattle among young trees	Height:	45 m	Height:	25–50 cm
Insects:	Leaf miner	Diameter:	6 m	Diameter:	0.3–1.0 cm
Fungi:	*Phytophthora*	Volume:	175 m³	Volume:	<5 to >14 m³

Other: Time to utilization: 70–80 years

Optimum log diameter: 60–70 cm

NOTES: Recent investigations reveal that on very good sites where seasonal water supply is not limiting, kauri will grow very fast, reaching 10 cm diameter and 8 m height in 6 years.

* Provisional shade-tolerance rating in parentheses. See explanation on page 41.

References: 4, 13, 14, 66, 91, 118

SPECIES: *Alnus rubra*	COMMON NAME: Red alder	SCORE: 22

Altitudinal limits: 0–760 m
Latitudinal limits: 34°–60° N
Indigenous location: West Coast U.S.A from Alaska to California
General site requirements:

Climate:		**Soil:**	
Climate type:	Humid / super humid	Optimum and extremes:	Grows on wide range but is best on moist, fertile, well-drained alluvial soils of river-banks, gullies and similar sites. Tolerates heavy soils.
Rainfall:	630–3050 mm	Soil moisture:	Low moisture level main limitation and tolerates poor drainage although well-drained moist sites are best.
Temperature:	Midwinter mean 0.2–11°C Midsummer mean 13–20°C		
Frost / Snow:	Susceptible to autumn frost	pH:	Intolerant of high pH
Wind:	Prone to stem break in strong wind and less wind-firm than other alders. Will grow in coastal situations..	Fertility:	Reasonable fertility required
		Soil hardness:	Probably not on hard soils.
Drought:	Not tolerant		

Shade tolerance*: Low to medium (4–5). More tolerant than poplar and birch and less than maple, Douglas fir, western red cedar
Competition tolerance: Intolerant
Form, habit, and shape: Erect when young, crown spreads in older trees
Epicormics: Following pruning are prolific in more open stands. Basal suckers also.
Coppice ability: Yes
Regeneration: Seed or coppice
Naturally associated species: Sitka spruce, western hemlock (*Tsuga heterophylla*) western red cedar, Douglas fir, redwood, Lawson's cypress
Nitrogen fixing: Higher content of nitrogen fixed in leaves than any other U.S. species
Nurse potential: An important nurse species because it can fix N and is deciduous. Trials required.

Pests:		**Maximum Growth:**		**M.A.I. Range:**	
Animals:	Deer, possum	Height:	32 (40)m	Height:	0.5–1.2 m
Insects:	Ghost moth and similar insects can be problem in some areas.	Diameter:	0.8 m	Diameter:	0.6–1.7 cm
Fungi:	No known problems	Volume:	?	Volume:	1.5–4.0 m^3/yr

Other: Is fire resistant
Time to utilization: ?
Optimum log diameter: 50cm

NOTES: Is fastest growing alder, especially on heavy soils. Provenance trials from different parts of U.S.A required in NZ. M.A.I data from limited NZ trial.

* Provisional shade tolerance rating in parentheses. See explanation on page 41.

References: 29, 30, 43, 45, 63, 92, 111, 113, 116

SPECIES: *Beilschmiedia tawa*	COMMON NAME: Tawa	SCORE: 23

Altitudinal limits: 0–900 m
Latitudinal limits: 34° 30' to 42° S
Indigenous location: North Island and South Island to Kaikoura
General site requirements: Susceptible to dieback from crown exposure when podocarp overstorey is removed.

Climate:		**Soil:**	
Climate type:	Warm temperate	Optimum and extremes:	Grows over wide soil range. Probably best on central North Island pumices.
Rainfall:	>1250 mm, well distributed	Soil moisture:	Intolerant of poor drainage and dry rocky sites
Temperature:	Mean annual temperature limit for optimum growth may be 10–13°C. Not found where long, cold winters or where snow fall usual.	pH:	?
Frost / Snow:	Down to –8° C but less as seedling very susceptible to snow damage.	Fertility:	Grows on low – moderate fertility soils.
Wind:	Protect seedlings from wind	Soil hardness:	Not on hard sites
Drought:	Will not tolerate dry conditions or grow in areas with low humidity.		

Shade tolerance*: Germinates in low light; saplings tolerate low light (2–4). Mature trees tolerate partial shade (4–5).
Competition tolerance: Very tolerant of other species except tree ferns.
Form, habit, and shape: Good form when nursed under partial conifer canopy. Round headed when mature.
Epicormics: No
Coppice ability: Coppices readily as sapling and tree. Branches of tawa that are blown over grow into new, individual trunks.
Regeneration: Bears annual seed crops varying from light to very heavy.
Naturally associated species: Rimu, miro, matai, totara, kahikatea, hinau, rewarewa, pukatea, mangeao, taraire, kohekohe, puriri, red beech and hard beech.
Nitrogen fixing: No
Nurse potential: None, requires to be nursed.

Pests:		**Maximum Growth:**		**M.A.I. Range:**	
Animals:	Not very palatable to goats, deer cattle. Rats eat seed.	Height:	24 m	Height:	<50 cm
Insects:		Diameter:	1.0 m	Diameter:	0.3–0.4 cm
Fungi:		Volume:	?	Volume:	?

Other: Time to utilization: 150 years (est)
Optimum log diameter: 60cm

NOTES: Data on growth rates of planted tawa are not available.

* Provisional shade tolerance rating in parentheses. See explanation on page 41.

References: 4, 66, 73

SPECIES: *Cryptomeria japonica*	COMMON NAME: Japanese cedar, Sugi	SCORE: 25

Altitudinal limits: To 400 m South Island and 800 m North Island
Latitudinal limits: 33–35°
Indigenous location: Japan
General site requirements:

Climate:		**Soil:**	
Climate type:	Moist cool	Optimum and extremes:	Fertile, reasonably moist. Reasonable on heavy clays and drier sandy soils.
Rainfall:	1200–2500 mm <1000 mm is too dry	Soil moisture:	Reasonable drainage required. Not on waterlogged or very dry sites.
Temperature:	Mean annual temperature 6–18°C	pH:	?
Frost / Snow:	Tolerates –8°C	Fertility:	Moderately fertile
Wind:	Wind resistant. Makes good windbreak. Moderately tolerant of saline winds.	Soil hardness:	Not on hard soils
Drought:	Killed by severe drought		

Shade tolerance*: Tolerant of shade (2–4). Suppressed but survives at low light levels. Mature trees require full light (5).
Competition tolerance: Sensitive to grass competition
Form, habit, and shape: Strongly conical with even shape and form
Epicormics: No
Coppice ability: No
Regeneration: Occasional
Naturally associated species:
Nitrogen fixing: No
Nurse potential: Possible

Pests:		**Maximum Growth:**		**M.A.I. Range:**	
Animals:	Possums can damage tops	Height:	70 m	Height:	0.5–0.9 m
Insects:		Diameter:	4 m	Diameter:	1.0–1.7 cm
Fungi:		Volume:	?	Volume:	12–26 m^3/ha

Other: Time to utilization: 40 years
Optimum log diameter: 55 m

NOTES: Suitable for under planting and mixtures — possibly with redwood, blackwood, *Eucalyptus* species and natives.

* Provisional shade tolerance rating in parentheses. See explanation on page 41.

References: 10, 37, 38, 63, 73, 92, 113, 116, 117

SPECIES: *Cunninghamia lanceolata*	COMMON NAME: Chinese fir	SCORE: 26

Altitudinal limits: 200–2800 m
Latitudinal limits: *ca* 15–30° N
Indigenous location: China, Vietnam & Laos
General site requirements: (Sub)monsoon evergreen forest

Climate:		**Soil:**	
Climate type:	Warm humid	Optimum and extremes:	Prefers better soils such as moist and well-drained loams but tolerant of a wide range sandy to clay, except poorly drained.
Rainfall:	900 - 2350 mm		
Temperature:	Mean annual temperature between 16 and 19°C	Soil moisture:	?
Frost / Snow:	Tolerant. Young trees damaged by –15°C.	pH:	4.7 to 6.4
		Fertility:	C:N ratio between 6.8 and 16. Responds to phosphate.
Wind:	Foliage killed by strong saline winds	Soil hardness:	
Drought:	High tolerance		

Shade tolerance*: Stands light to moderate shade (3–5).
Competition tolerance: High tolerance. Can be interplanted with crops and trees.
Form, habit, and shape: Strongly conical; even shape and form.
Epicormics: Yes, after pruning when spacing is wide.
Coppice ability: Strong ability to coppice. Development of basal shoots from trees at spacing wider than 1.5 m.
Regeneration: Seed, cuttings, and suckers.
Naturally associated species: Mixed evergreen/deciduous.
Nitrogen fixing: No
Nurse potential: Paulownia has been used as a nurse in China.

Pests:		**Maximum Growth:**		**M.A.I. Range:**	
Animals:	Possums strip bark from upper stem and branches.	Height:	50 m	Height:	0.5–0.8 m
Insects:	Resistant to wood insects and termites	Diameter:	3 m	Diameter:	1.2–1.9 cm
Fungi:	Wood relatively durable	Volume:	?	Volume:	?

Other: Time to utilization: ?
Optimum log diameter: ?

NOTES: Cultivated for over 8000 years in China. It is now impossible to determine the natural range. Close spacing (<1.5 m) suppresses basal suckers.

* Provisional shade tolerance rating in parentheses. See explanation on page 41.

References: 39, 47

SPECIES: *Cupressus lusitanica*	COMMON NAME: Mexican cypress	SCORE: 24

Altitudinal limits:	1200–3000 m
Latitudinal limits:	15°–25° N.
Indigenous location:	Mexico and Guatemala
General site requirements:	In NZ 300 m @ lat. 41°S and 610 m @ 38°S. Favoured site is sheltered, warm and wet gullies. Not hard exposed sites.

Climate:

Climate type:	Warm humid
Rainfall:	750–3000 mm. Best over 1000 mm. Requires summer moisture
Temperature:	Does not thrive in hot, dry summers.
Frost / Snow:	Stands –5°C frost. Very susceptible to snow damage.
Wind:	Not near coast. Requires shelter by scrub or nurse. Prone to topple age 18 months to 5 years on soft soils where exposed.
Drought:	Does not tolerate dry conditions.

Soil:

Optimum and extremes:	Moderately fertile sandy clay loams, moist gully and bottomland sites Not on hard or very wet sites.
Soil moisture:	Best on moist but not waterlogged soils.
pH:	Not on alkaline soils
Fertility:	Sensitive to variations in soil fertility.
Soil hardness:	Fails on compacted soils.

Shade tolerance*:	Will stand some shade (3–5).
Competition tolerance:	Useful for under planting where light is sufficient.
Form, habit, and shape:	Variable. Usually needs competition to achieve good conical form.
Epicormics:	Nil
Coppice ability:	Nil
Regeneration:	Occurs on scarified sites. Has annual seed production.
Naturally associated species:	
Nitrogen fixing:	No
Nurse potential:	More an associate than nurse for species with similar site preferences.

Pests:

Animals:	Deer (debarking). Possum if populations high
Insects:	Lemon tree borer and similar
Fungi:	Resistant to canker

Maximum Growth:

Height:	30 m (40 m)
Diameter:	?
Volume:	?

M.A.I. Range: (provisional)

Height:	0.4–1.1m
Diameter:	0.60–2.0 cm
Volume:	5.7 m³

Other:	Time to utilization:	30 years
	Optimum log diameter:	50 cm.

NOTES: Growth exceeds Douglas fir on some sites. Planting stock must be hard and well conditioned. Grows well in mixtures. Prone to cross pollination with other *Cupressus* so collect seed from isolated stands.

* Provisional shade tolerance rating in parentheses. See explanation on page 41.

References: 63, 85, 92, 113, 116, 117

SPECIES: *Dacrycarpus dacrydioides*	COMMON NAME: Kahikatea	SCORE: 25

Altitudinal limits: 0–750 m
Latitudinal limits: 35° 30' to 47° S
Indigenous location: All New Zealand
General site requirements: Commonest in Westland. Best growth where side shelter and light.

Climate:

Climate type:	Cool humid to warm humid.
Rainfall:	Prefers high rainfall areas.
Temperature:	
Frost / Snow:	Tolerant.
Wind:	Seedlings not tolerant of wind. Moderately tolerant
Drought:	?

Soil:

Optimum and extremes:	Grows on wide soil range. Best on deep, well-drained river terraces.
Soil moisture:	Tolerates alluvial areas subject to periodic inundation. Best growth on well-drained soils. Does not like dry sites.
pH:	?
Fertility:	Linear response to increased NPK fertilizer but not as good as totara.
Soil hardness:	Not on hard soils

Shade tolerance*: Seedlings tolerant of shade (1–3) but need high overhead light to thrive (4–5).
Competition tolerance: High survival rate following planting cf many other natives. Suppressed and killed by tree ferns and scrub.
Form, habit, and shape Generally very good (trees are erect and monopodal).
Epicormics: Occasionally on saplings.
Coppice ability: No
Regeneration: Very good seed production most years.
Naturally associated species: Often in pure stands but frequently in mixed podocarp forest and with pukatea. In South Island often associated with beech species.
Nitrogen fixing: No
Nurse potential: No

Pests:		**Maximum Growth:**		**M.A.I. Range:**	
Animals:	Deer where populations high	Height:	60 m	Height:	10–40 cm
Insects:	Cicada on saplings	Diameter:	1.5 m	Diameter:	0.1–0.9 cm
Fungi:		Volume:	?	Volume:	?

Other: Time to utilization: ?
Optimum log diameter: ?

NOTES: Not as tolerant as rimu of extreme sites.

* Provisional shade tolerance rating in parentheses. See explanation on page 41.

References: 4, 66, 98, 99, 104

SPECIES: *Dacrydium cupressinum*	COMMON NAME: Rimu	SCORE: 26

Altitudinal limits: 0–1100 m (600 m South Island). Most abundant below 750 m North Island)
Latitudinal limits: 34° 30'–47° S
Indigenous location: All New Zealand
General site requirements: Probably the most site-tolerant of main podocarps.

Climate:

Climate type:	Cool temperate to moist humid
Rainfall:	> 1000 mm
Temperature:	
Frost / Snow:	Tolerant down to –11° C. Not suited to areas where snow lies for more than a few days at a time.
Wind:	Seedlings require shelter. Trees tolerate wind and salt spray.
Drought:	Not tolerant

Soil:

Optimum and extremes:	Grows on wide soil range. Deep, well-drained alluvials best. Reasonable on sandy soils. Intolerant of extreme podzols.
Soil moisture:	Better growth where soil has good drainage.
pH:	Acidic to neutral
Fertility:	Linear response to increased nutrition but not as good as totara.
Soil hardness:	?

Shade tolerance*: Tolerates low light when young surviving >30 years in shade (3–4). High overhead light needed to grow well (4–5).
Competition tolerance: Not tolerant beyond seedling stage. Intolerant of tree ferns.
Form, habit, and shape: Visually better form than other podocarps.
Epicormics: Minimal
Coppice ability: None
Regeneration: Seed or tip cuttings from young plants.
Naturally associated species: Found in association with almost all other NZ trees.
Nitrogen fixing: No
Nurse potential: No

Pests:

Animals:	Relatively resistant to attack by most animals
Insects:	Cicada damage to small saplings
Fungi:	

Maximum Growth:

Height:	35 (60) m
Diameter:	2.5 m
Volume:	40 m^3

M.A.I. Range:

Height:	0.06–0.56 m
Diameter:	0.1–0.82 cm
Volume:	?

Other: Greatest cause of mortality is windthrow caused by previous canopy disturbance.
Time to utilization: Estimated minimum 120 years.
Optimum log diameter: ca 1.0 m

NOTES: Planted rimu have a relatively high survival rate — better than kahikatea and totara over a range of hill country sites. Slow heartwood formation means a long time to utilizable size.

* Provisional shade tolerance rating in parentheses. See explanation on page 41.

References: 4, 66, 98, 99

SPECIES: *Eucalyptus microcorys*	COMMON NAME: Tallow wood	SCORE: 24

Altitudinal limits: 0–100 m
Latitudinal limits: 25–33° S, North Island 0–50 m, South Island
Indigenous location: East coast Queensland and New South Wales
General site requirements: Gullies, slopes and, broad ridges in tall open forest.

Climate:		**Soil:**	
Climate type:	Warm humid	Optimum and extremes:	Fertile soils preferred but will grow on poor sand. Good free-draining loams and friable clays most suitable. Best in fertile gullies on rainforest margin.
Rainfall:	1000–2000 mm with summer maximum		
Temperature:	MMTHM* 24–31°C MMTCM 0–10°C	Soil moisture:	Requires moist conditions during summer.
Frost / Snow:	Down to –4°C. Seedlings frost-tender first year.	pH:	?
		Fertility:	?
Wind:	Reasonably tolerant.	Soil hardness:	Not on hard sites
Drought:	Intolerant		

Shade tolerance†: Reasonably shade-tolerant (3–5)
Competition tolerance: Grows well in openings cut in scrub (gap diameter 1.5 × scrub height).
Form, habit, and shape: Good form in gaps.
Epicormics:
Coppice ability: Coppices well.
Regeneration: From seed and coppice.
Naturally associated species: *Eucalyptus saligna, E. pilularis, E. globoidea, E. maculata, Syncarpia glomulifera*
Nitrogen fixing: No
Nurse potential: Untested, but most eucalypts are poor nurse species because they are strong competitors for moisture and nutrients.

Pests:		**Maximum Growth:**		**M.A.I. Range:**	
Animals:		Height:	60 (70) m	Height:	1.0 m
Insects:	Low susceptibility to those known to attack eucalypts.	Diameter:	2 (2.9) m	Diameter:	0.5 cm
Fungi:	None known	Volume:	33 m^3	Volume:	?

Other: Time to utilization: ?
Optimum log diameter: ?

NOTES: Is probably the most valuable eucalypt. Timber very durable.

* MMTHM & MMTCM = mean minimum and maximum temperatures in the coldest and hottest months.
† Provisional shade tolerance rating in parentheses. See explanation on page 41.

References: 11, 26, 54, 65, 78, 92

SPECIES: *Nothofagus fusca*	COMMON NAME: Red beech	SCORE: 24

Altitudinal limits: 300–1100 m North Island; from sea level, South Island
Latitudinal limits: 37° 30' to 46° S
Indigenous location: Central North Island to Southland
General site requirements: Lower - mid slopes with deep, fertile soils preferred.

Climate:

Climate type:	Cool temperate
Rainfall:	>1200 mm
Temperature:	Requires high sunshine hours and generally higher temperatures than black and silver beech.
Frost / Snow:	Frost to –11°C tolerated.
Wind:	Not as wind tolerant as other beech.
Drought:	Not tolerant

Soil:

Optimum and extremes:	Deep, well-drained and moist. Requires more fertile soils than other beech species.
Soil moisture:	Requires better drainage than other beech species
pH:	?
Fertility:	170 species of ectotrophic mycorrhizal fungi are associated with the beech species and seedlings must be infected to survive in field. Main function is associated with phosphate uptake.
Soil hardness:	?

Shade tolerance*: Is the least shade tolerant of the beeches (4–5).
Competition tolerance: Tolerates strong competition.
Form, habit, and shape: Needs competition for good form.
Epicormics: Growth can follow pruning and thinning.
Coppice ability: Young plants can coppice.
Regeneration: Regenerates well on mineral soil. Average 4–5 years between good mast years.
Naturally associated species: Often pure or with other beech species, but also with rimu and other podocarps.
Nitrogen fixing: No
Nurse potential: Probably not.

Pests:

Animals:	Deer and goats
Insects:	German wasp, ghost moth, *Platypus* beetle, *Epichorista* and *Proteodes* spp.
Fungi:	*Sporothrix* (assoc. with *Platypus*), *Inglesia fagi*, several white rot spp.

Maximum Growth:

Height:	30 m
Diameter:	2 m
Volume:	?

M.A.I. Range:

Height:	0.35–0.50 cm
Diameter:	0.50–1.13 cm
Volume:	6–19 m^3/ha

Other: Mistletoe can be a pest.
Time to utilization: 60 (120) years
Optimum log diameter: 50 cm

NOTES: Hybridizes with black beech, mountain beech, and hard beech. Early and successive light thinnings essential for achieving good growth rates.

* Provisional shade tolerance rating in parentheses. See explanation on page 41.

References: 3, 4, 66, 104, 115, and J. Wardle (pers. comm.)

SPECIES: *Nothofagus menziesii*	COMMON NAME: Silver beech	SCORE: 25

Altitudinal limits: North Island 760–1500 m, South Island 0–900 m
Latitudinal limits: 37° 30' to 46° S
Indigenous location: Central North Island to bottom of South Island
General site requirements:

Climate:		**Soil:**	
Climate type:	Cool summers	Optimum and extremes:	Grows on wide range of soil but best on well drained, recent alluvials.
Rainfall:	1000–6300 mm. Usually in higher rainfall areas than other beech species.	Soil moisture:	?
Temperature:	?	pH:	?
Frost / Snow:	Tolerant of heavy frost and snow.	Fertility:	170 species of ectotrophic mycorrhizal fungi are associated with the beech species and seedlings must be infected to survive in field. Main function is associated with phosphate uptake.
Wind:	On exposed sites with low humidity seedlings need protection from wind for up to 2 years		
Drought:	Least tolerant of beech species.	Soil hardness:	?

Shade tolerance*: Can germinate, survive, and grow in greater shade than other beech species (2–4)
Competition tolerance: Reasonably tolerant Can be an understorey to red beech and very rarely to black.
Form, habit, and shape: Needs competition for good form and opengrown trees always branch from low down.
Epicormics: Epicormics can follow pruning and thinning.
Coppice ability: Young plants can coppice.
Regeneration: Regenerates well from seed on bare soil and will directly colonize exposed sites. Average of 6 years between good mast years but mast years are less periodic than other beech species.
Naturally associated species: Often pure but also with red beech and black beech, rimu, miro, and Hall's totara.
Nurse potential: ?

Pests:		**Maximum Growth:**		**M.A.I. Range:**	
Animals:	Deer and goats	Height:	30 (39) m	Height:	25–50 cm
Insects:	German wasp, ghost moth, *Platypus* beetle	Diameter:	2 m	Diameter:	0.38–0.82 cm
Fungi:	*Sporothrix* (assoc. with *Platypus*), several white rot spp., *Cyttaria* spp. (galls)	Volume:	?	Volume:	5–7 m^3/ha

Other: Mistletoe can be a pest.
Time to utilization: 80 (120) years
Optimum log diameter: 50 cm

NOTES: Does not hybridize with other beech species.

* Provisional shade tolerance rating in parentheses. See explanation on page 41.

References: 3, 4, 66, 104, 115, and J. Wardle (pers. comm.)

SPECIES: *Nothofagus solandri* var. *solandri*	COMMON NAME: Black beech	SCORE: 25

Altitudinal limits: 0–700 m
Latitudinal limits: 37° 40' to 46° 20' S
Indigenous location: Central North Island to Southland.
General site requirements: Black beech prefers lowland sites.

Climate:

Climate type:	Cool temperate
Rainfall:	1200–2500 mm
Temperature:	?
Frost / Snow:	Less tolerant of frost and snow than silver beech.
Wind:	Shelter required for seedlings. Large felling coupes allow wind desiccation.
Drought:	Moderately drought-tolerant.

Soil:

Optimum and extremes:	Similar to red beech, growth is much better on deeper and more fertile soils. Grows on poorer soils than red beech.
Soil moisture:	More common on drier soils and needs fairly free-draining soil.
pH:	?
Fertility:	170 species of ectotrophic mycorrhizal fungi are associated with the beech species and seedlings must be infected to survive in field. Main function is associated with phosphate uptake.
Soil hardness:	?

Shade tolerance*: Black (3–5) falls between red (least tolerant) and silver (most tolerant).
Competition tolerance: Tolerates extreme competition at seedling stage.
Form, habit, and shape: Needs competition for good form.
Epicormics: Growth can follow pruning and thinning.
Coppice ability: ?
Regeneration: Regenerates well from seed on bare soil. Average of 5 years between good mast years.
Naturally associated species: Mainly other beeches and podocarps. Often in pure stands.
Nitrogen fixing: No.
Nurse potential: Probably not.

Pests:

Animals:	Deer and goats
Insects:	German wasp, ghost moth, *Platypus* beetle
Fungi:	*Sporothrix* (assoc. with *Platypus*), several white rot spp.

Maximum Growth:

Height:	25 m
Diameter:	1 m
Volume:	?

M.A.I. Range:

Height:	0.3–0 5 m
Diameter:	1.0 cm
Volume:	10 m^3/ha

Other: Mistletoe can be a pest

Time to utilization:	50 years
Optimum log diameter:	45 cm

NOTES: Hybridizes with mountain beech, red beech, or hard beech.

* Provisional shade tolerance rating in parentheses. See explanation on page 41.

References: 3, 4, 66, 104, 112, 115, and J. Wardle (pers. comm.)

SPECIES: *Phyllocladus trichomanoides*	COMMON NAME: Tanekaha	SCORE: 24

Altitudinal limits: 0–600 m (occ. to 1000 m)
Latitudinal limits: 35° to 39° S and 41° S
Indigenous location: Northern North Island to Taupo, and tip of South Island.
General site requirements: Good growth and form in canopy gaps on upland sites and well-drained volcanic soil. Also lowland forest on fertile, well-drained alluvials. Best growth in moist sheltered gullies.

Climate:		**Soil:**	
Climate type:	Warm temperate	Optimum and extremes:	Wide range, preferrably well-drained lowland alluvials or moisture-retentive pumice.
Rainfall:	>1500 mm (will grow down to 1200 mm)	Soil moisture:	Intolerant of poor drainage, especially on flat sites. Requires reasonably high moisture level for good growth.
Temperature:	Mean annual temperature >10°C Warm summers required for seed set.		
Frost / Snow:	Tolerates down to –11°C as adult.	pH:	Tolerates <5.0
Wind:	Moderate	Fertility:	?
Drought:	Tolerates if roots sheltered.	Soil hardness:	Grows slowly on hard sites.

Shade tolerance*: Seedlings germinate and survive in shade (2–4). Requires high light for growth (4–5).
Competition tolerance: Fairly high. Survives and grows in relatively dense scrub.
Form, habit, and shape: Good apical dominance as saplings and poles.
Epicormics: No
Coppice ability: No
Regeneration: Good seed years 1 in 10 but light seed crops annually. Requires warm summers for good seed set.
Naturally associated species: Kauri, rimu, matai, miro, totara, kahikatea, tawa, hinau, taraire, red beech, hard beech.
Nitrogen fixing: No
Nurse potential: Possible

Pests:		**Maximum Growth:**		**M.A.I. Range:**	
Animals:	Goats and deer strip bark	Height:	25 m	Height:	20 to 35 cm
Insects:		Diameter:	1.0 m	Diameter:	0.4–0.6 cm
Fungi:		Volume:	?	Volume:	?

Other: Time to utilization: 80 years
Optimum log diameter: 40 cm

NOTES: Common pioneer species on dry ridges in north but never grows into large tree and the timber is prone to shakes. Grows well in scrub with overhead light.

* Provisional shade tolerance rating in parentheses. See explanation on page 41.

References: 4, 66, 98, 99

SPECIES: *Pinus strobus*	**COMMON NAME:** Eastern White Pine	**SCORE: 19**

Altitudinal limits: ?
Latitudinal limits: 34°–51° N
Indigenous location: Eastern USA and Canada*
General site requirements: Not suitable for planting north of Rotorua.

Climate:		**Soil:**	
Climate type:	Temperate to moderately severe	Optimum and extremes:	Poor to moderately fertile deep loams with clay but best on well-drained sandy loams. Also grows on fine sandy loams formed from glacial tills.
Rainfall:	500–2000 mm, with 500 mm in growing season		
Temperature:	Mean summer temperature 16–21°C	Soil moisture:	Require a moisture surplus all seasons. However will tolerate poor dry sites.
Frost / Snow:	?		
Wind:	Requires shelter.	pH:	?
Drought:	Not tolerant.	Fertility:	?
		Soil hardness:	?

Shade tolerance†: Requires light when young but will tolerate light shade (4–5).
Competition tolerance: As seedling is susceptible to competition but tolerates close stocking with only limited mortality — >500 stems/ha at 23 m top height.
Form, habit, and shape: Conical
Epicormics: ?
Coppice ability: ?
Regeneration: ?
Associated species: Northern red oak, white oak, hemlock.
Nitrogen fixing: ?
Nurse potential: Could have potential as long-term nurse for broadleaved species.

Pests:		**Maximum Growth:**		**M.A.I. Range:**	
Animals:	?	Height:	65 m	Height:	50 cm
Insects:	?	Diameter:	3 m	Diameter:	0.06–2.5 cm
Fungi:	?	Volume:	?	Volume:	?

Other: Time to utilization:
Optimum log diameter:

NOTES:

* A variety grows in Mexico and Guatemala. In New Zealand grows from Rotorua south. Early growth is usually slow. Ideal conifer for mixed planting with hardwoods.

† Provisional shade tolerance rating in parentheses. See explanation on page 41.

References: 30, 45, 66, 92.

SPECIES: *Podocarpus totara*	**COMMON NAME:** Totara	**SCORE: 27**

Altitudinal limits: 600 m North Island, 300 m South Island
Latitudinal limits: 35° 30' to 46° 30' S
Indigenous location: All of New Zealand
General site requirements: Best grown in association with a tall-growing nurse.

Climate:		**Soil:**	
Climate type:	Warm humid to cool & dry.	Optimum and extremes:	Well-drained alluvials and volcanic preferred. Can dominate on fertile alluvial soils subject to periodic flooding.
Rainfall:	>700 mm		
Temperature:	Best where summer temperatures high, i.e., between 21° and 27°C.	Soil moisture:	Intolerant of poor drainage and poor aeration. Less tolerant of wetter ground than kahikatea and rimu.
Frost / Snow:	Tolerant		
Wind:	Tolerant of wind except where very exposed.	pH:	?
		Fertility:	Moderate levels. Responds well to NPK, especially N.
Drought:	Tolerates drought and dry soils better than most NZ species.		
		Soil hardness:	?

Shade tolerance*: Most light-demanding of podocarps. Seedlings stagnate in heavy shade. Vigorous in gaps (5).
Competition tolerance: Low. Rapid mortality when suppressed by hardwoods or tree ferns.
Form, habit, and shape: Spreading and often multi-trunked in the open. Must have side competition.
Epicormics: Rare
Coppice ability: Nil
Regeneration: Low in mature stands. Common in scrub and pole stands, stand edges, and open dry-site grassland.
Naturally associated species: Kahikatea is most common. Also kauri, puriri, mangeao, rimu, matai, tawa.
Nitrogen fixing: Nil
Nurse potential: Could be used to nurse more shade-tolerant species because the canopy of young totara is fairly open.

Pests:		**Maximum Growth:**		**M.A.I. Range:**	
Animals:	Possums, deer, goats	Height:	40 m	Height:	25–55 cm
Insects:	Susceptible to defoliation by several species	Diameter:	2.5 (3.6) m	Diameter:	0.25–0.5 cm normal. Capable of >1.0 cm.
Fungi:	Several minor species	Volume:	77 m^3	Volume:	Capable of >17 m^3/ha at age 80.

Other: Time to utilization: 60 years
Optimum log diameter: 50 cm

NOTES: *Podocarpus hallii* is a smaller tree than *P. totara* and its timber is inferior.

* Provisional shade tolerance rating in parentheses. See explanation on page 41.

References: 4, 23, 40, 66, 76, 87, 98, 99, 104

SPECIES: *Prunus avium*	COMMON NAME: Gean, Wild cherry	SCORE: 24

Altitudinal limits: 0–300 m UK, to 1000 m Germany
Latitudinal limits: 35° to 60° N
Indigenous location: Europe
General site requirements: Best planted in small groups or as single trees.

Climate:

Climate type:	Wide range from cool temperate to Mediterranean
Rainfall:	Not < 500 mm
Temperature:	Mean annual temperature not <10°C
Frost / Snow:	Frost hardy
Wind:	Not tolerant of strong wind but will grow near coast.
Drought:	?

Soil:

Optimum and extremes:	Fertile, deep, and well-drained loams and clays of lower slopes are best, but grows well on podozolic soils if well drained and on drier sandy soils. Prefers deep loams over calcareous base.
Soil moisture:	Intolerant of poor drainage and gleyed soil.
pH:	4 to 8
Fertility:	Some fast growth recorded on 4–5 pH clays with mull humus.
Soil hardness:	Not suited to hard soils.

Shade tolerance*: Relatively tolerant, especially in first few years (2–4). Good as sub-dominant under oak with basal area of 18 m³/ha.
Competition tolerance: Sensitive to weed competition. Releasing important.
Form, habit, and shape: Has strong apical dominance but lack of side competition leads to heavy branching.
Epicormics: Slight
Coppice ability: Will sucker; coppices reasonably well.
Regeneration: Fairly high rate. Most seed dropped within 50 m of parent tree. Trees produce seed from about age 10. Potential for seed to be spread through native forest by birds.
Naturally associated species: Best grown as mixture (or small clumps) with other broadleaves. Faster than oak, ash, and beech.
Nitrogen fixing: No
Nurse potential: No

Pests:

Animals:	Deer. Appears to be possum resistant.
Insects:	Pear slug
Fungi:	Silver leaf, Armillaria, heart rots, *Phytophthora* on waterlogged sites.

Maximum Growth:

Height:	30 m
Diameter:	1.1 m
Volume:	>590 m³/ha

M.A.I. Range:

Height:	0.3–0.6 m
Diameter:	0.7–0.9 cm
Volume:	3–12 m³/ha

Other: Time to utilization: 50–60 years
Optimum log diameter: 40 cm

NOTES: Can be planted at fairly wide spacing (3 × 3 m) because of strong apical dominance. Requires pruning to produce clean timber as it retains dead branches. Potential for seed to be spread to unwanted sites.

* Provisional shade tolerance rating in parentheses. See explanation on page 41.

References: 41, 43, 63, 92, 106

SPECIES: *Pseudotsuga menziesii* NZ Douglas fir is var. *menziesii*	COMMON NAME: Douglas fir	SCORE: 25

Altitudinal limits: 0–920 m, North Island 0–800 m, South Island
Latitudinal limits: 20° to 55° N, below lat. 38° S in NZ
Indigenous location: West and west-central USA, Canada, and Mexico
General site requirements: Best on shady slopes. Mycorrhizas essential.

Climate:

Climate type:	Mild humid with dry summers
Rainfall:	(500) 1000–1700 mm
Temperature:	Mean annual 7–13°C Mean coldest month 1.1–7.8°C Mean hottest month 15–17°C
Frost / Snow:	Unseasonal damage possible especially in frost hollows. Reasonably resistant to snow break.
Wind:	Strong winds cause leader damage and and windthrow can occur after heavy rain. Not near coast.
Drought:	?

Soil:

Optimum and extremes:	Fairly deep, well-drained, moderately fertile sites but will grow on wet clay soils.
Soil moisture:	Intolerant of wet sites with poor drainage, and very dry sites.
pH:	5–5.5 best. Not on alkaline sites.
Fertility:	Moderate fertility required. May be susceptible to boron deficiency.
Soil hardness:	Growth poor on compacted soils.

Shade tolerance*: Moderately shade tolerant. Responds well to delayed thinning and grows in low–low/moderate shade (2–4). Requires higher light levels than western red cedar and Sitka spruce, but tolerates more shade than red alder. Seedlings require *ca* 33% of full light for maximum photosynthesis.
Competition tolerance: Not very tolerant. Once seedlings are established they do best in full light.
Form, habit, and shape: Good apical dominance, pyramidal shape. Branches generally small.
Epicormics: Nil
Coppice ability: Nil
Regeneration: On relatively open disturbed sites. Lessens as shade increases. Recommended gap size 1000–2000 m^2. Wind spread seed with reasonable crops 2 years out of 3.
Associated species: Western hemlock, Lawson's cypress, ponderosa pine, red alder, Sitka spruce, and western red cedar.
Nitrogen fixing: No
Nurse potential: Possibly

Pests:

Animals:	Browsed seedlings – deer & goats
Insects:	?
Fungi:	*Phytophthora*, white rot (*Fomes*)

Maximum Growth:

Height:	117 m
Diameter:	4.5 m
Volume:	1300 m^3/ha@ age 50

M.A.I. Range:

Height:	56–90 cm
Diameter:	0.8–1.2 cm
Volume:	4–24 m^3/ha

Other: Time to utilization: 50 years
Optimum log diameter: 50 cm

NOTES: Potential for seed to be spread to sites where it is not wanted.

* Provisional shade tolerance rating in partentheses. See explanation on page 41.

References: 30, 45, 62, 63, 66, 86, 92, 111, 113, 116, 117

SPECIES: *Sequoia sempervirens*	COMMON NAME: Coastal redwood	SCORE: 23

Altitudinal limits: 900 m

Latitudinal limits: 35° 41'–42° 09' N

Indigenous location: Coastal (up to 55 km from sea) California and south-west Oregon

General site requirements: Natural distribution is probably limited to areas with high rainfall, humid air, moist soil and low summer temperatures, or combinations of these. In New Zealand is best on sites with good year-round rainfall.

Climate:		**Soil:**	
Climate type:	Mild and super humid to humid	Optimum and extremes:	Deep, moist loams, sandy loams, clay loams on flats and alluvial terraces close to streams.
Rainfall:	900–3000 mm. Best at 1300–1800 mm. Coastal summer fogs important in California	Soil moisture:	Intolerant of poorly drained soils but better on heavier & wetter soils than *P. radiata* or Douglas fir. Relatively moist soil required for seed germination. Intolerant of dry, sandy soils.
Temperature:	10° to 16°C mean annual temperature		
Frost / Snow:	Damaged by –8°C frost when young. Older trees hardy but best if frost-free period 6–11months.	pH:	4.0 to 8.5
Wind:	Low tolerance and can be susceptible to windthrow. Top breakage common.	Fertility:	Good nutritional balance. Growth rate can be doubled by increasing NPK levels.
Drought:	Low tolerance	Soil hardness:	Not good on hard and compacted soils.

Shade tolerance*: Seedlings have high shade tolerance (2–3). Require half the light of Douglas fir seedlings but grow best in full light.

Competition tolerance: High for seedlings and small trees which can endure suppression almost indefinitely.

Form, habit, and shape: Strong apical dominance; conical shape.

Epicormics: Strong epicormic growth if crowns destroyed, when trunks exposed to increased light, or trees pruned.

Coppice ability: Coppices readily. Strong coppice growth outgrows most competing vegetation.

Regeneration: From seed and crown root coppices but seedlings are initially less vigorous.

Naturally associated species: Douglas fir, Lawson's cypress, ponderosa pine, grand fir, western hemlock, Sitka spruce, oak spp.

Nitrogen fixing: No

Nurse potential: Yes, for species with greater shade tolerance.

Pests:		**Maximum Growth:**		**M.A.I. Range:**	
Animals:	Possums damage tops. Deer and goats.	Height:	115 m	Height:	0.6–0.9 m
Insects:	Several insects cause minor defoliation. Dry wood termite.	Diameter:	2.5 (7.0) m	Diameter:	0.1–2.5 cm
Fungi:	Seedlings subject to damping off. Heartwood rots.	Volume:	2000 m³/ha	Volume:	12–45 m³/ha

Other: Susceptible to fire when young.

Time to utilization:	30 years
Optimum log diameter:	60

NOTES: In mixtures of species in its natural habitat, redwood is always the dominant tree. Is suited to shelter-wood and selection systems. Continuous cover management systems are being developed in California.

* Provisional shade tolerance rating in parentheses. See explanation on page 41.

References: 10, 24, 30, 36, 45, 63, 77, 92, 113, 116, 117

SPECIES: *Thuja plicata*	COMMON NAME: Western red cedar	SCORE: 26

Altitudinal limits: 0–2000 m
Latitudinal limits: 40°–57° N
Indigenous location: North-west USA and West Canada
General site requirements: Not suited to low-altitude sites north of Hamilton.

Climate:		**Soil:**	
Climate type:	Cool summers and mild winters	Optimum and extremes:	Best on flats, terraces, slopes, and stream banks and moist gullies which are wet but reasonably well drained. Reasonable on limestone soils.
Rainfall:	760–2500 mm	Soil moisture:	Intolerant of high watertables, also very dry sites. Soil moisture not <12% in mid summer.
Temperature:	7–11°C mean annual temperature	pH:	Good on >6.0 sites.
Frost / Snow:	Tolerates –5°C frost as juvenile and –12°C as adult.	Fertility:	Reasonable fertility required.
Wind:	Not tolerant of strong wind. Not tolerant of saline conditions.	Soil hardness:	Not tolerant of compacted sites.
Drought:	Not tolerant.		

Shade tolerance*: Fairly high (2–3). Can grow to maturity in shade, but responds well to increased light.
Competition tolerance: Very tolerant.
Form, habit, and shape: Conical when young.
Epicormics: No
Coppice ability: None
Regeneration: High seed production and high survival rate. Recommended gap size <500 m².
Naturally associated species: Hemlock, Sitka spruce, grand fir, Douglas fir, Port Orford cedar, redwood, big leaf maple, red alder.
Nitrogen fixing: No
Nurse potential: No

Pests:		**Maximum Growth:**		**M.A.I. Range:**	
Animals:	Possums can debark leaders	Height:	60 m	Height:	30–70 cm
Insects:	Huhu attacks live trees where there is access to heart via branch stubs.	Diameter:	2.5 (5.0) m	Diameter:	0.3–1.3 cm
Fungi:	?	Volume:	400 m³/ha (USA): 4.3 m³/tree	Volume:	7–22 m³/ha

Other: Susceptible to fire.
Time to utilization: 45–55 years
Optimum log diameter: 50 cm

NOTES: Is possibly the most shade-tolerant of all conifers.

* Provisional shade tolerance rating in parentheses. See explanation at beginning of Appendix 2a.

References: 30, 43, 45, 62, 63, 64, 111, 113, 116, 117

SPECIES: *Vitex lucens*	COMMON NAME: Puriri	SCORE: 25

Altitudinal limits: 0–800 m
Latitudinal limits: 34° 30' to 39° 30' S. Southern limit Opunaki and Mahia Peninsula
Indigenous location: Northern half of North Island.
General site requirements:

Climate:		**Soil:**	
Climate type:	Warm humid	Optimum and extremes:	Deep, rich soil. Puriri is typicallyfound on volcanic soils, e.g., Waimate North and Pukekohe. Grows on most reasonably well-drained soils.
Rainfall:	>1000 mm		
Temperature:	Mean annual temperature >13°C.	Soil moisture:	Intolerant of poor drainage.
Frost / Snow:	Will not tolerate when young.	pH:	6
Wind:	More tolerant than most natives. Reasonably tolerant of saline wind.	Fertility:	Moderate to high
Drought:	Moderately tolerant	Soil hardness:	Probably not on hard soils.

Shade tolerance*: Slight to moderate tolerance. At all stages growth is fastest when exposed to overhead light (3–5).
Competition tolerance: Tolerates moderate competition.
Form, habit, and shape: Juveniles tall and slender when growing with competition; crown spreads at emergence.
Epicormics: Occasionally
Coppice ability: Yes
Regeneration: From seed and coppice.
Naturally associated species: Hinau, matai, pukatea, rewarewa, taraire, kauri, rimu, miro, kahikatea, and totara.
Nitrogen fixing: No
Nurse potential: Because it is wind tolerant it may have potential, once established, to nurse other native species.

Pests:		**Maximum Growth:**		**M.A.I. Range:**	
Animals:	Goat, deer, possum	Height:	20 (30) m	Height:	0.25–1.0 m
Insects:	Puriri moth (*Aenetus virescens*)	Diameter:	1.0 (2.62) m	Diameter:	0.5–1.5 cm
Fungi:	None serious	Volume:	2.0 (42) m^3	Volume:	0.04 m^3

Other: Time to utilization: 50 years but potentially less
Optimum log diameter: 50 cm

NOTES: According to Geoff Wightman (Waimate North) there are several varieties of puriri, one of which appears to be resistant to puriri moth.

* Provisional shade tolerance rating in parentheses. See explanation on page 41.

References: 31, 66, 97

SPECIES:	× *Cupressocyparis ovensii*	COMMON NAME:	Oven's cypress	SCORE: 25

Altitudinal limits: Probably low altitude
Latitudinal limits: Unknown
Indigenous location: United Kingdom (hybrid)
General site requirements: New Zealand experience to date suggests that it is best suited to reasonably fertile and sheltered sites.

Climate:		**Soil:**	
Climate type:	Cool to warm humid	Optimum and extremes:	Moderately fertile, moist soils. Soil tolerance limits not known.
Rainfall:	>1100 mm	Soil moisture:	Relatively moist soils are probably best.
Temperature:	Grows well @ means between 9° and 14°C	pH:	?
Frost / Snow:	Tolerant of at least –4°C	Fertility:	Reasonably fertile soil best.
Wind:	Not tolerant especially aged 18 months to 9 years when toppling can occur on moist sites. Not tolerant of saline winds.	Soil hardness:	Probably intolerant.
Drought:	Unknown but growth poor where annual rainfall <800 mm.		

Shade tolerance*: Probably more shade-tolerant than × *Cupressocyparis leylandii* "Leighton Green". Similar to *Cupressus lusitanica* (3–5).
Competition tolerance: Moderately tolerant.
Form, habit, and shape: Conical. Has stronger apical dominance than other Leyland cypresses.
Epicormics: Must remove incipient branches at pruning.
Coppice ability: Nil
Regeneration: Seed is infertile. Grows easily from cuttings.
Naturally associated species: N/A
Nitrogen fixing: No
Nurse potential: Probably some potential with indigenous species but not tested.

Pests:		**Maximum Growth:**		**M.A.I. Range:**	
Animals:	Deer and goats	Height:	Unknown	Height:	0.85–1.19 m
Insects:		Diameter:	Unknown	Diameter:	1.42–2.11 cm
Fungi:	Fairly resistant to cypress canker	Volume:	Unknown	Volume:	Not available

Other: Time to utilization: Probably 30 years
Optimum log diameter: 50 cm

NOTES: Because Oven's cypress is a relatively new introduction to New Zealand, more growth and site data are needed to determine its limits.Despite its infertility it probably has a role in CCF, especially in the establishment phase, because of its moderate shade tolerance and rapid growth. Some of the Leyland clones may also be suitable , e.g., Ferndown, but most are susceptible to cypress canker in warmer and more humid areas.

* Provisional shade tolerance rating in parentheses. See explanation on page 41.

References: 46

APPENDIX 2b

SUPPLEMENTARY LIST OF SPECIES WHICH COULD BE CONSIDERED FOR CONTINUOUS COVER IN NEW ZEALAND

	Timber	Shade	Growth	Climate	Soil	Total score	Notes
× *Cupressocyparis leylandii* "Leighton Green"	7	5	4	5	4	25	Not suitable for areas where cypress canker is a problem
Acer platanoides	5	4	2	2	2	15	
Acer pseudoplatanus	6	4	2	4	4	20	Can be a serious weed
Agathis macrophylla	7	4	4	2	2	19	Shade-tolerant seedlings and saplings will persist waiting for canopy gaps.
Agathis robusta	5	4	4	2	2	17	
Alnus cordata	4	5	3	4	4	20	
Araucaria angustifolia	8	5	2	4	3	22	Light-demanding at all stages. Susceptible to *Phytophthora.*
Araucaria araucana	7	5	2	2	2	18	
Araucaria cunninghamii	7	5	2	2	2	18	
Araucaria heterophylla	7	5	2	2	2	18	
Beilschmiedia taraire	7	4	1	2	4	18	Would be suitable but at present there is insufficient knowledge to make major use of this species.
Chamaecyparis lawsoniana	7	4	2	3	3	19	Can survive in fairly heavy shade. Susceptible to cypress canker.
Cupressus macrocarpa	7	5	4	4	4	24	Tolerates less shade than *C. lusitanica*. Canker restricts it to the South Island.
Dysoxylum spectabile	8	3	2	3	3	19	Frost tender but capable of fast initial growth. There is insufficient knowledge to make major use of this species.
Elaeocarpus dentatus	7	4	1	3	2	17	Would be suitable but at present there is insufficient knowledge to make major use of this species.
Eucalyptus pilularis	7	4	4	4	4	23	More tolerant of shade than many eucalypts. Can be managed by group selection.
Eucalyptus fastigata	6	4	5	5	4	24	Seed will germinate in low light. From Rotorua south.
Eucalyptus maculata	6	5	4	5	3	23	Tolerates long periods of suppression as a sapling.
Eucalyptus muelleriana	6	5	4	4	4	23	In northern New Zealand only.
Eucalyptus obliqua	6	5	4	5	3	23	
Fagus sylvatica	7	3	2	4	4	20	
Fraxinus excelsior	8	5	2	5	2	22	Shelter from wind required. Best on moist sites.
Knightia excelsa	6	4	2	4	4	20	Seed will germinate in low light but adults do not appear to be shade-tolerant. Is often a pioneer and nurse species.
Larix decidua	6	5	5	3	3	22	
Laurelia novae-zelandiae	5	3	1	4	2	15	Very shade-tolerant as seedlings. Mature trees need full light. There is insufficient knowledge to make major use of this species.
Libocedrus bidwillii	5	4	1	4	3	17	Light requirements probably fairly high. There is insufficient knowledge to make major use of this species.
Liriodendron tulipifera	7	4	4	4	2	21	Sheltered moist valleys.
Litsea calicaris	7	4	2	4	3	20	Would be suitable but at present there is insufficient knowledge to make major use of this species.
Metrosideros excelsa	7	5	4	4	4	24	Durable but poor form and possum palatable. Coastal and relatively frost-free areas.
Nestegis cunninghamii	8	3	2	3	3	19	
Nothofagus truncata	5	4	2	4	3	18	More tolerant of shade than *N. fusca* and less tolerant than *N. menziesii.*
Picea abies	7	4	2	4	4	21	Southern South Island.
Picea sitchensis	8	4	2	4	4	22	Only in colder areas. Subject to attack by spruce budworm.
Pinus elliottii	4	5	4	4	4	21	Nurse for kauri.
Pinus radiata	5	5	3	5	4	22	Intolerant of shade at all stages. Possibly manageable using group shelterwood system.
Populus spp.	4	5	3	5	3	20	

	Timber	Shade	Growth	Climate	Soil	Total score	Notes
Prumnopitys ferruginea	8	3	1	5	3	20	Would be suitable but at present there is insufficient knowledge to make major use of this species.
Prumnopitys taxifolia	8	3	1	5	3	20	Would be suitable but at present there is insufficient knowledge to make major use of this species.
Quercus robur	8	5	2	4	3	22	Growth from coppice is more vigorous than from seedlings.
Quercus rubra	6	4	1	4	3	18	
Robinia pseudoacacia	5	4	2	5	3	19	Severe sucker problem in shady areas.
Syncarpia glomulifera	8	5	2	4	2	21	Similar sites to *Acacia melanoxylon*. Best in sheltered gullies.

NB: The scoring is used to give an overall suitability rating for growth, siting, and use for CCF

SCORING FOR SPECIES ON SUPPLEMENTARY LIST

		Score	Notes
TIMBER	Timber quality, value and usefulness based on NZ situation / requirements	1–10	E.g., black walnut + 10; kauri = 9; *P. radiata* = 5; poplar = 4
SHADE	Shade tolerance	1–5	1 = shade-tolerant; 5 = light-demanding.
GROWTH	Growth rate based on MAI data or an estimate of growth	1–5	See below
CLIMATE	Estimate of climatic tolerance	1–5	See below
SOIL	Estimate of soil tolerance	1–5	See below

GROWTH

5 Moderate growth *ca* 1cm dbh/yr
4 Fast growth *ca* 1–2 cm dbh/yr
3 Very fast growth >2 cm dbh/yr or slow to moderate growth *ca* 7–10 mm/yr
2 Slow growth 4–7 mm/yr or growth unknown
1 Very slow <4 mm dbh/yr

CLIMATE

5 Tolerates wide climate range
4 Tolerates most climatic factors
3 Average tolerance
2 Intolerant of a major climatic factor (e.g., frost)
1 Intolerant of several climatic factors

SOIL

5 Tolerates a wide range of soils
4 Tolerates most sites
3 Average
2 Low tolerance of most sites
1 Tolerates specific sites only

The total scores shown on individual species sheets in Appendix 2a are calculated in the same way as the scores above.

APPENDIX 2c

POTENTIAL NURSE SPECIES AND THEIR CHARACTERISTICS

Spec ies	Common Name	Indigenous or Exotic	Nurse characteristics	Timber uses	Disadvantages
Acacia melanoxylon	Blackwood	Exotic	Nitrogen fixing. Creates litter conditions conducive to regeneration of indigenous species. Coppices well from cut stumps.	High quality hardwood which can be harvested from about age 20 on good sites	Will sucker in high light areas. Ability to coppice can be a drawback
Alnus cordata	Italian alder	Exotic	Nitrogen fixing. Creates litter conditions conducive to regeneration of indigenous species. Coppice ability relatively poor.	Higher timber value than other European alders.	Reasonably wind and drought tolerant. Only alder which will grow on calcareous soils (pH >7).
Alnus rubra	Red alder	Exotic	Nitrogen fixing; leaves have high N content. Coppices from cut stumps. Deciduous nature allows nursed species to grow when leaves absent.	Medium quality hardwood now becoming more used. Suitable for flooring.	Epicormic growth bad at high light levels. Not good on high pH, windy, or droughty sites.
Betula pendula	Silver birch	Exotic	Free seeding and in its natural habitat plays similar role, as a primary colonizer, to kanuka in NZ. Useful as nurse for range of species and very frost-tolerant. Deciduous and will grow on poor fertility sites.	Limited use as trees often of poor form. Pulpwood, posts (treated) and turnery.	Not in warmer parts of NZ.
Chamaecytisus palmensis	Tagasate, tree lucerne	Exotic	Nitrogen fixing. Dies out when over-topped so does not require felling as most nurses do. Attracts native birds.	Nil	Short lived
Coprosma robusta	Karamu	Indigenous	Rapidly establishes and covers ground quickly. Fruits early and attracts native birds. Will usually die out so does not need felling although pruning in early stages to prevent overtopping of desired species may be required.	Nil	Does not grow particularly tall
Kunzea ericoides	Kanuka	Indigenous	Natural nurse for species like kauri and tanekaha, also for rimu, totara, etc. Being tall-growing it draws timber species up.	Firewood. It is a fairly high quality hardwood and may eventually be developed for other uses, e.g., handles.	When too dense tends to dry soil out, taking vital moisture from the desired species.
Pinus elliottii	Slash pine	Exotic	Improves kauri growth because of a mycorrhizal association. This also works with other *Agathis* but not tested for other species.	Low-grade softwood.	Young bark eaten by possums.

Species	Common Name	Indigenous or Exotic	Nurse characteristics	Timber uses	Disadvantages
Pinus radiata	Radiata (Monterey) pine	Exotic	Has potential because of fast growth rate but main use may be as shelterbelts to break wind.	Medium-quality softwood with wide range of uses.	Care must be taken not to let pines get too large or removal is very difficult. High water use dries sites.
Pittosporum eugenioides	Tarata (lemon wood)	Indigenous	Fast and fairly upright growth which does not become too dense.	Nil	
Plagianthus regius	Ribbonwood	Indigenous	Deciduous tree with upright habit and moderately fast growth. Is frost-tolerant.	Nil	Will not tolerate dry sites. Grows to 15 m.

APPENDIX 3a

WOODSIDE FOREST: BLACK BEECH AND *PINUS RADIATA* USING CONTINUOUS COVER

BACKGROUND

Woodside is a 121-ha forest located on the southern flanks of Mount Oxford, 66 km north-west of Christchurch. It has been owned by the Wardle family since 1973. Currently there are 70 ha of sustainably managed black beech forest, 29 ha of exotic plantation species (mainly *P. radiata*), 14 ha of beech forest reserve, and 8 ha of grazing and garden area. Prior to the Wardle's ownership the land had been managed as a sheep farm, although not intensively since the depression of the 1930s. In earlier years most of the natural forest in the area was destroyed by timber milling and fire, with Woodside Forest being logged between 1895 and 1909. A serious fire in 1898 destroyed much of the remaining forest in the area. The beech forest now growing on the property has regenerated in three phases since about 1900; initial regeneration after the 1898 fire, after the abandonment of grazing in the 1930s, and from the management programme in place since 1973 when land management emphasis shifted from grazing to sustainable production forestry.

The terrain is fairly steep and dissected, with the altitude of the property ranging from 400 to 550 m. However, despite most slopes being about 20–25°, the property is well ridged and access is generally easy to construct. The presence of reasonable quantities of shattered rock in the soil makes road construction much less costly than in most forests (Plate 6 No.22).

The climate and soils of the area are well suited to forestry. Rainfall is a well-distributed 1300 mm/year with temperatures being mild although frosts can occur throughout the year and snowfalls of up to 12 cm are common — occasionally 1-m falls occur. Droughts are rare but can be severe and north-west winds can rise to gale force. Problems with wind and snow are the main inhibitors of forest practice. The soil is a lowland yellow brown earth of medium fertility which is derived from greywacke, greywacke loess, and weathered colluvium.

EARLY MANAGEMENT

The management regime for the black beech forest is to follow the ecological processes which determine the natural structure of the forest. The forest is operated under a management plan approved by the Indigenous Forestry Unit of MAF. The requirements of the plan are that the prescribed annual harvest shall not exceed 700 m^3 (based upon a mean annual increment of 10 m^3/ha). Initially the process was somewhat mechanistic and involved dividing the forest into six blocks. Timber was extracted from one block each year and the process was intended to continue for 48 years, with each block visited eight times over this period. At each visit the harvesting regime targeted groups rather than individual trees, and felling coupes ranged from 0.05 to 0.15 ha (Plate 6 No.23). The 48-year cycle was decided upon because it was considered that after this age the timber began to deteriorate as the trees became vulnerable to pinhole borer and internal rot.

Regeneration of stands was undertaken by encouraging natural regeneration which is normally prolific in open areas such as felled coupes or windthrow areas but also occurs with partial canopy opening and is scattered throughout older stands. Where ground competition was excessive, such as in shady areas where crown fern (*Blechnum discolor*) grows prolifically, 1-m-diameter patches were cleared by hand grubbing. Once regenerated seedlings were established, the procedure was to thin the regeneration to 2500 stems/ha and then progressively reduce these to about 800 stems/ha, the selected stems being pruned to about 4 m. Before silvicultural treatment began the natural forest stands carried about 400 m^3/ha and had a mean annual diameter increment of about 0.2 cm. Most of the generating cohorts of beech seedlings were in coupe areas of a hectare or less. Stands which have received full silvicultural treatment have diameter increments close to 1.0 cm.

When the property was purchased the plan was to progressively plant the unimproved pasture with *Pinus radiata* and manage this on a 30-year rotation. Seed origin varied — initially run-of-nursery stock and later some elite and GF-rated seedlings — but overall the trees are of very good form and vigour. In some areas where establishment was poor, enrichment planting with other conifer species was undertaken. Black beech is now regenerating in some of these areas.

TRANSITION PERIOD

Over several years of attempting to manage the beech forest on the basis of pre-determined coupe areas, the system has gradually changed. The main driver of this has been the aim to harvest trees when they reach their most valuable size, although this process is confounded by wind. Thus a large proportion of the annual cut is obtained from windthrown trees or from dead and dying trees. This means the process has become almost totally natural, with areas of extraction being determined by where trees have fallen or are becoming moribund. On average about 90% of the timber harvested now comes from these sources.

Early in the development phase of the forest the decision was made to convert the *P. radiata* stands to mixed age/mixed species stands. This began with trial inter-planting of poorer areas with species such as coastal redwood, Douglas fir, larch, Mexican cypress, deodar cedar, Leyland cypress

"Fernsdown" and ×*Cupressocyparis ovensii*, and Japanese cedar. In 2000, when the original pines were 26 years old, extraction of the larger stems began and has continued by extracting over the whole stand on a 2-year cycle.

The reasons for moving to CCF with single-tree selection are as follows:

- to improve the visual impact of forestry;
- to allow a sub-canopy species such as beech to reach economic size, for beech would be destroyed by clearfelling;
- to obtain greater economic returns from trees that are harvested at their ultimate productive size;
- to produce trees, especially *P. radiata*, with improved wood quality (especially stiffness);
- to create mixed species stands which will provide insurance against disease and climatic damage;
- to use the taller *P. radiata* as an over-wood shelter to reduce early wind and snow damage and improve the form of smaller trees.

CURRENT MANAGEMENT

Black Beech

Wherever possible the Wardles favour continuous cover selection, with individual-tree removal rather than small coupe felling. This is because the retention of a canopy as full as possible provides regeneration with better protection against winter desiccation, protects the cambium of trees from the "sunburn" effect of hot dry winds, and provides greater wind stability within stands. It is hoped that, with improved management and extraction systems, windthrow will be reduced but it will continue to confound the process because it seems to be an almost random occurrence which goes on all the time. In windthrown areas the procedure is to extract as much useful material as possible — sawlogs and firewood — and to clean up the site sufficiently to reduce pinhole borer (*Platypus* spp.) infestation, reduce fire risk, and allow vigorous regeneration. Windthrow is taken into account when determining the allowable cut for the year, with excessive windthrow requiring a compensating reduction in following years.

The mean annual increment of these black beech stands is close to 10.0 m^3/ha which provides for an annual cut of 10.0 × 70 ha = 700 m^3. This is removed either as dead, windthrown, or poor quality trees, or as individual trees above the cutting limit of 45 cm dbh. Each block is revisited every 6 years.

Harvesting is undertaken using a rubber-tyred skidder on permanent access tracks to winch larger trees from the forest and a tracked, hand-controlled, mini-skidder on minor access tracks to extract smaller piece sizes. The beech and pine forest areas have a total of 9 km of roads which will allow access by logging trucks and trailers and 6–8 km of 1-m-wide mini-skidder tracks. Most tracks are cut and side cast, with larger streams being either culverted or forded. Fords are stabilized where necessary by placement of demolition concrete. The narrow tracks are usually constructed by hand using a mattock. Because of the high percentage of shattered rock in the soil, very little extra track metalling is required and where this is needed sufficient material is readily available.

Beech can be harvested all year round, with windthrows extracted about twice a year. It is possible to leave logs lying for up to 6 months because sap stain is not such a problem as in warmer parts of New Zealand and, most of the time, windthrown trees still have some live roots in the ground. Logs left too long become riddled with pinhole borer or begin to rot.

Cleaning harvest sites to remove material which can cause a fire risk (important in Canterbury) and is vulnerable to pinhole attack is very important. This is done after every harvest operation and the material is sold as firewood.

Once established, regeneration must receive silvicultural treatment in order to improve the quality of final logs and to enhance wind-firmness. This begins by progressively removing competition from around selected stems, initially cutting a 1-m-diameter gap which is increased in size by further releasing as the trees grow. Thinning begins at about age 10 when the 5- to 6-m-tall saplings are reduced to between 800 and 1000 stems/ha, with pruning done a year later to remove epicormic growth. Delaying pruning for 1 year after thinning gives the crowns of the retained trees time to expand, thus reducing the incidence of epicormic growth. A second thinning follows 3–4 years later to remove trees which will compete with their better-formed neighbours. Further trees are removed in subsequent thinnings on the same basis. The aim is to leave a final stocking of 500–600 stems/ha. Pruning to 4–5 m is done on selected stems to obtain a reasonable stocking of good sawlogs.

Pinus Radiata

The decision to convert the *P. radiata* stands to continuous cover has meant using size class, form, and spacing as the major selection criteria. The current prediction is that there will be a sustainable harvest of 1100–1200 m^3 from the *P. radiata* forest, which equates to 40 m^3/ha annually. (This compares with an estimated 600 m^3 if the stand were managed on a clearfell system.)

The first harvest was in 2000 when the stands were 26 and 27 years old, and is done annually in April/May, before snowfall but after the autumn growth slowdown. Harvesting is carried out over half of the *P. radiata* area every 2 years, felling about 13–15 trees/ha which yield some 40 m^3 (Plate 6 No.21). The annual cut, currently 580 m^3 per annum, is growing slowly as tree sizes increase. There is a lower cutting limit of 60 cm dbh, although smaller trees of poor form or trees which have been damaged are also removed. At each harvest it is individual trees, rather than groups of trees, that are selected for removal, since the removal of more than two trees in close proximity at any harvest reduces the wind stability of the stand.

Felling is carefully directional to minimise damage; edge trees are pulled over and into the stand, even when on the base of the slope. Within the stands, direction of fall is either with the contour or uphill in order to minimise stem shatter which is an increasing problem with larger trees. To reduce damage to residual trees during felling and hauling, logs are cut to length in the bush and extracted using conventional skidders.

Stocking has been kept high throughout the life of these stands; at first thinning it was reduced to 750 stems/ha and now is 350–400 stems/ha. Keeping the stands tight helps keep branch size down and minimizes windthrow. Small branches also cause less damage to residual trees during felling. Pruning is done using the usual *P. radiata* regime for the area except that the final stocking of pruned trees is higher than normal — about 500 stems/ha before the final thinning to 350–400 stems/ha.

The net effect of individual tree and occasional two- and three-tree group removals is to create small gaps which will progressively increase in size, since trees left on the edges of gaps, having more space and light, will grow faster. Therefore at each successive harvest an increased percentage of the trees over 60 cm dbh will be on the edges of gaps, and gap sizes will increase still more rapidly with the bulk of the stand increment going on to trees on the edges of gaps.

Indications are that *P. radiata* will begin to regenerate when average stocking drops to about 200 stems/ha and may come away in a major burst. This is very likely to happen in gaps as soon as light levels reach the equivalent of 200 stems/ha. However, where there is a source of black beech seed this is also beginning to establish in the pine forest. Thus the future composition of these forests is still uncertain.

Apart from environmental factors, a major reason dictating the move to CCF is economic — that is, to produce a higher income than that obtainable from conventional clearfell forestry. The approach is to grow trees up to the size class which maximizes the production of 6-m lengths of Class 1 pruned logs. This appears to be working for, based upon the first 3 years of harvesting, over 45% of the volume felled is yielding either peeler or P1 class material (cf. the NZ average of 24%). Because the stands are kept tight, the upper branches are small; consequently there is a marked increase in the value of unpruned logs. Slower tree growth also means logs yield timber of better quality and stiffness — 10% of the unpruned wood is sold for the production of knotty veneer, and at the lower end of the grade only 10% is classed as domestic chipwood or firewood.

NON-TIMBER PRODUCTS

Honey production is a very important part of the income stream of this forest. Beech bark is infested with an indigenous coccid insect (*Ultracoelostoma assimile*). In the intermediate stage of its life cycle it excretes excess carbohydrate extracted from the sap of the tree and known as honey-dew. This is an important food source for various birds and insects present in the forest. Honey bees can utilize the honey-dew as an alternative to the nectar of flowers to produce beech honey-dew honey. Honey-dew production can vary from year to year but there is sufficient to run 300 beehives while leaving enough for the resident bird population. Current production of honey is in the vicinity of 170–180 kg/ha annually, a total of 15 000 kg from the whole forest, most of which is exported to Germany.

The other main product of this forest is knowledge. Although this produces no income, it must be regarded as a very valuable product freely given by the Wardle family, on 15 to 20 days each year, to a very wide range of visitors interested in this unique operation. In addition, facilities are provided for students and research organizations to undertake projects on the property.

PEST MANAGEMENT

Several pests are present in this forest. Fallow deer have the greatest impact on tree growing and must be kept under control if regeneration is to succeed, but red deer and possums cause only minimal damage. Also important, because of their effect upon birdlife, are stoats, cats, and rats. The other major pest is the German wasp which not only consumes honey-dew (as incidentally do possums) but also destroys bees. The ready availability of honey-dew has caused wasp populations to explode in many South Island areas, Woodside being no exception.

To reduce pressure on indigenous wildlife, control of smaller pests is undertaken by trapping and the use of appropriate bait stations using Feratox. Deer are shot or kept out of planted and regenerating areas by the use of single-wire electric fences which are zigzagged through the sites requiring protection. Wasps, the biomass of which outweighs all other predators and competitors combined, and which have probably caused the extinction of the weta and spiny stick insect in the area, are controlled by poisoning nests with pirimiphosmethyl (Actellic dust). The use of Fipronil as an alternative poison is currently being investigated.

THE FUTURE

There appear to be three factors which are essential to the long-term future of this venture; none is more important than the others and all are interdependent.

- The ability to market the produce profitably,
- Ensuring the long-term succession of the forest ownership and operation,

- Further development of sustainable long-term management systems for the major species involved.

The Wardle family has already spent many years perfecting the sawing methods and establishing the most effective drying and storing techniques for black beech. As soon as they were able to provide a quality product it was taken up by local furniture manufacturers and is used as well for flooring, panelling, turnery, and tool handles, with lower quality wood being sold for fuel. Because black beech timber has similar qualities to cherry*, a very highly regarded furniture and panelling timber, it should not be difficult to expand the market in the future.

Another factor which could play a role is certification of the operation by the Forest Stewardship Council or similar organization, which would probably be easy to get. However, there is no intention to follow this route because the cost is far too high for such a small operation.

Ensuring the long-term succession of forestry operations such as this is vital, for continuous cover forests outlive man's short time-span by a considerable amount. The Wardles already operate as a Family Trust and this mechanism, because it is carefully crafted to suit the particular circumstances, should guarantee the continuance of this forest for many years into the future.

The management systems for black beech and *P. radiata* are not yet perfected and it is expected that it will take at least another 30 years before the way ahead is clear. At this stage it appears that black beech will continue to be managed much as at present but that improved silvicultural techniques will enable the amount of windthrow to be gradually reduced. However, although windthrow will probably always be a factor in forest management on this property the same may not apply in more sheltered areas. The development of management techniques on this property, where conditions are generally more severe, will be of considerable benefit to other forest growers in New Zealand.

At this stage the potential for *P. radiata* managed using continuous cover is not so easy to predict. Two possibilities stand out, however. First is that the gradual enlargement of gaps, as a higher percentage of larger trees are progressively removed from their edges, will result in rapid regeneration of pine once the gaps are large enough to let in sufficient light. The type of forest which will result will be close to irregular shelter-wood (Matthews, 1989).

Secondly, where black beech (being more shade-tolerant than pine) begins to regenerate under the pine, the forest which will develop will probably be a mixture of pine, beech, and some of the other exotic species being trialled. From this point three lines of development appear possible:

- Widely spaced pine with an understorey of beech and pine which, because of the varying light requirements of the two species, will probably result in discrete groups, with beech on wetter and pine on drier sites;
- Where exotic species such as redwood and Douglas fir have been introduced, the forest could evolve into a mixture of pine, beech, and the other species — probably in discrete groups as above;
- Using the pine as a nurse for beech and gradually converting the entire area to black beech forest — the natural forest for this area — by thinning out all pine regeneration where there is sufficient beech, but leaving pine where beech is not regenerating, and completing the conversion in future cycles.

The third option is not being followed by the Wardles because they desire to spread the risk by maintaining resources of pine and beech plus a smaller one of alternative exotic species. At present it is too early to predict the future of these other exotic species and considerably more work will be needed before this is possible.

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* They have similar densities: black beech density at 12% mc is 657–721 kg/m^3 and cherry is 600 kg/m^3 (Wardle, 1984)

APPENDIX 3b

CONVERSION TO CONTINUOUS COVER OF A COMPARTMENT AT AMAKIWI FOREST

INTRODUCTION

Amakiwi Forest, 151 ha in area, is owned and managed by the Amakiwi Forest Trust which comprises a number of families from New Zealand and the United States (Plate 7 No.26). It is located near Waikaretu in the northern Waikato, some 25 km east-north-east of Huntly. The original aim was to take the area, originally a sheep and beef farm, and create a forest largely of species other than *Pinus radiata*. Planting commenced in 1989 but it soon became obvious that the sometimes severe westerly and south-westerly winds of the area limited the range of sites upon which species such as Mexican cypress (*Cupressus lusitanica*) and blackwood (*Acacia melanoxylon*) would grow.

Accordingly the plans were revised to site *P. radiata* on the most exposed sites, *Cupressus* species on intermediate locations, and blackwood in sheltered areas. At the same time, earlier wind-affected plantations of *Cupressus*, blackwood, and *Eucalyptus* species were interplanted with *P. radiata* and, in more sheltered areas, with *Cupressus*. The mixtures which ensued, which also included coppicing blackwood and *Eucalyptus* from the stumps of trees which had been felled, was the genesis of the continuous cover approach on the property. In addition some small trial blocks of species such as Chinese fir (*Cunninghamia lanceolata*), sugi (*Cryptomeria japonica*), the Leyland cypresses, tulip tree (*Liriodendron tulipifera*), red alder (*Alnus rubra*), European ash (*Fraxinus excelsior*), European cherry (*Prunus avium*), pārana pine (*Araucaria angustifolia*), kauri (*Agathis australis*), totara (*Podocarpus totara*), puriri (*Vitex lucens*), and the *Paulownia* species were trialled. So far about 30 different potential production species have been planted at Amakiwi.

The climate and soil of Amakiwi make this a property well-suited to forestry. Annual rainfall ranges between 1180 and 1730 mm and is reasonably well-distributed throughout the year; even summer rainfall, averaging about 97 mm per month, is adequate in most years. Mean annual temperature is 13.8°C and, in the more sheltered valleys, there are approximately 30 ground frosts annually. Wind is the only limiting factor and this mainly on higher ridges and some gullies which act as funnels. Apart from tiny areas of wet gley soils in the few swamp areas, all of the soils are well-suited for trees with the *P. radiata* site indices ranging from 29 to 36 — the lower level being determined by wind and not soil. The main soil type is Kaawa hill soil with Waingaro steepland soil, the former being an ash soil which has almost all washed off the underlying steep Waingaro soil but is up to 50 cm deep on the easy spurs and ridges.

By 2003 the consequences of some of the early inter-plantings were becoming evident. One mixture, established from 1992, which shows promise comprises an overstorey of scattered *Eucalyptus saligna* and *E. botryoides*, with *Cupressus lusitanica* and ×*Cupressocyparis ovensii*, currently sub-dominant but which may eventually replace the eucalypts, plus coppiced blackwood which can be grown as a shade-tolerant species (Plate 7 No.24). Other mixtures being experimented with are:

- *P. radiata* over × *C. ovensii* and *C. lusitanica*;
- *C. ovensii* and *Paulownia*;
- sugi, Chinese fir, and blackwood (Plate 7 No.25);
- red alder, ash, tulip tree, and European cherry;
- kauri and blackwood under *C. ovensii* and *Eucalyptus*;
- totara and puriri with blackwood under scattered indigenous species such as kohekohe (*Dysoxylum spectabile*) and kahikatea (*Dacrycarpus dacrydioides*).

So far most of this work is being done in the 10.2-ha Compartment 3 and the remainder of this case study will concentrate on that block.

COMPARTMENT 3 — CURRENT STOCKING AND PROPOSED MANAGEMENT

Details of the Compartment are given in Figures 3b.1 and 3b.2. In Figure 3b.1 the situation at the time of establishment is shown and in Figure 3b.2 the situation in 2007 as determined by an inventory done using the British Forestry Commission's transformation monitoring system (Kerr *et al.*, 2002). This preliminary inventory has enabled a reduction in the number of sub-compartments from 17 to 7, based upon the softwood/hardwood/native species components currently present. Further variations are likely as the forest matures.

Future management is intended to follow the process of tending all stages of growth (dominant, sub-dominant, and shrub strata) to encourage a range of species and size classes through each compartment, while at the same time working toward inducing the establishment of seedling and coppice regeneration.

The size class distribution of all species is shown in Tables 3b-1 and 3b-2, and when these are plotted with their currently assumed optimal growth distribution (reverse "J" curve) the deficiencies in the present situation become clear (Figures 3b-3 and 3b-4).

In the exotic forest area the stocking of small trees is very high but this will adjust over time with thinning and the movement of trees into larger size classes. Because no natural regeneration is occurring here, deficiencies in the seedling class will need to be made up by planting up to a further 200 stems/ha of relatively shade-tolerant species. This should not be difficult for, as can be seen from Figure

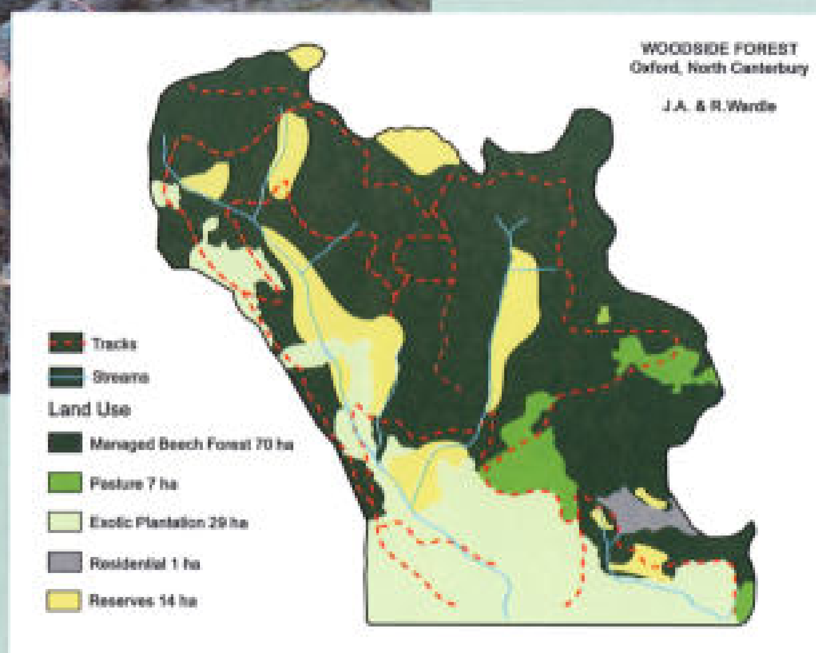
18: Wood-Mizer band mill cutting small *Cupressus* logs.

17: Aerial photo Hohneck property 1961, showing contour tracks established in early 1950's *(Photo NZ Aerial Mapping Ltd, 1961).*

19: Harvesting with horses in Bavaria, Germany *(Photo Ian Platt).*

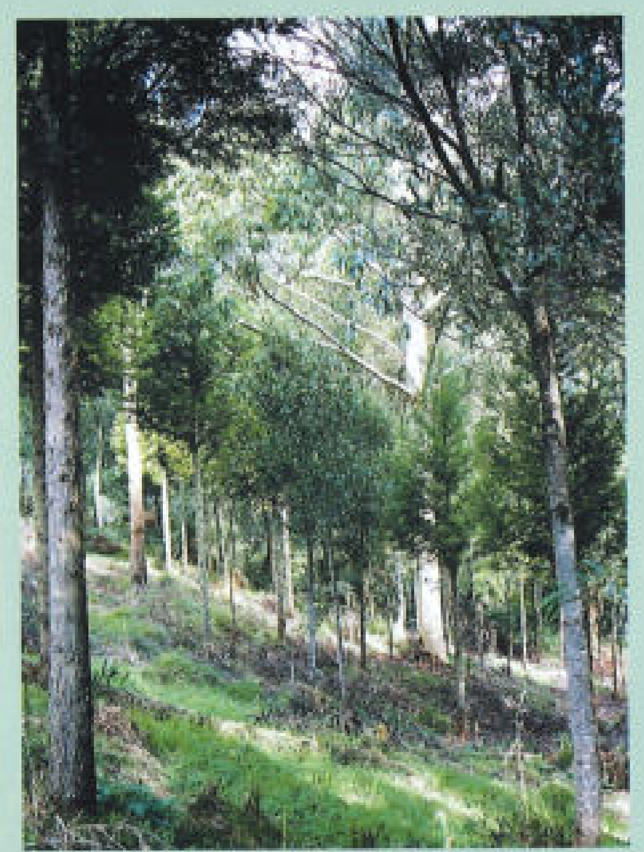
20: Modern harvesting techniques in Bavaria, Germany *(Photo Ian Platt).*

21: Harvesting *Pinus radiata* in Woodside Forest *(Photo Ian Platt).*

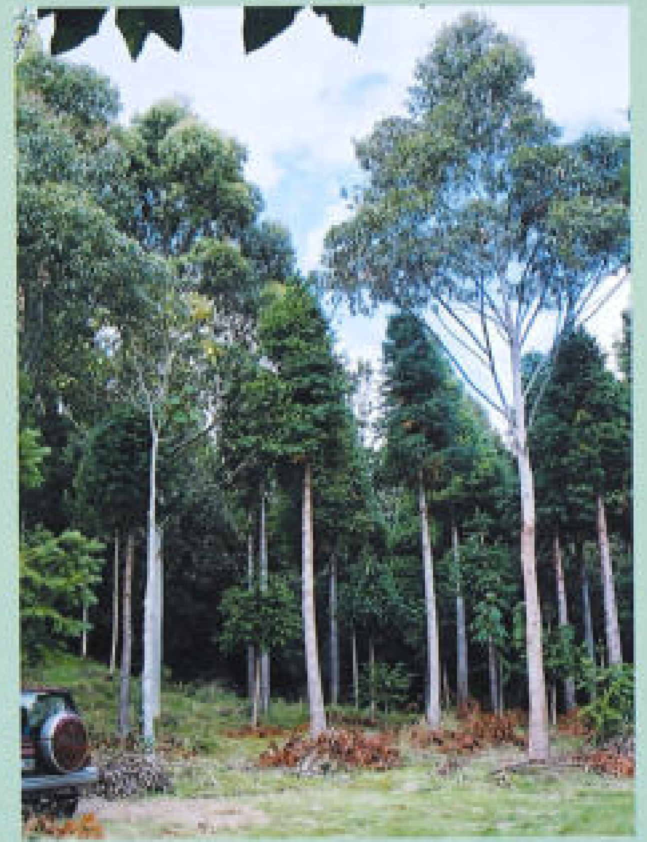


22: Map of Woodside Forest *(Ian Platt).*

23: Black beech pruned pole regeneration growing in a small gap.



24: CCF at Amakiwi - 18-year-old *Eucalyptus saligna* over coppiced blackwood and 10-year-old sugi.

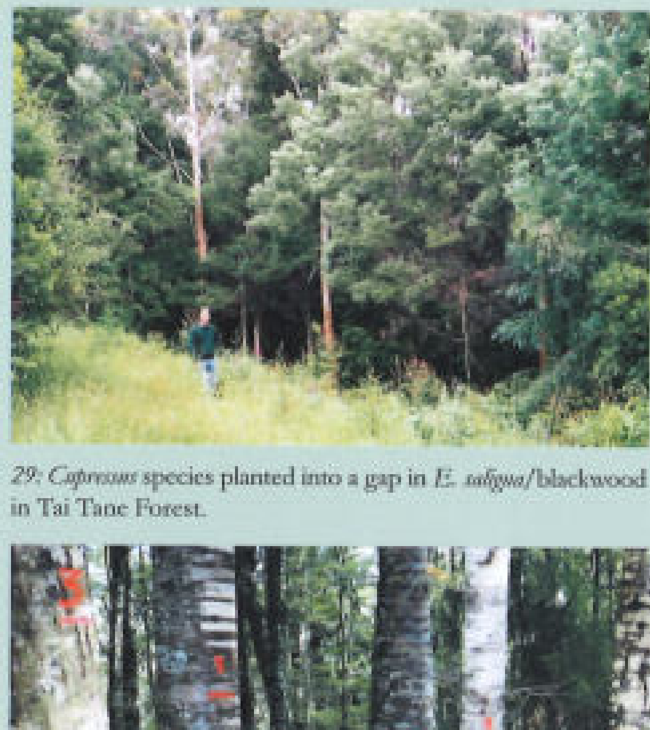


25: Amakiwi - the beginnings of CCF with 18-year-old *Eucalyptus saligna* and Chinese fir over 10-year-old Chinese fir

26: Amakiwi Forest looking south to Mt Karioi. April 2007 - the beginning of transformation to CCF. Compartment 3 is at upper right.

27: Kauri regeneration in a gap left by the removal of a small group of merchantable poles during a 1982 helicopter harvesting trial.

28: A gap in blackwood and *Cupressus* planted with *Eucalyptus muelleriana* and *E. pilularis* inTai Tane Forest.

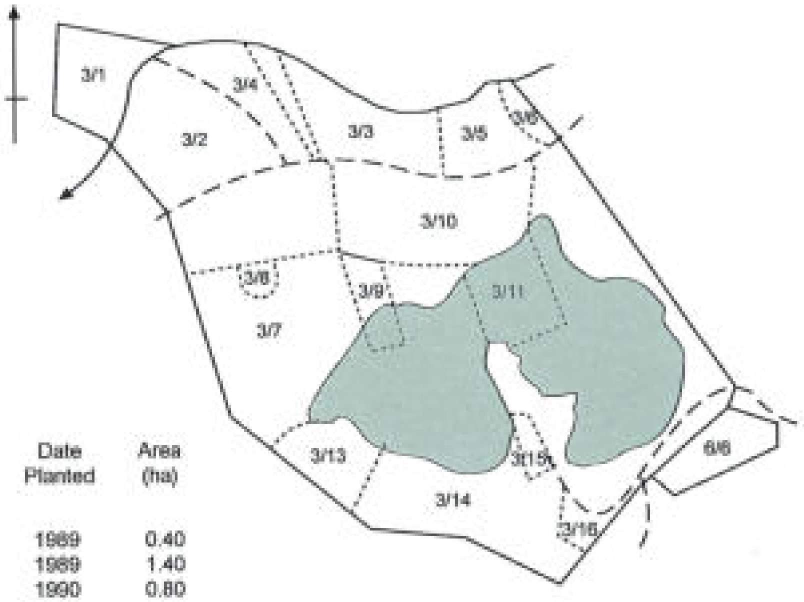


29: *Cupressus* species planted into a gap in *E. saligna*/blackwood in Tai Tane Forest.

30: Cutting small *Cupressus* logs with a bandsaw in Tai Tane Forest (Note quality of material being cut) (*Photo Paul Millen*).

31: A "5th tree" plot in a dense stand of kauri and hard beech. Plot centre is the orange peg, horizontally banded trees are dominants, vertically marked trees are sub-dominants. Dots indicate shrub strata and the white peg shows the location of a ground plant.

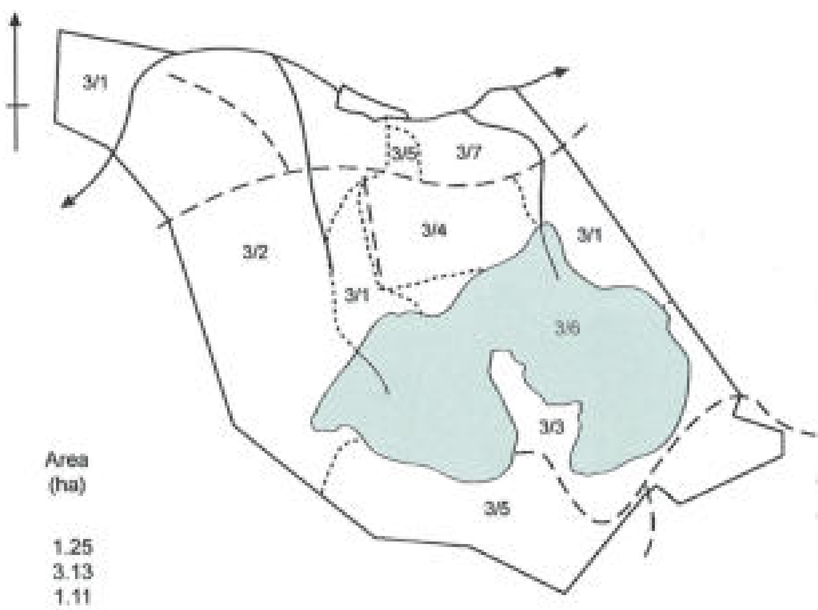
AMAKIWI FOREST
COMPARTMENT 3
ORIGINAL SUBDIVISION 1991



Sub Compartment		Date Planted	Area (ha)
3/1	Trial	1989	0.40
3/2	Euc.saligna / E.botryoides	1989	1.40
3/3	Ac. melanoxylon / E. botryoides	1990	0.80
3/4	Ac. melanoxylon / Alnus spp / Castanea	1991	0.20
3/5	Ac. dealbata / E. botryoides	1990	0.50
3/6	Ac. dealbata	1990	0.10
3/7	Ac. melanoxylon / E. saligna	1989	2.00
3/8	Ac. elata	1990	0.10
3/9	Cunninghamii lanceolata / Paulownia	1989	0.20
3/10	Paulownia trial	1989	0.70
3/11	Agathis trial	1989	0.40
3/12	Bush-gaps interplant A. melanoxylon	1989	1.70
3/13	x Cup. Leylandii (Leighton Green)	1989	0.20
3/14	Cupressus macrocarpa	1989	0.80
3/15	Araucaria angustifolia	1990	0.10
3/16	x Cup. Leylandii (Leighton Green)	1990	0.10
6/6	Bush (scattered) underplanted A. melanoxylon / totara / puriri	2001	0.50
			10.20 ha.

0 100 200 300 Metres

FIGURE 3b-1: Amakiwi Forest, Compartment 3, original subdivision in 1991



Sub Compartment		Area (ha)
3/1	Mixed hardwood / softwood	1.25
3/2	Predominantly hardwood	3.13
3/3	Mixed hardwood /softwood/ indigenous	1.11
3/4	x Cup. Ovensii / Paulownia	0.68
3/5	Predominantly softwood	1.20
3/6	Predominantly indigenous	2.28
3/7	Hardwood / softwood (2006 underplant)	0.57
		10.20 ha.

0 100 200 300 Metres

FIGURE 3b-2: Amakiwi Forest, Compartment 3, subdivision for conversion to continuous cover forestry March 2007

TABLE 3b-1: DATA FOR EXOTIC PART OF COMPARTMENT 3 AMAKIWI

Species	Seedlings	Saplings	Dbh (cm)								Stems/ha over 35 cm
			5–14	15–24	25–34	35–44	45–54	55–64	>64	TOTAL	
Ac melanoxylon	217	122	289	35						663	
E saligna	9	74	88	39	43	9				262	
×*C ovensii*	13		23	66						102	
Parana pine	30		23	18						71	
Cup lusitanica				41						41	
Paulownia		4	23	9						36	
Sweet chestnut	4	9	15							28	
Leighton Green				4	22					26	
E botryoides	4				5	8	4			21	
Totara	4	17								21	
Chinese fir	4	4	5	4	4					21	
Puriri	4	13								17	
Kauri	4	13								17	
Rewarewa	9									9	
Ash			4	4						8	
Beech			4							4	
C japonica			4							4	
Kahikatea	4									4	
Redwood		4								4	
Actual stems/ha	306	260	478	220	74	17	4			1359	21
Calculated stems/ha a = 4, q = 1.8	441	246	136	76	42	23	13	7	4	988	47

TABLE 3b-2: DATA FOR INDIGENOUS AREA OF COMPARTMENT 3 AMAKIWI

Species	Seedlings	Saplings	Dbh (cm)								Stems/ha over 35 cm
			5–14	15–24	25–34	35–44	45–54	55–64	>64	TOTAL	
Kohekohe	1188	150	12		12					1362	
Pukatea	1275				12			12		1299	
Kahikatea	425	50	12		12	12		24		535	
Rewarewa	225			12	12	12				261	
Ac melanoxylon	38	50		12	12					112	
Tawa	50			49		12				111	
Puriri	88	13								101	
Miro	50									50	
Kauri	50									50	
E saligna		13	24							37	
Mangeao	13									13	
Actual stems/ha*	1800	276	48	73	60	36	0	36	0	2329	72
Calculated stems/ha a = 5, q = 1.9	849	447	235	124	65	34	18	9	5	1786	66

* Actual for seedlings is 3402 stems/ha. Has been reduced to make reverse "J" curve chart more legible.

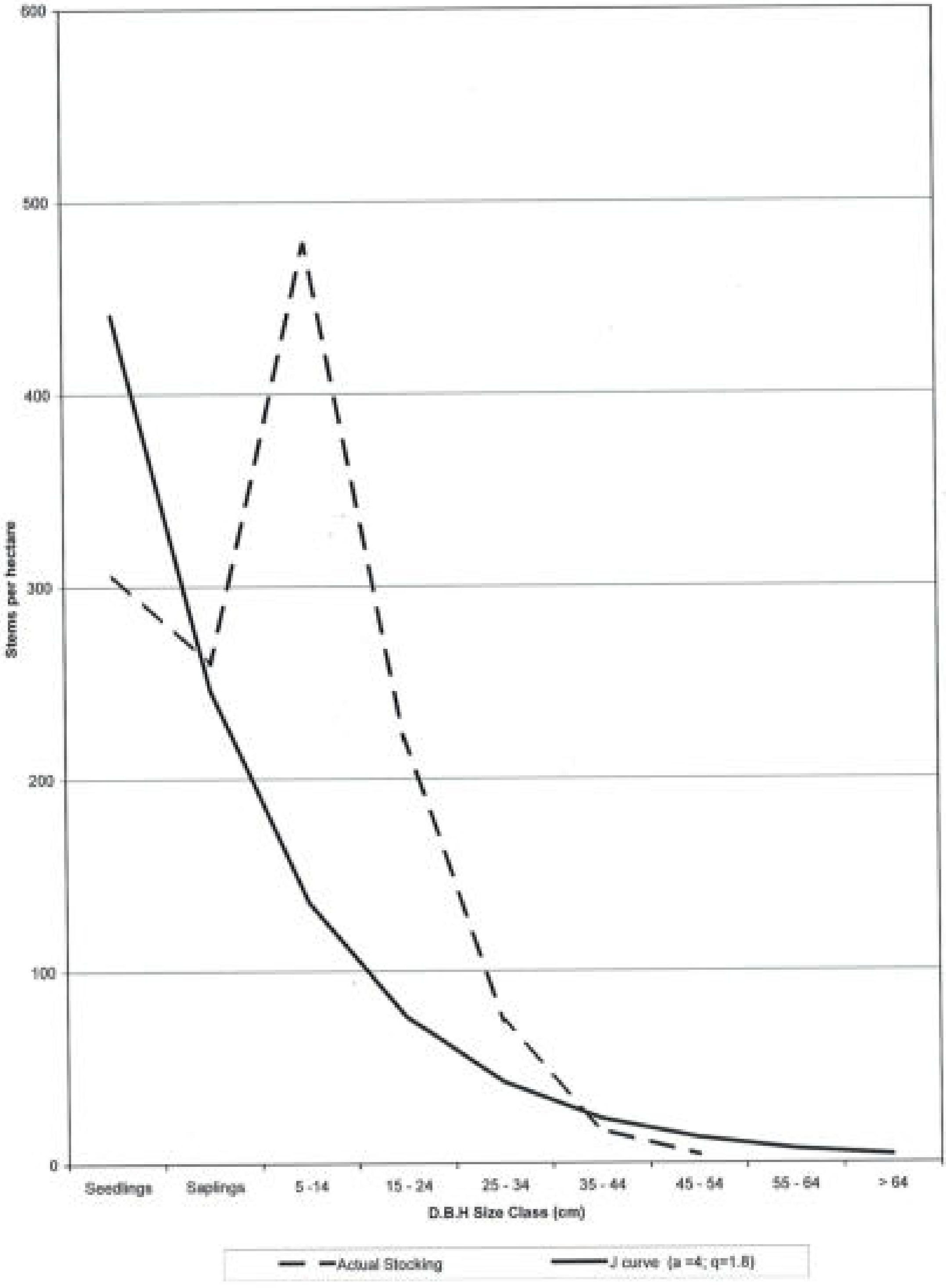


FIGURE 3b-3: Actual stocking and reverse "J" curve, exotic forest, Amakiwi

3b-5, most of the ground cover still consists of grasses, indicating that considerable light is still reaching the forest floor.

Actual diameter distribution in the indigenous area is close to the curve for the larger size classes and there is an excess of seedlings, although these tend to be clumped. However, there are serious deficiencies in the size classes between saplings and 24 cm dbh, highlighting the fact that the forest was heavily grazed from about 1900 until 1989. The best method of increasing growth here will be to remove small numbers of the larger trees, but more especially to reduce the number of tree ferns and woody shrubs around regenerating timber trees (Figure 3b-6). In addition, because regeneration is clumped, it may be necessary to induce regeneration in low-stocked areas by scarification and the removal of overhead shade.

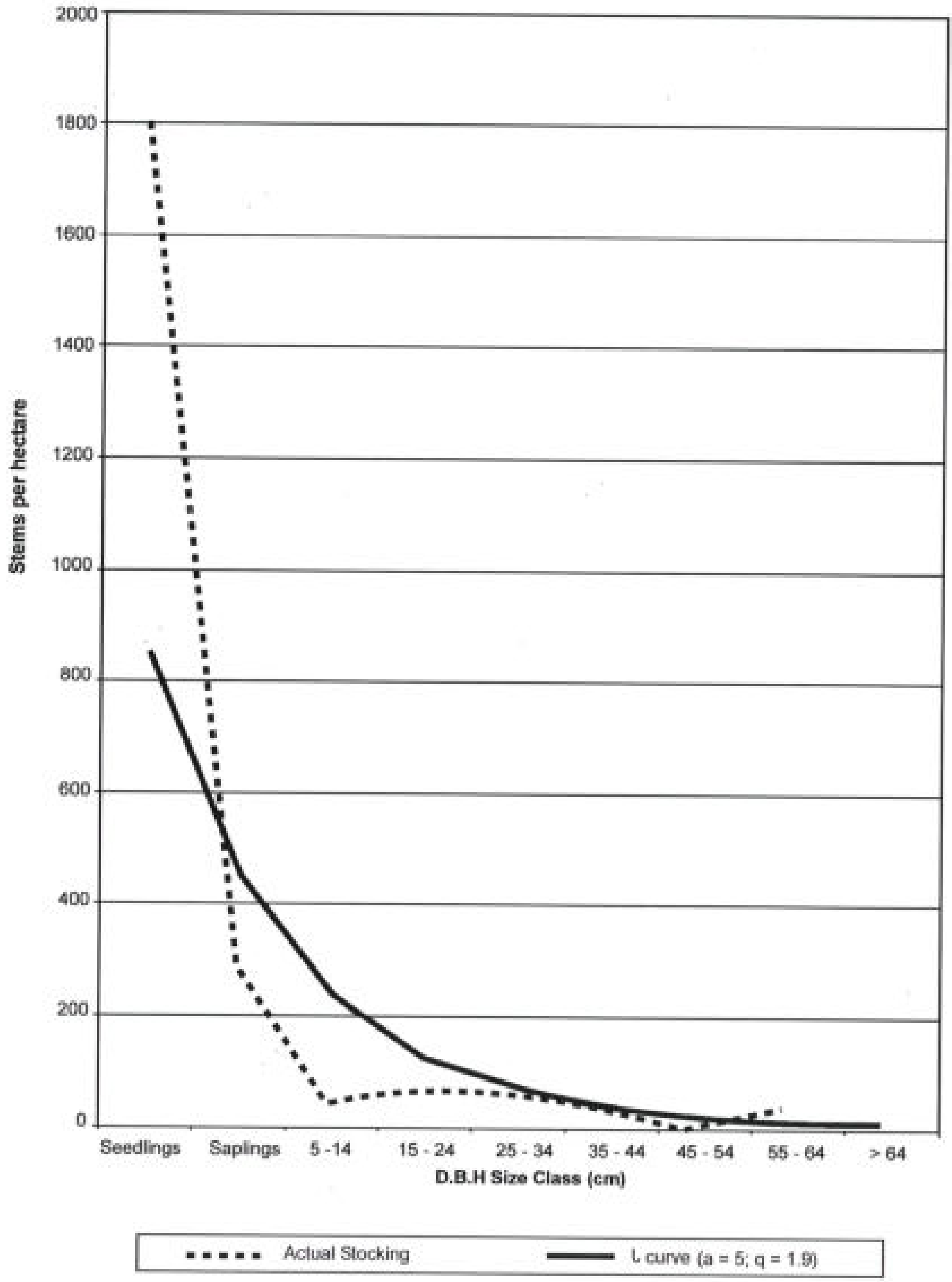


FIGURE 3b-4: Actual stocking and reverse "J" curve, indigenous forest, Amakiwi

PROCESS TOWARD ATTAINING THE IDEAL CONTINUOUS COVER STRUCTURE

Over the next 5 years the growth rates and characteristics of each species will be observed and recorded. Species which prove to be unsuitable will gradually be removed; *E. saligna*, because of its heavy branching characteristics on this site may fall into this category.

Every 5 years the inventory survey will be repeated until, at the appropriate time, a decision as to the probable best species/size composition can be made and silviculture directed toward achieving this. It is proposed that frame trees will be selected at the next inventory.

To date no decision has been made about when harvesting might commence but, as some trees are now close to

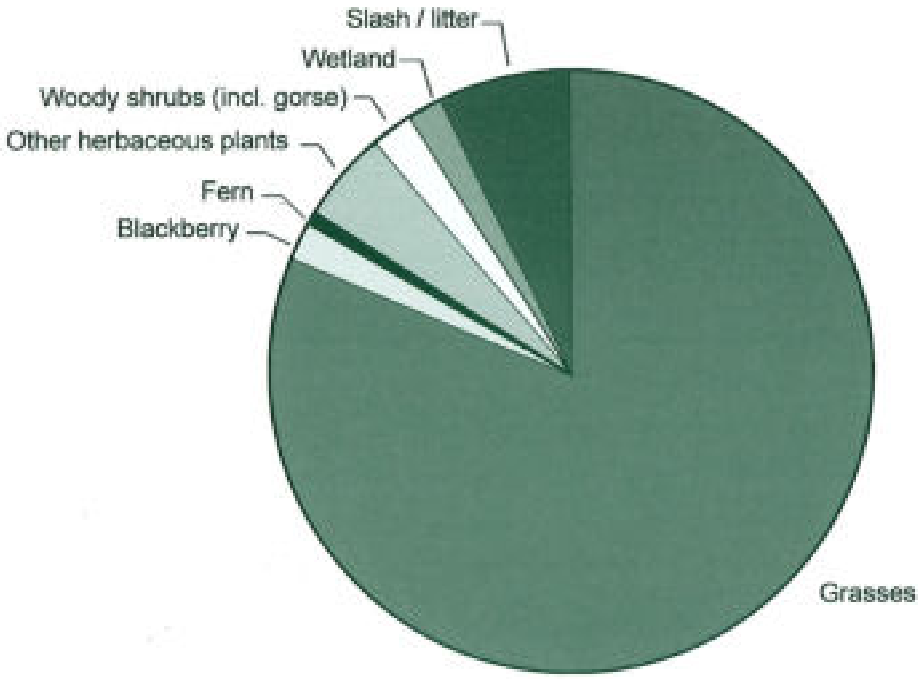


FIGURE 3b-5: Ground cover, exotic forest area in Compartment 3.

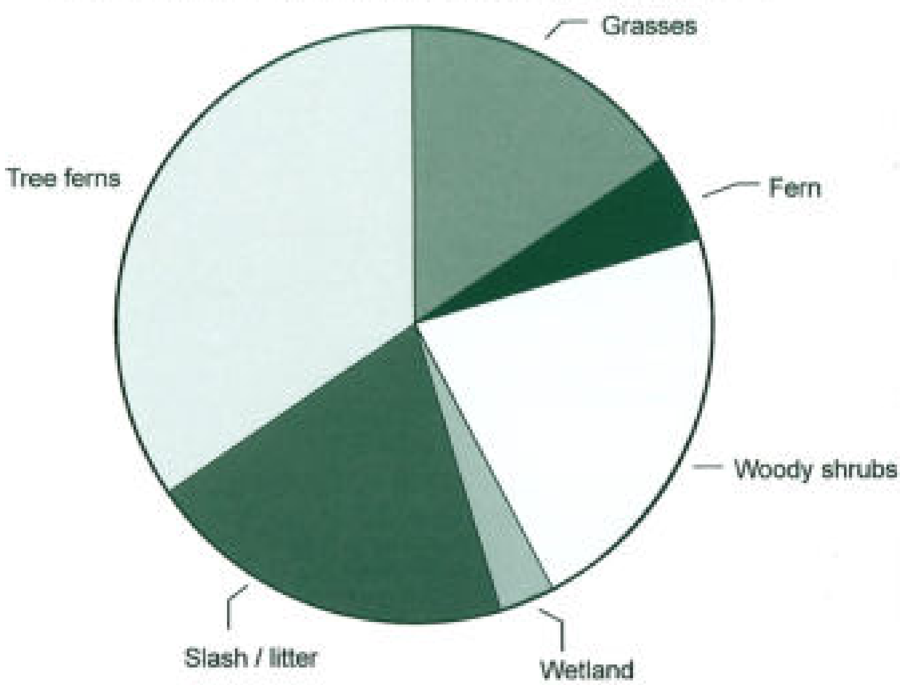


FIGURE 3b-6: Ground cover, indigenous forest area in Compartment 3.

50 cm dbh, this is expected to be probably within 5 years, especially as some larger trees may need removal to increase the growth rate of smaller sizes. Prior to harvest commencement a great deal of attention will need to be paid to the economics of the operation and the harvesting and sawing methodologies used.

From now on the process at Amakiwi is expected to be as follows:

(1) An inventory of each compartment will be made using the British Forestry Commission's systematic sampling system (Refer Inventory Section 3.1). Each plot centre will be recorded using GPS and the nearest frame tree will be numbered to enable the plot to be relocated should this be required.

(2) From the data obtained a type map will be drawn up and a treatment programme and timetable for each compartment developed.

(3) When a stand becomes due for further silviculture or harvesting the following process will be implemented:

- Determine the management system best suited to the species;

- Select frame trees at first or second inventory;
- Remove poor-quality dominants;
- Thin sub-dominants to remove poor-quality trees and, if necessary, reduce stocking. If required, prune remaining trees;
- Remove poor-quality saplings and seedlings or regeneration of the wrong species;
- Release good-quality sapling and seedling regeneration by opening gaps around selected trees. Prune and form-prune if required;
- Plant under-stocked areas where regeneration is deficient.

Many of the remaining compartments in the forest contain either a single species or two or three species located according to shelter, aspect, and altitude. On the higher and more exposed parts, where *P. radiata* now grows, it is expected that much will remain as a clearfell monoculture. However, it is intended that plantations of other species and more sheltered areas of *P. radiata* will be converted to continuous cover over time. Apart from a few places where inter-planting has already been done, and which will be managed in a similar way to Compartment 3, it is expected that the monocultural areas will be converted by harvesting patches of trees in appropriately sized coupes and replanting these with species appropriate to continuous cover. It is also intended that trials will be done to investigate the potential of using *P. radiata* in continuous cover as is currently practised by J. and R. Wardle.

At this stage it is not known how frequently individual stands will be visited for harvesting and re-treatment but the initial assumption is every 5 years although, if pruning is required, it may have to be more frequently. In any event the inventory process will be repeated at 5-yearly intervals.

The number and size of trees removed in each diameter class at each harvest visit will depend upon the current annual increment of the compartment and be guided by the size class distribution of trees as reflected in the reverse "J" curve for the compartment as determined by the last inventory. As a general rule inventories will be timed to immediately precede harvest.

It is unlikely that the large number of species present in the forest will continue to be used. The likely final scenario will be to have three or four major species plus a similar number of minor ones. The final decision on this is not likely to be made for at least another 20 years.

APPENDIX 3c

A KAURI FOREST AT MANGATANGI

LOCATION, TOPOGRAPHY, AND PHYSICAL CONDITIONS

Around the slopes of the Hunua Ranges, particularly the southern edge, the predominant forest type between 100 and 300 m above sea level is kauri (*Agathis australis*) usually in combination with hard beech (*Nothofagus truncata*) and tanekaha (*Phyllocladus trichomanoides*). The part of that area involved in this study consists of 14.3 ha, located on the east bank of the Mangatangi River just above the point where it debouches from the ranges into farmland. It is currently part of the Hunua Regional Park, which encompasses one of Auckland's main water supply catchments, having been acquired for this purpose in 1943 (Barton, 1978). The area, draining into the Mangatangi River, is steep and dissected; it is mostly inaccessible by tracked or wheeled vehicle, although the road to the Mangatangi Dam runs along the south-west side and a disused 4 × 4 track runs up the east boundary and into the top of the block (Figure 3c-1).

Fifty years ago the southern third of the block was covered with low kanuka (*Kunzea ericoides*) scrub, slowly reverting to kauri forest; the remainder was a forest of mature hard beech and pole kauri with associated tanekaha and rimu (*Dacrydium cupressinum*), a scattering of other podocarp species, and rewarewa (*Knightia excelsa*). In places the tanekaha were regenerating through tall kanuka and it is probable that the eastern fringes of the block were destroyed by fire when the adjacent farmland was cleared for farming about 1900.

The soil over much of the area is Hunua brown granular clay composed of weathered greywacke and small amounts of Hamilton ash. It is not very fertile.

Annual rainfall at Mangatangi is 1750 mm, reasonably well-distributed but usually with a dry period between mid January and late March. However, droughts (periods without rain for more than 15 days) are not common. Cyclonic storms with very high rainfall occur on average every 12 years but periods between these range from 1 year to 28 years.

The mean annual temperature is 14°C with a mean maximum of 18.8°C and minimum of 8.6°C. Six months of the year have mean temperatures over 15°C, which is the minimum level for reasonable kauri growth (Barton, 1999).

HISTORY

The whole of the area below the Mangatangi Dam was logged for kauri between 1900 and 1915, the timber being floated down the river from a dam, probably located about a kilometre upstream of the present bridge, to a boom in the farmland just south of the forest (Barton, 1978). Apart from some gum bleeding in the 1920s, no further forestry activity occurred until the 1960s. This began with the planting of a trial plot near the road in 1964; further line or gap planting was done in the southern portion between 1974 and 1978 with kauri and some rimu. This was extended into the northern areas of regenerating forest in 1979. In 1982 a trial helicopter logging was carried out in the forested part of the study area and after this stands, mainly in the west/central portion which were poorly

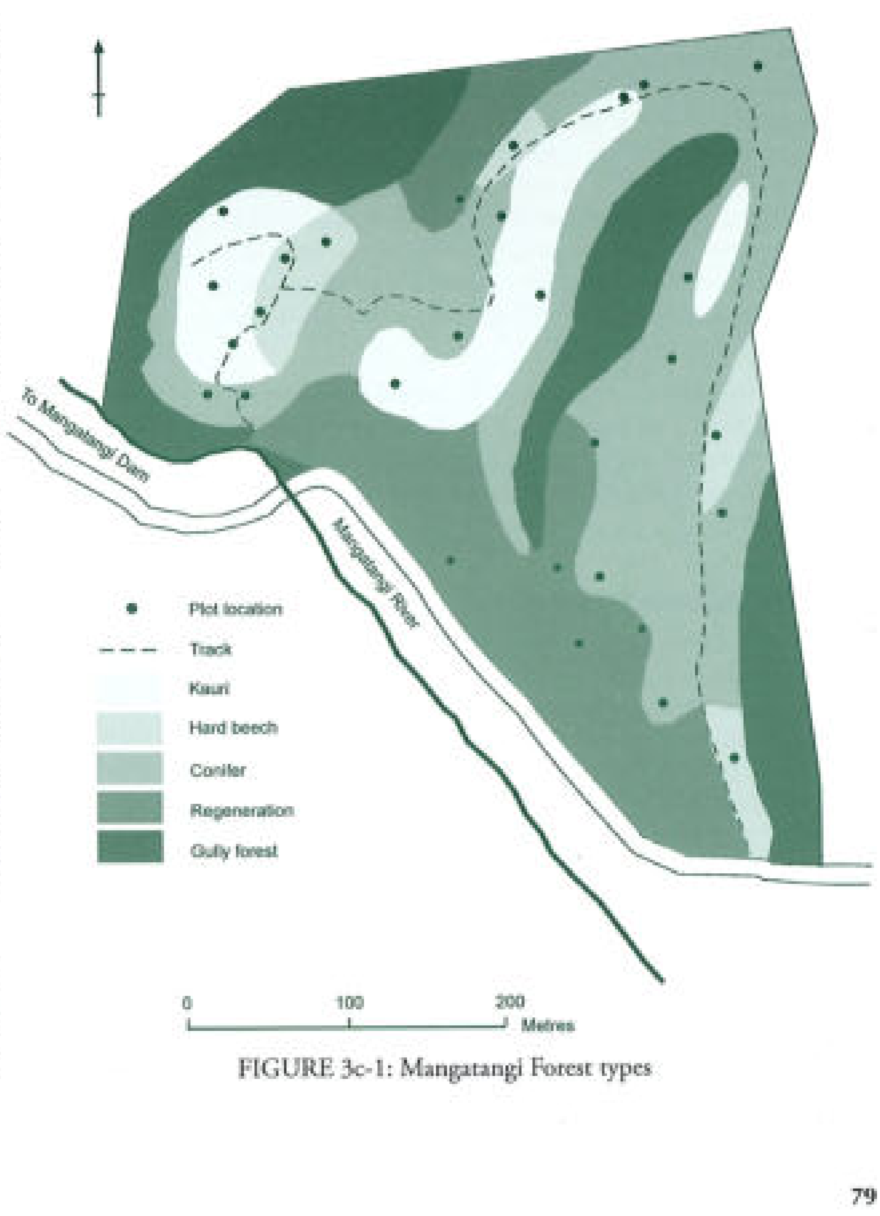


FIGURE 3c-1: Mangatangi Forest types

stocked with kauri, were planted with kauri seedlings. While plantings in 1964 and the late 1970s were released from competition at least once, none of the later plantings were. However, many are known to have survived and some are now well-established.

The volume of kauri removed from this area 100 years ago can only be speculated upon but based upon the evidence of stumps revealed when the dam site was cleared in 1973 and, assuming average tree sizes, the volume of stocked kauri forest would have been between 200 and 600 m^3/ha in the Mangatangi Valley. Removals from the study area were probably much less than this because the trees remaining suggest that the vegetation here comprised a much younger stand with mostly pole kauri and scattered medium-sized trees.

In 1982 the extraction was from a much smaller area, a little under 5 ha, from which 36 trees averaging 0.31 m^3 were extracted (total volume 11.2 m^3).

MANAGEMENT 1963 TO 1986

During this period the forest was controlled by the Forestry Section of the Auckland Regional Council's Water Division. The original objective was to attempt to manage the existing kauri pole stands and to plant kauri seedlings into under-stocked areas. Most of the work in this period involved research in the form of trial planting and extractions because the information available on kauri management at that time was minimal. Early work was impeded by the lack of suitable extraction systems and by the impact of goats which destroyed planted seedlings. Once goats were largely eliminated, planting was extended from fenced trial areas into the site described above, and the advent of helicopter harvesting from the late 1970s enabled the trial to proceed.

From the late 1970s there was an increased desire on the part of the Auckland Regional Council to cease harvesting native species; this decision was made in the mid 1980s, since when no work apart from forest typing has been done.

INVENTORY OF THE FOREST

In the early 1980s an inventory system, based on earlier work by Barton (1982), was designed and the study area plus the forest to the north and west, a total area of 72 ha, was assessed. The biggest problems are the complex composition of this forest, where virtually all of the major trees groups found in New Zealand are present in various mixtures, and with the inventory system which relied on the mechanical sorting of species by computer programme. This produced a somewhat artificial typing of the forest which it divided into 15 sub-types, which were manually regrouped into five major types:

(1) Kauri / hard beech

(2) Kauri with conifers (mainly tanekaha) and xeric scrub

(3) Xeric scrub (species of drier sites, mainly kanuka)

(4) Podocarp/broadleaves with mesic scrub — mainly mamaku (*Cyathea medullaris*), mahoe (*Melicytus ramiflorus*), etc.)

(5) Podocarp/broadleaves with mixed xeric and mesic scrub.

Later examination of this arrangement suggested that it was still quite artificial when compared with the actual situation on the ground, and so further attempts were made to rationalize the forest typing. In this forest the pattern tends to a mosaic of similar species in patches, or species arranged more or less altitudinally, with broadleaves such as tawa in the gully bottom, then beech, then rimu, then kauri on the ridge. However, this is an oversimplification because microclimate effects mix species even more.

This case study involves an area of some 14 ha where plot data and field observation suggested division into five basic forest types:

(1) Kauri (with some podocarps and beech)

(2) Conifers (can also have broadleaves, e.g., rewarewa, but is mainly tanekaha with rimu, totara, miro, and some kauri)

(3) Hard beech (with some kauri and podocarps)

(4) Regeneration (mainly dominated by kanuka and other xeric scrub species but where sapling and pole tanekaha can function as a major scrub component and other timber species are beginning to establish)

(5) Gully forest (mainly mesic scrub species where mamaku is often the dominant and where very few timber species are found).

INVENTORY METHOD

An early forest-type map drawn up from some plot data but mostly field observation was used to randomly locate plots with GPS or ground measurement. No plots were located in the gully forest because of the lack of trees and the difficulty of measuring plots on ground as steep as 50°.

The inventory method used, the "5th tree system", was devised by the author some 25 years ago and is based upon dividing the forest into four strata — dominant, sub-dominant, shrub, and ground (Plate 8 No.31). From a randomly chosen plot centre, the closest six timber species in each stratum* are identified and the distances to the 5th and 6th plants measured. The mean of these give the plot diameter. Species and dbh for the five closest dominants and sub-dominants are recorded, and species only for the five closest shrub and ground species. Other details collected are plot slope, altitude, and aspect; frequencies of the non-timber species present in each stratum; and brief notes on the plot. The data are analyzed using spread

* If no timber species are present in the dominant and sub-dominant strata, non-timber species are recorded.

sheets, although a fully computerised system could be developed.

INVENTORY RESULTS

For this inventory a total of 29 plots (1 plot per 0.5 ha) were established (Figure 3c-1) and upon completion each plot was assigned to a forest type based upon the dominant and sub-dominant species present. Dominant trees were scored 2 and sub-dominants 1 to give a total of 15 points. A score greater than 41% for one of the species groups listed above determines the forest type (see examples in Table 3c-1).

Once allocated to a forest type, the average data for each type are calculated (Table 3c-2). The next step is to analyse the composition of each forest type and determine the silvicultural treatment required to obtain the future structure of the forest.

In this case the most valuable species present is kauri and, when all types except "Regeneration" are combined into one, it is the major species in all strata except sub-dominant, which still has a predominance of tanekaha. Further, because kauri is establishing well in the shrub and ground strata of the "Regeneration" forest type, there is good reason to expect that the area as a whole is regenerating toward a forest type heavily dominated by kauri (Plate 8 No.27). Management should thus concentrate on advancing kauri in all size classes, favouring some rimu, totara, and miro where appropriate, and reducing the percentage of tanekaha, except in moister gullies where it can do well. Tanekaha is treated in this way because experience suggests that, in this part of the country and on dry and exposed sites, it is small (usually under 40 cm diameter) and the timber is prone to shake.

FUTURE MANAGEMENT

Now that this area is part of a Regional Park, it will not be managed further for timber production, but left to grow naturally. It was chosen as a case study because it is one of the few kauri areas about which a reasonable amount of information is available and so can be used to demonstrate how the owner of such an area might proceed, should they wish to place their forest under sustainable management.

The first action will be to undertake an inventory of the forest and at the same time collect what growth data may be available. Some height and diameter measurements may have been taken over a period of years and calculations can easily be made. Usually, however, this will not be so and the best procedure will be to select a number of trees, over a range of size classes, and take increment borings from which a preliminary idea of growth rate can be obtained.

Data collected from a similar forest quite near the Mangatangi stand are given in Table 3c-3. In it we see that the annual diameter increment of kauri ranges from less than 0.1 cm (usually when the tree is a suppressed sapling) to 1.36 cm (when it is a fast-growing emergent). The average growth rate of the dominant kauri is 0.7 cm annually but for those below dominant status it is only 0.3 cm annually. This information can now be combined with plot data from the Mangatangi site to predict that it will take 21 years for the larger dominants to reach harvestable size and that during this time the sub-dominants will have increased a further 6.3 cm in diameter (Table 3c-4).

Next, the silvicultural requirements for the Mangatangi area need to be derived. In Figure 3c-2 is shown the optimum reverse "J" curve for the site plus diameter class distribution of the pure kauri, combined forest types, and regenerating forest. The curve for the combined types shows that the forest as a whole has a reasonably good diameter class distribution, although stocking between 15 and 45 cm diameter is too high. Distribution of kauri is similar but more pronounced while, as would be expected, there is a very high stocking in the 15–25 cm class for the regeneration; this is the size of the dominant/sub-dominant canopy of kanuka and tanekaha.

How then to manage this area to get size classes as close as possible to the predicted line? As there are few, if any trees, large enough to harvest, the objective for the next 5 years would be to release as much of the kauri and good specimens of other species in the 15 to 45 cm classes as possible in order that they may increase their growth rates and shift into higher size classes. This would be done by removing large non-timber species such as kanuka and towai (*Weinmannia silvicola*) and any timber species of poor stability and form, keeping in mind the desired species proportions and the need to move the forest structure toward the desired reverse "J" curve position. At this time it is not necessary to calculate basal area and volume data but a small number of plots should be established so that accurate growth rate information is available within a few years. It is suggested that randomly located plots of 0.04 ha be used at one for every 2 ha up to 6 ha, and one for every 5 ha after that up to a maximum of 10 plots; this should give sufficient data to derive growth rates and enable prediction of the first allowable cut. From that point on the inventory and yield data can be determined as outlined in Chapter 3. At the same time as the larger size classes are released, attention should be paid to protecting and releasing sufficient plants in the smaller size classes to ensure adequate future stocking of larger trees.

Another inventory should be done 5 years after the thinning/releasing operation and the data from this, combined with that from the growth plots, will enable determination of the volume of the first harvest. Inventory data should also show that the diameter class distribution has moved closer to the calculated curve.

TABLE 3c-1: FOREST TYPE DETERMINATION

Plot	Stratum	Species							Forest type
		Kauri	Beech	Tanekaha	Rimu	Other podocarps	Broad-leaves	Kanuka	
1	Dominant	2		2	1				
	Sub-dominant	4		1					
	Score	8		5	2				
		53%		33%	13%				Kauri
2	Dominant	2		2	1				
	Sub-dominant			2	1		1	1	
	Score	4		6	3		1	1	
		27%		40%	20%		7%	7%	Conifer
3	Dominant			1			1	3	
	Sub-dominant	1		1	1	1		1	
	Score	1		3	1	1	2	7	
		7%		20%	7%	7%	13%	47%	Regeneration

TABLE 3c-3: SUMMARY OF DATA FROM INCREMENT BORINGS TAKEN FROM KAURI AND OTHER SPECIES ON A PROPERTY NEAR MANGATANGI April 2006

Tree No.	Species	Dbh (cm)	Height (m)	Stratum	Diameter CAI range (cm/year) Min.	Diameter CAI range (cm/year) Max.	Mean MAI (cm/year)	Remarks
1	Kauri	57.5	35	Dominant	0.28	1.28	0.78	Sited on easy spur
2	Kauri	63.8	35	Dominant	0.80	1.36	0.96	Sited on easy spur
4	Kauri	76.0	38	Dominant	0.40	0.92	0.60	Emergent tree
3	Kauri	32.0	30	Sub-dominant	0.23	0.92	0.42	Under canopy of taller trees
8	Kauri	24.1	18	Dominant	0.28	0.92	0.67	Small but emergent
7	Kauri	17.5	18	Dominant	0.20	0.80	0.52	Small but emergent
6	Kauri	12.8	11	Co-dominant	0.08	0.77	0.29	In light but not emergent
9	Kauri	7.8	8	Sub-dominant/ suppressed	0.10	0.26	0.19	Vigorous tree but under other kauri.
5	Tanekaha	40.0	24	Dominant	0.28	0.52	0.39	Big rata vine on tree
10	Totara	47.3	36	Dominant	0.24	0.48	0.37	In group of similar totara plus puriri

Dbh Diameter of tree at breast height (1.4 m above ground)
CAI Current annual increment (1 year's diameter growth at that time)
MAI Mean annual increment (average diameter growth per year over time covered by increment core)

TABLE 3c-4: ESTIMATED TIME TO HARVEST FOR KAURI AT MANGATANGI

	Mean dbh 2007 (from Table 3c-2) (cm)	Estimated MAI (from Table 3c-3) (cm)	Probable minimum harvest dbh (cm)	Years to reach minimum harvest size
Dominants	35	0.7	50	(50 – 35)/0.7 = 21
Sub-dominant size when dominants harvested	16	0.3	[16 + 6.3 = 22]	[21 × 0.3 = 6.3]

TABLE 3c-2: FOREST COMPOSITION DETAIL BY FOREST TYPE

Type	Stratum	Altitude (m)	Slope (°)	Aspect	Stratum height (m)	Plot area (m²)	Stems/ha	Mean dbh (cm)	BA/ha (m²)	Species breakdown (%) Kauri	Beech	Tanekaha	Rimu	Miro	Totara	Tawa	Rewarewa	Non-timber
Kauri	Dominant	175	23	198	30	155.4	322	33.8	28.93	67	7	20	7					
	Sub-dominant				18	59.5	841	17.6	20.50	43	17	40						
	Shrub				8	48.8	1024			50	10	20	20					
	Ground				1.3	5.62	8897			73		10	3	3	3		7	
Beech	Dominant	170	17	192	28	304.8	164	39.0	19.56	10	77	13						
	Sub-dominant				21	102.5	488	15.5	9.23	10	30	40						20
	Shrub				7	31.34	1596			47	3	33	7			3	3	
	Ground				1.02	21.87	2286			47		20		7	10	3	13	
Conifer	Dominant	177	26	221	24	212.77	235	32.7	19.71	20	5	44	7				2	22
	Sub-dominant				17	78.75	635	15.3	11.74	5	5	58	7		2	2	2	18
	Shrub				8	34.02	1470			42		42	2	4	5			5
	Ground				1.3	24.59	2033			47	2	20	5	5	11	2	7	
Combined Types	Dominant	175	23	207	27	218.53	229	34.9	21.86	30	24	30	5				1	10
	Sub-dominant				18	79.16	632	16.0	12.72	17	15	49	3		1	1	1	14
	Shrub				8	36.88	1356			45	3	34	8	2	3	2	1	3
	Ground				1.2	17.72	2821			47	2	20	5	5	11	2	7	
										Kauri	Kahikatea	Tanekaha	Rimu	Miro	Totara	Kohekohe	Rewarewa	Non-timber
Regeneration	Dominant	162	20	219	17	98.52	508	12.4	6.17			3						97
	Sub-dominant				10	94.17	531	10.4	4.47	7		27		10	3		7	47
	Shrub				5	80.65	620			40		47	3	3		3		6
	Ground				1.4	23.38	2138			10	13	40	3	3	3		27	

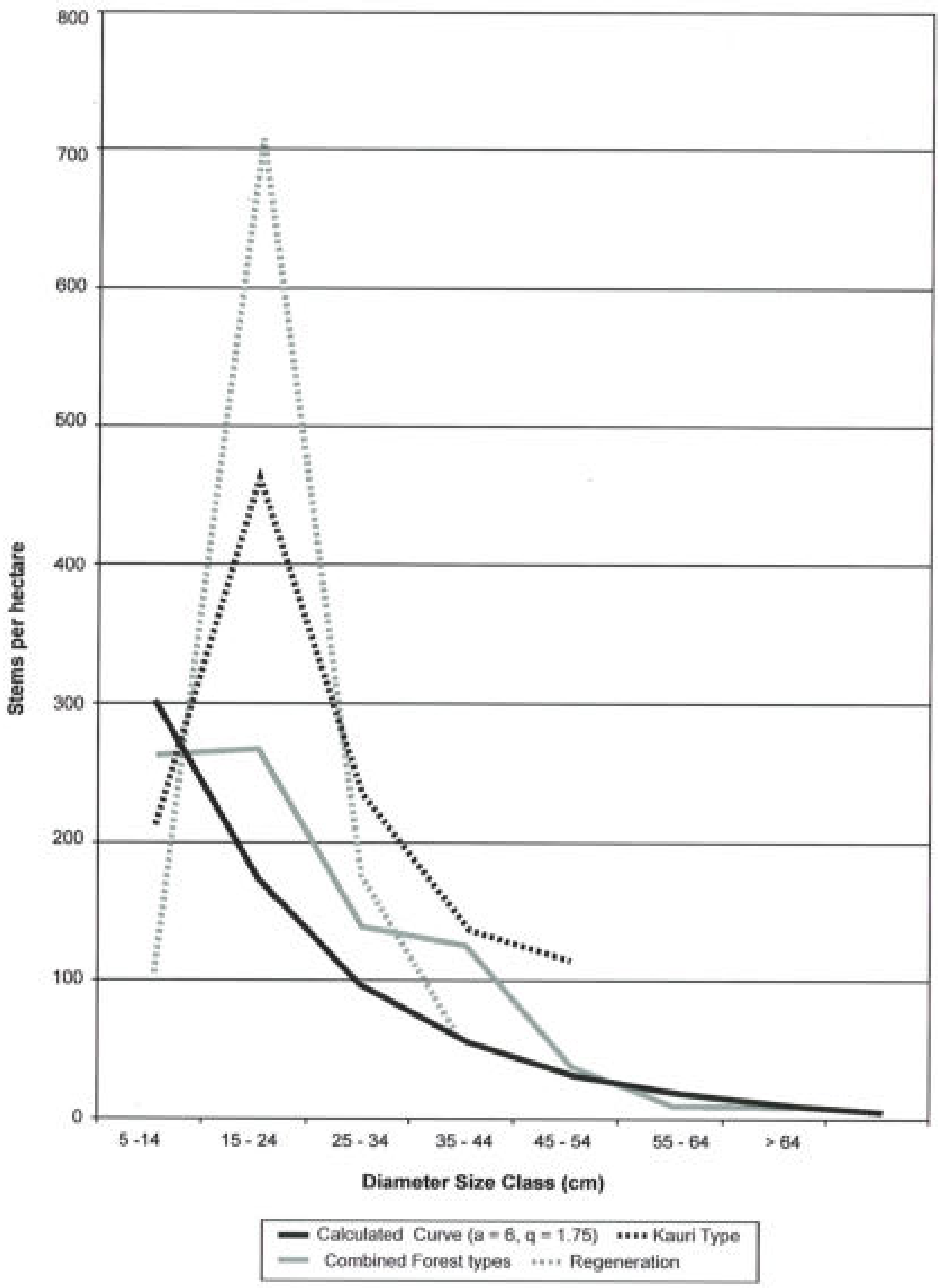


FIGURE 3C-2: Reverse "J" curves for Mangatangi Forest

APPENDIX 3d

TAI TANE FOREST, MARLBOROUGH SOUNDS

THE ORIGINAL VISION

When he left Canterbury University, Paul Millen was not particularly enamoured with the *Pinus radiata* emphasis of the New Zealand Forest Service and set out to find something different. This saw him working at a range of jobs culminating in a period with local government in Marlborough, while planting his own forest in the inner Marlborough Sounds. This he did in association with his brother Ash, a carpenter and joiner with experience in portable sawmilling. The brothers purchased the 27-ha Tai Tane in 1984 and began planting small stands of a range of exotic hardwood and softwood species. Their original objective was to plant and manage a small-scale multiple age-class forest, with specialty exotic species for a range of high-value uses. In recent years this has focused on new trials of naturally durable hardwoods, especially some of the lesser known eucalypts.

On this very productive forest site, trees begin to reach a utilizable size from about age 12 and in the late 1990s the Millens began to develop uses and markets for thinnings from the forest. So far production has been from *Cupressus macrocarpa* with smaller amounts of *C. lusitanica*, *Eucalyptus regnans*, *E. saligna*, and *Acacia melanoxylon* (blackwood).

PHYSICAL CONDITIONS AND ACCESS

The property is moderately steep with an altitude difference of about 100 m from the sounds on the north edge to the hills at the south. Fortunately the block is well broken into small basins and faces which provide a range of microclimates and aspects, with intervening ridges and spurs that are not too steep to lay out with a well-spaced track network (Figure 3d-1).

The original vegetation of the area was probably podocarp/hardwood/beech forest, the main species being rimu, miro, kamahi, red beech, and hard beech. This was cleared for farming in the 1870s and began to revert in the 1960s. By the time it was purchased by the Millens it had regenerated to a dense cover of scrub and weed species which was cleared as it was planted, with only one steep face still in native regeneration.

The soils of the property are steepland central yellow brown earths which have formed from hard siliceous sandstones, argillites, and sub schist. In many places broken rock is near the surface and is useful for track surfacing. The silt and clay loam soils have low natural fertility and suffer from sheet erosion; they are well suited to forestry.

The climate of the area is also well suited to growing trees, the forest being in an area which has warm summers, dry north-west winds, and rainfall mainly in winter.

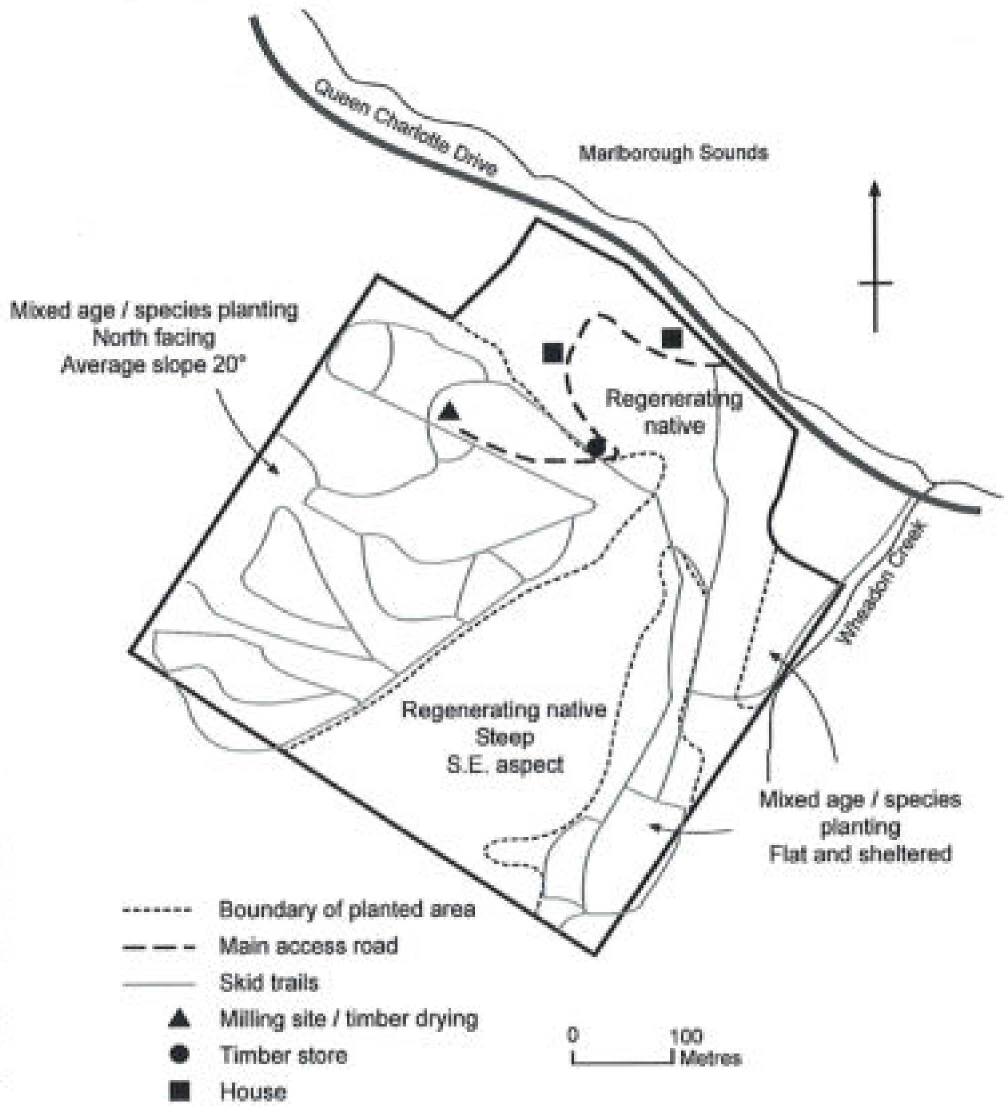


FIGURE 3d-1: Tai Tane Forest, Havelock

Although rainfall at the property is about 1500 mm, the nearest climate station at Rai Valley has an annual rainfall of over 2000 mm, and records ground frost most of the year, although seldom between December and March. Data from climate maps show that Tai Tane has a mean annual temperature of 11.0°C, a mean July temperature of 7°C, and a mean January temperature of 16.5°C. Soil temperatures are generally warm enough for tree growth between late September and late April.

Access is generally good, with over 5 km of 2-m-wide tracks which are periodically mown. This gives a ratio of about 360 m of road and track per hectare, compared with some 50 m for a conventional clearfell forest. A high ratio is common for continuous cover forests being worked by ground-based systems.

THE MANAGEMENT SYSTEM

Planting of the forest began in 1984 with the establishment of some blocks of *Cupressus macrocarpa*, eucalypts, and blackwood. Since then there have been small plantings of a range of species including *C. lusitanica* and several eucalypts, especially *E .regnans*. There is a small amount of *Pinus radiata*, mainly on the upper slope to provide shelter for lower sites. In addition trial blocks of several species were planted. These include *Thuja plicata* (western red cedar), *Pseudotsuga menziesii* (Douglas fir), *Cryptomeria japonica* (sugi), *Sequoia sempervirens* (redwood), *Prunus avium* (cherry), and several *Eucalyptus* species which have durable timber. To date over half of the property, a little over 14 ha, has been planted (Table 3d-1).

Establishment began with the selection of weedy areas and root raking with a bulldozer to clear areas for planting. Areas carrying good native scrub regeneration were usually bypassed, but some stands of kanuka have been cleared by a local firewood merchant before being planted. Planting follows within 3 months of clearance and planted seedlings are released, by hand or chemical spray, once or twice in the following 12 months. Stocking at planting is high — up to 1500 seedlings/ha — the aim being to grow the maximum volume of logs to allow optimal selection of high-quality main crop trees when production thinning. The most prominent exotic weed on the property is broom which, providing plants are well-released in the first year, makes a useful nurse species for seedlings which require some shade or frost protection in that year.

Pruning is conventional, often beginning with form-pruning for species such as blackwood and then in three lifts to about 6 m. Because of the tight spacing, the upper branch diameters are low and knotty cores restricted to about 15–20 cm. Thinning begins at about age 6 when poor form trees are thinned to waste. However, the objective is to utilize as much of the crop as possible and so production thinning commences from about age 16, although trees as young as 12 have been successfully milled. Trees are selected for thinning using form and vigour as the main criteria; spacing is less important.

The objective is to revisit trees every 4–8 years until at least 40 years from planting, by which time the stands may contain advanced regeneration or inter-plants growing under a canopy of some 100 dominant trees/ha. Currently the annual thinning harvest produces some 100 m^3 of logs and this volume is expected to increase as tree size increases to reach an annual total yield of some 200–300 m^3 of logs by 2020, a sustainable harvest of 14–21 m^3/ha.

It is not yet clear how these stands will be managed to maintain continuous cover. At this stage there is very little regeneration from seed although coppice regeneration of blackwood is flourishing. Some of the latest planting has been done where small patches of trees or cleared scrub have been felled and these will grow into stands of varying size. The hope is that in future years, when removal of the existing crop has reduced stockings to less than 200 stems/ha, regeneration of some species will begin; alternatively, small gaps can be planted (Plate 8 No.28 & 29). At this stage it appears that the forest is headed toward being composed of small stands of mostly single species, but if regeneration is successful greater mixing will occur.

The forest is remarkably healthy with the exception that cypress canker is afflicting some stands of *C. macrocarpa* and makes the future of that species in this forest a little uncertain. It has been noticed that canker is more prevalent on exposed sites and so recent planting of *C. macrocarpa* has been in more sheltered areas to reduce canker incidence. All new cypress plantings will be with some of the more canker-resistant *C. macrocarpa* clones or with *C. lusitanica*. It will be a loss to the forest if *C. macrocarpa* cannot be grown in future since it is one of the best speciality exotic species and is highly sought after in New Zealand. Observation around New Zealand also suggests that its ecology is such that it can regenerate from seed better than *C. lusitanica* and many other species; so not being able to grow it here will be a disadvantage.

Possums are the only animals present which can damage trees but they are controlled by local hunters with well over 1000 animals taken from this small block since planting began in 1984.

THE WOOD PRODUCTION PROCESS

The workhorse of the property is a 90 hp Same tractor equipped with mower, grader blade, winch, and forks. This is used to grade and mow tracks, cart gear around the forest, extract logs, and stack timber. Trees are carefully felled to avoid damaging residual stems, delimbed in the forest, and hauled in tree lengths to the sawmill site. The smallest logs extracted are 0.2 m^3 in size; logs smaller than this are uneconomic to remove.

Harvesting and sawmilling are usually done in summer and autumn using a local miller. He sets up his "Wood-Mizer" portable bandsaw on a central site located on unplanted ground under high-tension power lines that dissect the

TABLE 3d-1: TAI TANE — SUMMARY OF SPECIES PLANTED

Species	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	Total stems
					Approximate number of merchantable trees — Pruning complete											
Acacia melanoxylon	30	50	140		10		15	10	50	50		30			25	410
Cryptomeria japonica			30													30
Cupressus lusitanica			30	90	10										30	160
Cupressus macrocarpa	90	80	20					120	80	300		400	100			1190
Eucalyptus botryoides		20														20
Eucalyptus fastigata	40												50			90
Eucalyptus fraxinoides			10													10
Eucalyptus regnans	45	45								50						140
Eucalyptus saligna			60	10	10											80
Pinus radiata											400	80		200	200	880
Prunus avium							35									35
Pseudotsuga menziesii	20	40	30		30											120
Sequoia sempervirens			15													15
Thuja plicata	50	30														80
Total stems	275	265	335	100	60	0	50	130	130	400	400	510	150	200	255	3260

	2002	2003	2004	2005	2006	Total stems
	Number of trees planted					
Cupressus mixed spp.	200	600	100	100	100	1100
Eucalyptus saligna					600	600
Eucalyptus mixed species		600	300	2000	600	3500
Sequoia sempervirens		50				50
Total stems	200	1250	400	2100	1300	5250

property. This saw can cut logs down to 15 cm small-end diameter and 1.5 m long with minimal wastage because of the 2-mm kerf. *Cupressus macrocarpa* logs 18–20 years old have been yielding high-value beams and boards (Plate 8 No.30). Timber is stacked in fillets and dried on site before being sold into a strong local market. The Millen brothers are also good marketers of their own product, with several species used in the construction of their houses which are adjacent to the forest — *C. macrocarpa* for external weather boarding, furniture, and internal panelling; *E. regnans* and *E. saligna* for panelling, flooring, and furniture; blackwood for panelling; and *C. lusitanica* for furniture.

So far this operation has been very successful, helped by being on a good forest site with good access and a strong local market. A major factor has been starting small and gradually building the operation. Another key aspect appears to be the separation of their operation into two different companies — Tai Tane Forests grows the wood then sells logs to Marlborough Timbers Ltd which mills them and sells the sawn timber in the burgeoning local market. Logs, mostly *C. macrocarpa* so far, are currently sold for \$100/m^3 log measure; *C. macrocarpa* beams milled from 18-year-old 40-cm stems have fetched as much as \$1200/m^3 sawn when sold to local builders, with small quantities of clearwood sold for a premium over this.

Another potential key to success is the search for specialist local markets and to this end they have already begun to work with local vineyards producing specialist wood products. In the long term, however, their main success may lie with the production of ground-durable poles for vineyard use, thus allowing the high usage of treated timber poles to be phased out.

THE FUTURE

It is perhaps too soon to predict how this operation will develop. If it is to become a continuous cover forest, at least 50 years will need to elapse before the future is clear. However, at this early stage several paths are possible, depending upon the regenerative potential of the forest which will only become clear as it grows, and how this, and any future plantings, are managed.

The Millens already know that if they were to start over again they would do some things differently. Due to the canker problem with *C. macrocarpa*, only selected clones of this and more *C. lusitanica* would have been planted. *Eucalyptus regnans* would not have been planted, but rather stringybark eucalypts and other ground-durable species that are showing promise from more recent plantings. Blackwood would be planted only in small single-species stands, not in mixtures with eucalypts.

APPENDIX 4

GLOSSARY

Advanced regeneration (syn. advanced growth)	Young trees which have established naturally before clearfelling or uneven-aged fellings have begun. Can be seedlings, saplings, or poles.
Allelopathic	The inherent ability of some plants to excrete substances which prevent other species competing for space and resources (e.g., black walnut).
Basal Area	The area of the cross-section of a tree stem at breast height (1.4 m) including bark. Usually expressed as m^2/ha.
Biodiversity	The numbers and distribution of all flora and fauna existing on the land at any point in time.
Biomass	The total volume, at a given time, of living organisms of one or more species per unit area.
Clearcutting /clearfelling	The removal of the entire standing crop (Plate 2 No.5).
Climax forest	An association of trees and other plants that will prevail in the absence of disturbance; or the culmination of a successional cycle.
Close to nature forestry (syn. CCF)	See near-natural forestry.
Conversion	A change from one silvicultural system to another or from one set of species to another.
Corduroy	Road or track construction method which involves laying small logs, branches, etc. across a road to provide a firm surface. Usually employed on swampy or wet land.
Coupe	An area of forest felled at one time; may or may not be synonymous with stand.
Crown thinning	See thinning from above
Dauerwald (syn. CCF)	A term coined by German forester Alfred Möller. Translates as continuous forest which is a forest treated so that the soil is never exposed — the forest cover being continuously maintained over every part of the area.
Ecological forestry	Managing forests according to the appropriate ecological processes for that forest.
Economic selection	Selection of trees to be felled on the basis of their nett exploitation value; i.e., they have reached a certain size or have greatest value.
Even-aged	A forest management system that produces a stand composed of trees all about the same age.
Forest	A plant community, predominantly trees, growing closely together. A forest managed for timber is a specific area which will normally be made up of stands of trees varying in age and composition.
Frame trees	Frame trees or future trees are the framework upon which the forest is constructed. 40 to 80 dominant trees/ha are selected as frame trees because they are well formed, vigorous, stable, have high timber value, and are reasonably evenly distributed. They should be identified at an early stage as trees having the ability to dominate the stand. They should be retained at successive harvests and should remain until they reach a predetermined target diameter. When one is removed, an adjacent sub-dominant is chosen to take its place. The use of frame trees applies mainly to forests managed under single-tree and small-group selection systems. Where larger felling coupes are required — as with some of the *Nothofagus* spp. — the situation can vary. For example, frame trees could still be used for red beech coupes but there would be fewer of them, say 10–20 trees/ha. In Europe and U.K. the stability of individual frame tees is determined by calculating their height/diameter ratio (Tree height [m] / Tree dbh [m]), or the crown ratio (Green crown length [m] / Tree height [m]). For the first, a tree is assessed as stable if the ratio is <80 and for the second >0.50. Before this approach can be used with confidence in New Zealand, these parameters need to be thoroughly tested, especially with indigenous species. (See under Frame trees page 18)
Gley	A grey clay soil formed under water-logged conditions.
Group selection	An uneven-aged regeneration method removing small groups of trees and

	which favours the regeneration of shade-tolerant seedlings or species (Plate 1 No.2).
Group shelterwood	The leaving of shelter trees in group felling coupes to provide seed/shelter for the new crop.
Growing stock	All trees in a stand that have, or will have, market potential. Generally expressed as stems, basal area, or volume per unit area.
High grading (USA)	An exploitative logging practice which removes only the best, most valuable, and most accessible stems (i.e., NZ indigenous forest practice until about 1960).
Inventory	A periodic measurement of the growing stock in a forest or stand by species, age or size, top height, increment, stem quality, etc.
Irregular shelterwood	Compromise between uniform, group, and selection systems whereby a succession of regeneration fellings is undertaken which induces an indefinite regeneration period and produces young crops which are essentially uneven-aged. An important system in tropical forests and may be applicable to NZ northern hardwood / conifer forests.
Light-demanding	Refers to a species' light requirements. Some species (e.g., *Pinus radiata*) require high light levels throughout their entire life span. Others (e.g., *Agathis australis*) are shade-tolerant when young but light-demanding from sapling stage (cf. shade-tolerant).
Low-impact harvesting (syn. CCF)	See "positive impact forestry"
Mast	The seed of trees such as beech, oak, and sometimes pine; especially where the seed provides food for animals.
Mesic	Sites or habitats characterized by intermediate moisture conditions — i.e. neither decidedly wet (hygric) nor decidedly dry (xeric).
Monoculture	Tree crop of a single species, generally even-aged.
Near-natural forestry	Silviculture based upon the ecology of the natural indigenous forest.
Normal forest	A forest which has reached and maintains a practically attainable degree of perfection in all its parts, for the continued satisfaction of the objectives of management. This is the classic concept against which an actual forest may be compared.
Nurse crop	A crop of trees or shrubs established on an open site to protect a more economic crop from wind, sun, frost, etc. Usually they die out or are thinned out when the main crop is established but occasionally yield intermediate harvest(s) (Plate 3 No.10).
Old crop	A mature forest community which has reached a steady state or climax (syn old growth).
Patch felling	A modification of the clearfelling system which has large patches of forest (1–20 ha) felled while the areas around it are left untouched until the first patch has begun to regenerate (Plate 2 No.8).
Plantation	A forest crop or stand raised artificially, either by sowing or planting.
Plenterwald (syn. CCF)	The creation, conservation, and utilisation of mixed forest stands of uneven age, by harvesting single trees as they reach maturity. Some smaller trees may also be harvested to keep the composition and structure of the forests as close as possible to the reverse "J" curve distribution. The system works well in forests containing shade-tolerant tree species but becomes much more difficult for light-demanding species.
Positive impact forestry	Recognizes forestry's potential to achieve sustainable benefits while avoiding or mitigating negative impacts.
Rapid inventory	Any quick and low cost method of assessing Basal Area and species composition of a stand.
Regeneration	The natural or artificial renewal of a stand (usually the former) from seed or by planting. The young crop is also referred to as regeneration (Plate 8 No.27).
Reverse (inverse) "J" curve	A sustainable diameter distribution which is characterized by a constant quotient called "q" between the number of successive diameter classes. Part of the geometric series — a, aq, aq^2, aq^3....... where a = the number of stems in the largest diameter class and q the ratio of the geometric series. q represents the increase in the number

	of stems as the diameter decreases and normally ranges between 1 and 2. See example Appendices 3b and 3c. Is best derived over an area the size of a forest subdivision or a group of similar stands. Is meaningless if applied over the whole forest, unless it is homogeneous, and individual stands are usually too small.
Rotation	The length of time taken for an even aged stand to reach the point of financial maturity.
Scarification	Loosening the topsoil of the forest floor and mixing lightly with the litter to provide a suitable medium for seed germination and seedling establishment in the natural regeneration process. In some contexts (e.g., beech) involves exposing mineral soil.
Selection forestry	Felling and regeneration are not confined to certain parts of the forest but are distributed all over it, usually removing individual trees or small groups of trees. The term is sometimes degenerated to mean high grading.
Shade persistent (syn. shade enduring)	A tree (especially as a seedling or sapling) which can live under the forest canopy for a considerable period, usually exhibiting minimal growth.
Shade-tolerant	A species which can grow at the lower light levels found beneath a forest canopy.
Shake	Longitudinal fissures in the wood caused by stresses which make the wood fibres separate along the grain. These often split on felling.
Shelterwood system	A management system which uses a series of group or strip felling operations to open the stand and stimulate natural reproduction on the felled areas. It is intermediate between selection and clearcutting systems. For full details see Matthews (1989).
Single-tree selection	The felling of individual trees in an uneven aged forest. Used in selection forestry (Plate 3 No.11).
Stand	A community of trees which forms the primary management unit of a forest. Usually defined as an area that is relatively uniform in species composition and/or structure to distinguish it from surrounding areas (see coupe).
Strata	Division of a forest stand into horizontal layers which can be as many as four — ground, shrub, sub-dominant, and dominant. In some forest types the strata are very evident; in others much less so and the layering is somewhat artificial (Plate 8 No.31).
Strip felling	Clear cutting in the form of narrow strips which allows enough light on to the felled area to permit regeneration.
Sustainable (ity)	An ecosystem's capacity to provide benefits in perpetuity without compromising its integrity. The sustained yield of a forest or stand is the annual or periodic cut which does not exceed the increment of the forest or stand.
Thinning from above	Also referred to as crown thinning, which favours the most promising (but not necessarily dominant) stems by removing adjacent trees from any canopy class that are interfering with the selected trees.
Tree selection areas	Based upon the forest structure of areas delineated by geographic features such as waterways, roads, and tracks. Tree selection involves comparison of the current forest structure (by species diameter class) to that of a "normal" diameter distribution (reverse "J" curve) for the forest type. The harvest is based on single-tree and group selection which moves the diameter class distribution towards that of a normal forest.
Two-storied high forest	A forest comprising an upper and lower storey of trees growing in intimate mixture. There are usually two species involved — one light-demanding and the other shade-tolerant. Sometimes the forest may be managed as even-aged/clearfell, and sometimes as CCF.
Uneven aged (syn. all aged)	Management of a forest stand growing a wide range of species, ages and sizes (Plate 3 No.12).
Uniform system	An abbreviation of "shelter-wood uniform system" is a regular opening of the canopy for even aged regeneration.
Xeric	Sites or habitats characterized by dry conditions.

References: McEvoy (2004); Ford-Robertson (1983); Matthews (1989); Halkett (1984); Mason & Kerr (2004); Anon (2007).

APPENDIX 5

STANDARD BOTANICAL AND COMMON NAMES OF SPECIES IN THIS HANDBOOK

Acacia melanoxylon	blackwood / Tasmanian blackwood
Acer platanoides	Norway maple
Acer pseudoplatanus	sycamore
Agathis australis	kauri
Agathis macrophylla	Fijian kauri
Agathis robusta	kauri pine / Queensland kauri
Alectryon excelsus	titoki
Alnus cordata	Italian alder
Alnus glutinosa	common alder
Alnus incana	grey alder
Alnus rubra	red alder
Araucaria angustifolia	párana pine
Araucaria araucana	monkey puzzle / Chile pine
Araucaria cunninghamii	hoop pine
Araucaria heterophylla	Norfolk pine
Beilschmiedia tarairi	taraire
Beilschmiedia tawa	tawa
Betula pendula	silver birch
Blechnum discolor	crown fern
Blechnum novae-zelandiae	kio kio
Castanea sativa	sweet chestnut
Cedrus deodara	Indian cedar
Chamaecyparis lawsoniana	Lawson cypress / Port Orford cedar
Chamaecytisus palmensis	tagasaste
Coprosma robusta	karamu
Cortaderia jubata	pampas grass
Cortaderia selloana	pampas grass
Cryptomeria japonica	Japanese cedar / sugi
Cunninghamia lanceolata	Chinese fir
× *Cupressocyparis leylandii* "Leighton Green"	Leighton green
× *Cupressocyparis ovensii*	Ovens cypress
Cupressus lusitanica	Mexican cypress
Cupressus macrocarpa	Monterey cypress/macrocarpa
Cyathea medullaris	mamaku
Cytisus scoparius	broom
Dacrycarpus dacrydioides	kahikatea
Dacrydium cupressinum	rimu
Dysoxylum spectabile	kohekohe
Elaeocarpus dentatus	hinau
Eucalyptus botryoides	southern mahogany
Eucalyptus fastigata	brown barrel
Eucalyptus fraxinoides	white mountain ash
Eucalyptus maculata	spotted gum
Eucalyptus microcorys	tallow wood
Eucalyptus muelleriana	yellow stringybark
Eucalyptus obliqua	messmate stringybark
Eucalyptus pilularis	blackbutt
Eucalyptus regnans	mountain ash
Eucalyptus saligna	Sydney blue gum
Fagus sylvatica	beech
Fraxinus excelsior	ash
Juglans nigra	black walnut
Juniperus virginiana	eastern red cedar / red juniper
Knightia excelsa	rewarewa
Kunzea ericoides	kanuka
Larix decidua	larch / European larch
Laurelia novae-zelandiae	pukatea
Libocedrus bidwillii	pahautea
Liquidambar stryraciflua	sweet gum / liquidamber
Liriodendron tulipifera	tulip tree / yellow poplar
Litsea calicaris	mangeao
Melicytus ramiflorus	mahoe / whitey-wood
Metrosideros excelsa	pohutukawa
Metrosideros robusta	northern rata
Metrosideros umbellata	southern rata
Nestegis cunninghamii	black maire
Nothofagus fusca	red beech
Nothofagus menziesii	silver beech
Nothofagus solandri var. *cliffortioides*	mountain beech
Nothofagus solandri var. *solandri*	black beech
Nothofagus truncata	hard beech
Paulownia tomentosa	kiri / princess tree
Phyllocladus trichomanoides	tanekaha
Picea abies	Norway spruce
Picea sitchensis	Sitka spruce
Pinus elliottii	slash pine
Pinus patula	Mexican pine
Pinus radiata	radiata pine / Monterey pine
Pinus strobus	eastern white pine/ Weymouth pine
Pittosporum eugenioides	tarata / lemonwood
Plagianthus regius	ribbonwood
Podocarpus hallii	Hall's totara
Podocarpus totara	Totara
Populus spp.	poplar
Prumnopitys ferruginea	miro
Prumnopitys taxifolia	matai
Prunus avium	gean / European cherry
Prunus serotina	black cherry
Pseudotsuga menziesii	Douglas fir
Quercus robur	European oak
Quercus rubra	red oak
Robinia pseudoacacia	black locust
Rubus fruticosus	blackberry
Salix species	willow
Sequoia sempervirens	coastal redwood
Solanum mauritianum	woolly nightshade
Syncarpia glomulifera	turpentine
Thuja plicata	western red cedar
Ulex europaeus	gorse
Vitex lucens	puriri
Weinmannia racemosa	kamahi
Weinmannia silvicola	towai

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