An Evaluation of the Production and Profitability of Alternative Management Regimes for *Pinus radiata* on a High Fertility Site.

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Abstract

Keywords: STANDPAK, inventory, basal area increment, configuration, silviculture, pruning, thinning, regime.

Conversion of farmland to forestry is occurring at the rate of approximately 60,000ha/annum, much of it on hill country sheep and beef properties. The potential productivity of ex farm sites is high, mainly due to improved soil fertility but may produce trees with defects such as excessive branching, large branches and stem malformations. Adapting silvicultural practices to suit plantations on high fertility sites is necessary to effectively utilise this potential. However, many of the tools available for planning and assessing alternative silvicultural options in *Pinus radiata* stands have limitations for farm sites. This study utilises a 12.5ha stand of *Pinus radiata* established in 1973 on a Manawatu hill country sheep and beef property. Currently 'Tuapaka' has 31.3ha of *Pinus radiata* occupying land use capability class VI and VII. Of this total, 12.5ha is nearing maturity, while remaining areas are now reaching a stage where decisions on silvicultural management are necessary. The growth modelling system, STANDPAK, was used as an aid for developing and evaluating silvicultural options on Tuapaka.

Existing *Pinus radiata* growth models have been primarily derived from traditional forest site data. They can be utilised for simulating growth on ex farm sites but will generally provide more accurate predictions of growth and yield if they are configured with local growth data. The EARLY and NAPIRAD growth models are recommended for simulating the growth of *Pinus radiata* on farm sites and formed the basis for the simulation of the Tuapaka stand. Inventory data, including diameter at breast height, mean crop height, and stocking were collected from the existing 12.5ha stand and used to configure these growth models and other STANDPAK components.

Site index at Tuapaka was found to be 23m, with a high basal area increment potential. The best STANDPAK configuration combined the growth models EARLY (high +20% basal area increment) and NAPIRAD (switched at mean top height 18m). The results from this configuration predicted basal area to within 6% of the field estimate. These configurations were used to simulate and evaluate the growth of a new stand (at the 1ha level) for both clearwood and framing regimes. The combined influence of low site index and high basal area increment created problems associated with maintaining a target diameter over stubs (DOS) while utilising an acceptable number of pruning lifts. The required number of pruning lifts to achieve a 6.0m pruned height was able to be manipulated by delaying thinning, reducing the green crown length (CRL) at the first and second lifts, and maintaining a high ratio of unpruned trees through to thinning.

Net present value (NPV) was primarily used as the selection criteria to determine the best regimes, because it reflects the final harvest revenues and associated silvicultural costs. The most profitable regime required a 3 lift pruning schedule. This regime provided the best compromise between final harvest value and silvicultural costs and was achieved by severe early pruning (CRL of 2.0m and 2.2m), delayed thinning, and maintaining a high ratio of unpruned to pruned trees. Clearwood regimes were more profitable than the framing regimes because of a higher average timber value which more than compensated for increased silvicultural costs and reduced log volume. The clearwood regime produced a final merchantable volume of $698m^3$/ha, of which 37% graded in the higher value pruned log class. This regime had a pre tax net revenue of $39,500/ha and an NPV of $2,681/ha (8% discount rate). In contrast, the best framing regime produced a merchantable volume of $787m^3$/ha, a net revenue of $18,800/ha, and a NPV of $1,100/ha.

The best clearwood and framing regime were subjected to economic analysis at the estate level (31.3ha) to determine the best silvicultural options for existing and future stands on Tuapaka. The clearwood regime was the most profitable, having a pre tax IRR of 9.1%, compared with 7.6% for the framing regime. These returns are likely to exceed the potential returns from farming, particularly on steep hill country.

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Chapter One: Introduction

1.1 INTRODUCTION

Forestry is a well established primary industry and a major contributor to New Zealand's total export earnings. The forest industry contributed $2,574 million (12.8% of total) in export earnings for the year ended 1995, third after dairy ($2,798 million) and meat ($2,698 million) (Anon. 1996a).

Based on global supply and demand forecasts the market outlook for New Zealand forest products is positive. Consumers of forest products are increasingly looking toward sustainable plantations. This, coupled with New Zealand's exceptional growing conditions, especially for *Pinus radiata*, makes forestry an attractive investment option.

Future expansion of the area in plantation forestry will be based on farmland. In 1996 60,000ha was converted. Like agriculture, forestry cannot economically justify expanding further away from service and processing facilities, onto steeper, less fertile land.

The forest industry has become increasingly popular as an investment option for land owners and private investors for a number of reasons, including:

- Decreases in real returns from pastoral farming, especially hill country sheep and beef.
- Pastoral farmers recognising the need for diversification.
- The prominence of New Zealand land issues, in particular sustainability.
- The current investment opportunities, taxation benefits, and levels of return offered from forestry projects in comparison to other investment options.

Given the level of interest in forestry investment and diversification, there is a need to evaluate the benefits of converting marginal pastoral land to *Pinus radiata*. The potential productivity of farm sites is high, mainly due to the high fertility associated with these sites. However, this can often result in poor tree quality due to excessive branching, large branches and stem defects. There is also a limitation of the tools used for planning and evaluating the growth of timber on these sites.

Adapting silvicultural practices to suit plantations on high fertiltiy sites will be an important factor for effectively utilising the potential of these sites.

1.2 STUDY OBJECTIVES

The current situation and outlook for hill country sheep and beef farming is one of reduced viability. Many farmers are looking to, or have already diversified into alternative forms of production, including dairy, deer, and forestry in particular. In these situations there is a need to predict and evaluate the benefits of forestry conversion. Often the problems associated with taking on a forestry project are the losses in income from the land in trees and the funds and/or time required for silvicultural management in the project. Forestry diversification requires a long term commitment before harvest revenues are realised. The time scale of the investment means that very important and accurate decisions have to be made early on that affect the outcome of the investment.

This research project will use a Massey University hill country sheep and beef property as an example for investigating the issues associated with forestry diversification on farmland. Currently, 31.3ha of *Pinus radiata* has been planted on the Tuapaka property, of which 12.5ha is nearing maturity. The remaining trees are now reaching a stage where decisions on silvicultural management are necessary. The objectives for this research include the following:

- Collect accurate mensuration data through an intense forest inventory from an existing *Pinus radiata* stand grown on Tuapaka, including:
    - Mean crop height (MCH);
    - Diameter at breast height (DBH); and
    - Stocking (stems/ha).
- Use this information to configure existing growth models and components of the Forest Research Institutes stand evaluation software package STANDPAK.

- Use the STANDPAK configurations to simulate the growth of a new stand under two different management regimes, including:
    - Clearwood (pruned); and
    - Framing (unpruned).
- 'Optimise' the silviculture for each regime using the following indicators:
    - Net harvest revenue;
    - Net present value (NPV); and
    - Internal rate of return (IRR).
- Analyse the economic benefits of implementing these two regimes at the estate level, and determine the best silvicultural actions for current and future forestry diversification on Tuapaka.

This thesis has been written in six chapters. Chapter Two will introduce the history and development of New Zealand forestry, in particular the development of silvicultural regimes for high quality sites. The development and use of computer based stand modelling and discounted cashflow analysis techniques are also discussed.

Chapter Three outlines the necessary methodology and the results of the stand inventory and the resultant configuration of the stand evaluation package STANDPAK. In Chapter Four these configurations are used to develop appropriate silvicultural regimes suitable for the Tuapaka site conditions. In Chapter Five the selected regimes are then evaluated at the estate level and the best silvicultural option chosen. Each of these chapters involves a description of the method, and a presentation and discussion of the results and findings.

Chapter Six summarises and discusses the major findings of the research in relation to the stated objectives. The conclusions are also presented in this chapter

Chapter Two: Literature Review

2.1 INTRODUCTION

Forestry has always been a dominant New Zealand landuse. Currently 29% of New Zealand is covered in forest, natural forest contributes 24% (6.4 million ha) and planted production forest 5% (1.5 million ha). Radiata pine is the dominant species accounting for 91% (1.34 million ha) of planted production forest, followed by Douglas-fir with 5% (66,000 ha)(Anon. 1996a).

The New Zealand environment provides excellent growing conditions for radiata pine. Markets for forest products are well established and scientific research and development have played key roles in New Zealand's forest industry (MacLaren, 1993).

2.2 NEW ZEALAND TIMBER PRODUCTION

2.2.1 Current Situation

New Zealand was founded on several extractive industries, particularly coal, gold and timber (Horton, 1995). Since early European settlement New Zealand's forest industry has gone through significant changes. The majority of timber products are now produced from planted forests, with only small controlled volumes coming from natural forest.

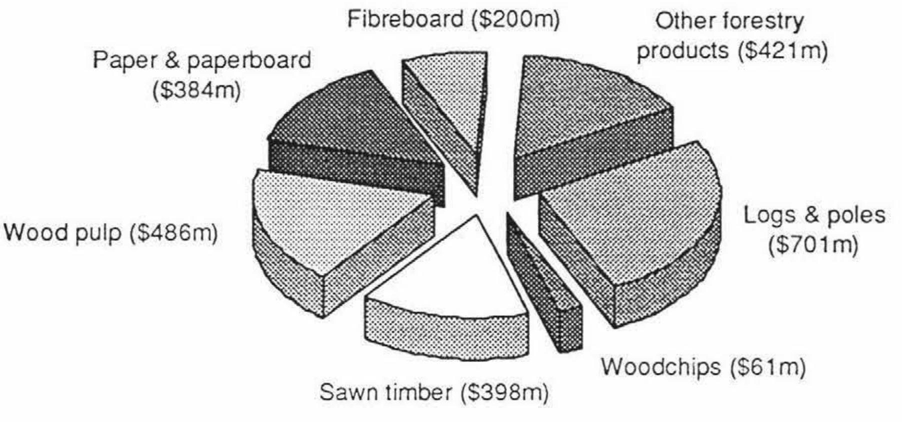
New Zealand export a range of forest products, contributing $2651 million in export revenue for the year ended March 1996 (Figure 2.1). The major export destinations are countries of the Pacific Rim, including Japan (29.3% of the total share), Australia (27.3%) and Korea (17.5%) (Anon. 1996a). If an increasing dependence is placed on plantation forests there is likely to be an associated increase in price for it's products. This would be a similar situation to the log price increases associated with the first half of 1993. MacLaren (1993), attributes this to five factors:

- North American timber reserves placed under increasing conservation pressures.
- Bans on hardwood logging and exports from Sabah and Sarawak, in line with recommendations from the International Tropical Timber Organisation.
- State forest subsidies removed from Russian log exports.

- Substitution for radiata pine as other species became too expensive.

- Depreciation of the New Zealand dollar.

Figure 2.1: Exports of forestry products by value for the year ended 31 March 1996.



[Source: Anon. 1996a].

However, in a supply and demand situation as price increases for a commodity additional supplies and/or substitutes are expected to be developed or found. This is a similar situation that is responsible for the log price slump experienced in the second half of 1993. MacLaren (1993), attributed this to:

- An oversupply of logs to certain markets, especially Korea.

- A substitution away from wood products.

The current market position is one of over-supply. Substantial supplies of logs and lumber are currently available to the Pacific Rim from countries such as Russia, Venezuela and Papua New Guinea. However, the long-term sustainability and recovery costs of these resources are questionable (Hipkins, 1995).

2.2.2 Future Outlook

Forestry investment has been consistently profitable for several decades, and there continues to be a long-term trend of increases in the real global prices for wood of between 1-2% per annum (MacLaren, 1993). The global annual demand for all wood is predicted to increase from 3.43 to

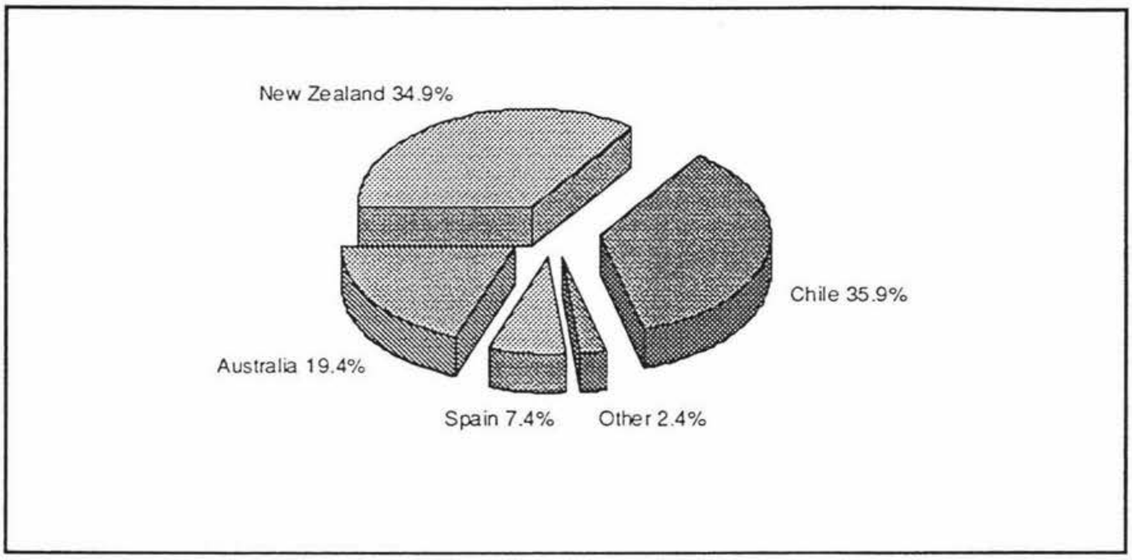
5.07 billion m^3 by 2010. This increase is largely dependant on an increasing population, and to a lesser extent, an increasing per capita consumption. Circumstantial evidence suggests that an improvement in living standards results in a declining population growth. However, an improvement in personal wealth is also associated with an increasing demand for industrial wood (Gorman, 1995).

New Zealand appears well positioned to take advantage of growing world demand for quality softwood. A growing world population and increasing restrictions on the decreasing timber supply from traditional sources are likely to increase the dependence on plantation forests (Gorman, 1995).

An increased timber price (refer Section 2.2.1) will mean remote timber resources can then become viable for extraction. However, the long-term sustainability of these resources and the cost at which they are being obtained are questionable in comparison with managed plantation forests. Wood substitutes also have problems, including a requirement for large amounts of energy for production, and problems created with CO_2 emissions (Gorman, 1995). For example, steel studs require 9 times as much energy to produce than wooden studs and concrete floors 21 times as much energy as wooden floors. So, unless there is a breakthrough in the production of cheaper environmentally acceptable energy, large scale substitution away from wooden products seems unlikely (Gorman, 1995; Sutton, 1995).

New Zealand was one of the first countries to establish a plantation resource before it was required. It is now in a position where it's exportable surplus timber comes from sustainably managed plantation forests with internationally acceptable environmental standards (Gorman, 1995). Radiata is New Zealand's dominant plantation species and has a proven management capability and market record (Sutton, 1995). The global radiata pine estate is approximately 3.8 million ha, about 35% of this is in New Zealand (Figure 2.2). As this forest resource matures, the rapidly increasing harvest levels from 1996 will require trees to be exported in either processed or unprocessed form. New Zealand's domestic consumption of forest products, already one of the highest in the world on a per capita basis, offers little opportunity for further growth (Hipkins, 1995). It would then appear that New Zealand's best opportunity to capitalise on it's forest resource is to produce value added products for export.

Figure 2.2: Global distribution of the radiata forest estate.



[Source: Anon. 1996a].

New Zealand has superior growing conditions for it's softwood species in comparison with other competing countries (Anon. 1996a). Well tended radiata pine stands producing high quality clearwood (knot-free wood) offer New Zealand it's best marketing opportunity (Sutton, 1995). Current global clearwood reserves are shrinking and radiata is an acceptable substitute for many uses traditionally reserved for hardwoods (MacLaren, 1993).

2.3 HISTORY OF NEW ZEALAND FORESTRY

2.3.1 Early European Settlement

Around 1500 years ago about three-quarters of New Zealand was covered in forests. Over the next 1000 years one third of this was cleared by the early Maori. About 150 years ago another third was cleared during European colonisation (Purey-Cust & Hammond, 1995).

During European settlement much of New Zealand's early forestry clearance was wasteful. The primary importance of this clearance was for settlement and agricultural development. The forest cover was perceived to be inexhaustible, and considered a hindrance to progress (Roche, 1987).

Wood was a basic and abundant raw material in colonial New Zealand. It was principally used for building and construction materials (Roche, 1990), and provided an income for early settlers before their farms became financially viable (Roche, 1987). The settlers recognised the potential to utilise this vast timber resource, and sawmilling quickly swept through many forested areas (Roche, 1990).

In the 1840's timber licences were introduced in order to regulate the resource. This was New Zealand's first attempt at forest management. The timber licensing was relatively unsuccessful, due to the abundance of timber and the lack of control on regulation (Roche, 1987). Concerns however, began to mount over the future wood supply and the depletion of natural forests at a substantial rate as early as the 1860's and 1870's. It was recognised that New Zealand would not be self-sufficient in it's production of timber, identifying a need for future plantings of principally exotic species.

2.3.2 Development of Exotic Forestry

In 1913 the Government set up a Royal Commission on Forestry in response to increasing public concerns for the future of the natural forest and the national timber supply. The commission identified a timber shortage and a need for future afforestation from large-scale plantings of introduced species. In response to this a State Forest Service was established in 1919 and the recommendations put into effect. Radiata pine was pushed as the major species for planting. It's building and packaging properties were recognised and were seen as the chief needs of the of the colony at the time (Purey-Cust & Hammond, 1995). A goal of a 125,000ha plantation estate was targeted in order to meet predicted New Zealand timber demands. The majority of this estate was planted on the pumice plateau of the central North Island, this area was largely a failure to farming because of a cobalt deficiency (Roche, 1987).

The self sufficiency goal was exceeded and extended to produce an exportable surplus. After 1935 the first planting boom slowed down and the emphasis placed on developing and establishing markets for the planted forest resource. However, natural timber still dominated the market, it was generally cheaper and of higher quality than the early plantation timber. To combat this the Forestry Service established demonstration sawmills in order to show what could be done with this new timber resource. This was very successful and the private sector began to increase it's sawn timber cut from plantation forests (Purey-Cust & Hammond, 1995). This was then followed by the development of other radiata products, particularly pulp, plywood, fibreboard and particleboard. By the late 1950's export markets had been established for these products (Bunn, 1979).

During the 1960's a second planting boom occurred in response to a Forest Service review. It identified a temporary export surplus based on the first planting boom, turning into a supply deficit by the end of the century (Purey-Cust & Hammond, 1995). This boom was again State promoted but differed from the first. The anticipated scale was much larger, the target was to plant 800,000 ha by 2050 to give a 1.2 million ha plantation forest estate. The plantings were to be continued over a longer time frame than a decade in order to give a better age-class distribution (Roche, 1990). Radiata pine accounted for nearly all the new plantings, and were much wider spread to give a better regional distribution, contrary to the first boom which was concentrated in the Bay of Plenty (Roche, 1990, Purey-Cust & Hammond, 1995).

In order to meet the planting target annual plantings needed to treble to around 12,500 ha per year. It was envisaged that the private sector would take on half of the required plantings. This group consisted of mainly farmers, who were at first sceptical and in some instances anti forestry (Roche, 1990). However, there was a recognition of the potential export contribution from forest products that had an economically viable future. For the first time forestry was recognised as a legitimate export-orientated land use (Purey-Cust & Hammond, 1995). This came at a time when national indicative planning goals were to reduce New Zealand's dependence on agricultural products sold in a few overseas markets (Roche,1990).

Incentive schemes were put in place to assist farmers with tree plantings and their interests initially took form of woodlots, later more expansive and integrated two-tier farm-forestry schemes were developed (Roche, 1990). By 1973 new plantings had risen to 40,000 ha per year and surpassed the target plantation of 1 million ha in 1984 (Purey-Cust & Hammond, 1995).

Plantings slowed during the late 1980's, with the introduction of unfavourable tax regimes for forestry. Natural forests were further wound down to a very low level of cut that complied with approved sustained yield management principles (Beveridge & Herbert, 1995). In 1991 the tax regime was rectified, improvements occurred in market prices, and the recognition of the value in forestry resulted in a third planting boom (Purey-Cust & Hammond, 1995). This boom has been taken up largely by small, private investors and expanded on to pastoral land (MacLaren, 1993). It is estimated that approximately 70,000 ha of former sheep and beef land have been planted in forestry in each of the last 3 years (Anon. 1995a).

2.3.3 The Development of Silvicultural Regimes

The trees of the first planting boom, referred to as the "old crop", had very little thinning carried out on it (Hinds, 1962). The trees were planted as densely as 3050 stems per hectare (sph) in the state sector and 1680sph in the larger scale private sector and were largely left untended or tended so belatedly that there was little effect on grade out turn (Bunn, 1981). Hinds (1962), contributes the minimal tending to a lack of markets for small wood, the plentiful supplies of high quality indigenous wood, the lack of appreciation of just how vigorous radiata pine was, the widespread theory that the species "thinned itself", but most of all the fact that "planters oi forests are usually reluctant to thin their own handiwork with any severity".

Since the 1960s, New Zealand forest management has generally trended toward an intensive style of silviculture, with the aim of producing an end product for a specific market. This has resulted in initial spacings becoming wider, earlier and heavier thinnings and timely prunings (Bun, 1981). Increasingly, production thinning was avoided, unless an obvious market existed, and currently, over half of New Zealand's estate is pruned to around 4m or more. The clearwood regimes were beginning to gain popularity (MacLaren & Knowles, 1995).

The first significant influences on forest management occurred when New Zealand began the utilisation of the "old crop". In 1939 commercial pulping of radiata pine began, the principal lesson from this was the unexpectedly quality of the wood (Hinds, 1962). However, timber from many of the native species contained a higher proportion of "clears" and untended radiata always contained knots (James, 1990). Although timber grading rules were devised in response to this, the links between silviculture and wood quality were not fully appreciated at this time.

James (1990), records another significant influence on silviculture in the 1940s, large scale mortality of the overcrowded stands resulting from attacks by the wood wasp *Sirex noctilio*. This mortality took the form of thinning, removing suppressed sub-dominants. Superior survival of the dominants resulted in response to a larger growing space. This identified the potential loss of increment that could have been captured by the crop trees. The theory that radiata "thins itself" lost ground (Hinds, 1962).

With little experience to guide them, New Zealand foresters set about actively designing silvicultural regimes for their species (James, 1990).

2.3.3.1 The First Tending Regimes

James (1990), cites Craib (1939), as being influential in forming opinions on silviculture in New Zealand. Craib worked on the thinning, pruning, and management of *Pinus* species in South Africa. He studied the relationships of height, diameter, and age, and then discussed how best to define thinning (by diameter, height, or age). He discussed rotation length and the effect of thinning on diameter, total volume, and merchantable yield. Pruning was also analysed in detail, particularly in relation to silviculture, utilisation management, and economics. Craib produced silvicultural proposals based on producing "neither the greatest volume nor the largest sizes in a given time but the production of material which will (best) fit the market (while also) yielding the greatest revenue (to the forest owner)".

Ure (1949), designed one of the first regimes for treating the regenerated second rotation crops of the Kaingaroa Forest. He prescribed an early thinning to reduce the crop stocking to 2500sph, followed by three latter thinnings, two with yield and clearfelling at height 37m or approximately 30 years. Ure suggested that "low pruning" take place at a 10m height, and that a "high pruning" should be timed appropriately only if enhanced returns are assured for the clears produced. These proposals were modified in 1953 so that the schedule contained only one thinning with yield (Penistan, 1960).

Foresters quickly recognised the manipulation of silviculture as a means of producing quality timber. Brown (1961) derived a new silvicultural regime with the objective of producing the maximum volume of high quality sawlogs and veneer logs. It involved five pruning lifts to 10m and four thinning operations. Brown's regime marked another turning point in New Zealand silviculture. It was a complicated regime involving nine operations, the trend after this point was to simplify and reduce the number of silvicultural operations (James, 1990).

Throughout the 1950s and early 1960s many variations of tending schedules were proposed. Almost all included at least one thin to waste and one production thinning, and differed in the timing and intensity of operation. New Zealand was beginning to lack clear objectives in respect to silvicultural developments. Was the prime objective maximum volume, clearwood, structural wood or maximum profit? (James, 1990).

Bun (1981), noted that foresters were still orientated to obtaining the maximum volume of merchantable timber per hectare with the perception they will obtain a higher financial return. This objective conflicts the growth of the crop in the shortest time, requiring either production thinnings or the retention of too many crop trees at final harvest. Both of which are at the expense of the crop trees, reducing mean diameter growth at a scheduled harvest date and endangering investments in pruning.

Ure (1949), had recognised that there is a balance between costs and returns associated with silviculture, and during the 1960s the question of profitability became increasingly important. An alternative regime proposed by Fenton and Sutton (1968), marked another revolutionary stage of New Zealand silviculture. Their regime was potentially more profitable and was proposed to eliminate any production thinning. It was designed to fully utilise the growing capacity of radiata pine with much the same net yield as schedules of the time. Fenton and Sutton reasoned that the operations of the time "failed to increase realisable volumes, provide adequate intermediate returns (sufficient to compensate for the loss of growth on the final crop trees) or significantly improve selection and quality of the final crop trees". This initiated debate over the operation of production thinning, its necessity, economics throughout the rotation, effect on final crop values and the value of the wood produced. These arguments are still not entirely resolved today (James, 1990).

The regime involved planting 1500sph, three pruning lifts to 6.0m, two thinnings to waste (370sph at age 11 and 200sph final crop at age 16) and a reduced rotation by 10 years (clearfelled at age 25-26 years). The regime was targeted toward producing clearwood on high quality sites and were a somewhat, significant and controversial departure from practices of the time (James, 1990).

Fenton and Sutton (1968), began to establish links between pruning and thinning. They argued that the first two logs of each tree are the most valuable and silviculture should be directed at enhancing their value. An intense thinning regime gave desired increment growth in the butt logs at the expense of framing grades in higher logs. If a less intense thinning regime was employed there was an improvement in upper log quality at the expense of a restriction in the pruned butt size. Less intense thinnings were likely to result in an increased rotation length to achieve similar size of an intensive regime, hence a need for earlier thinning to lower stockings.

The adoption of this type of regime was at first slow and often treated with caution. However, difficulties with the thinnings market was leading to the adoption of this regime. However, management opted for much higher final crop stockings than the recommended 200sph with a range from 300 to 500sph (James *et al*, 1970).

Fenton and Sutton (1968) had posed that logically only a sufficient number of trees need to be planted to ensure required final crop stockings, especially if improved seedlings are used. Knowles and West (1988) prescribed a similar silvicultural regime to that of Fenton and Sutton's for high quality sites. Theirs involved a lower initial stocking of 800sph and reduced to a final crop stocking at the final prune.

Initial stocking levels have declined markedly over the past two decades and it is now normal to plant between 600-1000sph, unless a specialist crop is required e.g., pulp, poles or Christmas trees. Perhaps one of the biggest debates in New Zealand forestry is the question of final crop stocking. There are a large variation of silvicultural regimes in use and no one growing or space regime can be expected to accommodate all the variations in management objectives, markets, localities, sites and site qualities relevant to radiata pine forestry in New Zealand (MacLaren & Knowles, 1995).

2.3.4 The Development of Farm Forestry

During the second planting boom foresters had anticipated that farmer involvement would centre on the creation of farm woodlots. However, enthusiasts seeking to diversify farming activities and revenues developed a new concept of an integrated farm and forest unit consisting of a low density tree crop amidst a grazed pasture. These activities were largely led by Northland farmer Neil Barr, and saw the formation of the New Zealand Farm Forestry Association in the 1950s (Roche, 1990).

The clearwood regime with it's early thinning developed in the late 1960s (Fenton and Sutton, 1968) created an opportunity for grazing animals to utilise the understorey vegetation (Knowles, 1972). Knowles discusses further that early thinning to waste means that there are several years where the site is not fully occupied. This suggests the possibility of obtaining an intermediate return using forestry combined with agriculture to give a fuller utilisation from the land. As a result of this, a series of joint New Zealand Forestry Service and Ministry of Agriculture and Fisheries trials were set up. These trials aimed at measuring the effect of various final crop stockings of radiata pine on the understorey pasture and livestock. These were planted in 1971 (Whatawhata), 1973 and 1974 (Tikitere), 1974 (Invermay), 1975 and 1976 (Akatore), and Waratah, planted in 1967 was converted to an agroforestry trial in 1975 (Knowles, 1988).

2.4 FARM FORESTRY IN NEW ZEALAND

2.4.1 Introduction

The combination of forestry and pastoral farming has been publicised since at least the early 1970s (Knowles, 1972). There are two approaches to combine the activities, with animals grazing among a widely spaced tree crop, or to develop forestry and farming on separate areas but in a planned and intricate pattern (Director General of Forests, 1972 as cited in Knowles, 1972).

Agroforestry is the general term used to define the establishment of forestry on an existing pastoral site where grazing can continue after planting (MacLaren, 1993). In a broader sense the definition could include all land-use systems involving cropping or livestock and pasture, grown in association with trees (Knowles, 1990a).

MacLaren (1993), describes three prominent management regimes associated with agroforestry:

- trees on pasture - where trees are planted onto existing pastoral land;
- forest grazing - refers to the situation where animals are grazed in existing forests. This usually requires modifying the existing forest to enable grazing to take place, including fencing, supply of water and oversowing with pasture species;
- timberbelts - these are shelterbelts grown and managed either specifically for timber production or for the combination of shelter and timber benefits.

2.4.2 The Origins of Agroforestry

The early concepts involved with agroforestry were to utilise the grazing opportunities available, especially associated with clearwood regimes. It was often supposed that the revenue from understorey grazing was such that silviculture be aimed toward maximising this component (MacLaren, 1993).

Knowles (1972), and again Knowles and West (1988), advocate early thinnings to final crop stockings of around 200sph. The major difference in the application between forestry clearwood regimes and agroforestry were final crop stockings. Agroforestry regimes tended to favour a range of 100-200sph in contrast forestry regimes ranged between 200-300sph (Knowles, 1990a). However, agroforestry is no different from conventional forestry, except that it is at the extreme end of the fertility spectrum (MacLaren, 1993) (refer Section 2.4.3). The general principles of silviculture should not change because of the existence of grazing. In fact assessment of the Tikitere trials at tree age 19, with grazing taken into account, shows the 400sph treatment to be more profitable than the 200sph, which is more profitable than the 100sph. This trial demonstrates that higher optimum stockings are obtainable on more fertile land and that the revenues from grazing are not the most important advantage. The Tikitere trial highlighted that although lower tree stockings produced trees with a far greater individual diameter, this did not compensate in terms of volume per hectare for fewer trees or for the substantial loss in height. There is also an associated increase in wind damage related to tree stocking. The low stockings incurred major damage while the higher stockings were relatively unaffected (Knowles *et al*, 1992) (refer Table 2.1 and Table 2.2).

1,600ha inland hill country farm in the Gisborne East Coast district would lead to only a 7% decrease in stock numbers. Land use changes of this type are increasingly acceptable to farmers. It is recognised as being environmentally desirable, especially on marginal land, and will contribute to the diversification of financial risk (Anon. 1995a).

Perhaps one of the biggest advantages associated with growing *Pinus* radiata on farm sites is that the potential productivity is greater than for conventional forest sites. This is mainly due to the store of fertility that has accumulated from a grass and clover cover, and the application of superphosphate (MacLaren, 1993). Basal area increment (before stand height 18m) can be up to 40% higher on ex-pastoral sites, compared with conventional forestry sites (Knowles & West, 1986). Due to this higher fertility, higher tree stockings can be supported without the same restrictions in diameter growths (MacLaren, 1993).

MacLaren (1993), identifies further advantages associated with farm sites, in particular a managed understorey can:

- Stimulate tree growth through the reduction in woody weed competition and through nutrient recycling;
- Return a intermediary income from grazing;
- Considerably reduce the cost of silviculture, by reducing the difficulty of within stand movement during silvicultural operations;
- Almost eliminate fire risk; and
- Improve the appearance of the stand.

MacLaren further discusses the problems associated with growing radiata pine on these fertile sites. Often poor quality trees result because of excessive branching, large branches and stem defects, especially in the upper logs. Management can be modified to remedy this problem through tighter stockings that control branch size, tree form, and minimise wind damage. Pruning operations may have to be scheduled more often to effectively utilise the potential growths from farm sites (refer Sections 2.5.2.5 and 2.5.3).

Table 2.1: Effect of stocking density on tree growth at Tikitere (19 years).

Stocking (sph)	Mean DBH (cm)	Height (m)	Total Volume (m^3/ha)
50	67.1	24.4	116.4
100	64.5	26.2	236.5
200	53.8	28.0	380.0
400	44.9	32.1	624.5

[Source: Knowles, Hawke and MacLaren, 1992].

Table 2.2: Wind damage at Tikitere, 1988, age 15.

Stocking	%Breakage	Damaged trees /ha
50	41	20
100	40	40
200	36	76
400	24	99

[Source: Knowles, Hawke and MacLaren, 1992].

2.4.3 The Potential of Forestry on Farms

For farmers, small-scale forestry offers the potential for greater financial profitability and a measure of diversification. The removal of subsidies in 1985 and very low product returns has been especially hard on the sheep and beef farming sectors. This has seen an increasing number of conversions to forestry and dairying. Forestry expansion is estimated to have taken up 0.6 million ha and dairying 0.4 million ha since 1985 (Anon. 1995a).

The long run rate of return on capital for sheep and beef farms has been 3.3% (Anon. 1994a). The majority now are only achieving 1-2% return based on current monitoring data and are under severe financial pressure (Anon. 1995a). Sheep and beef farmers are left with few options for improving their financial position, these may include leasing the property, diversification and at the extreme selling the property. For hill country farming the diversification into cropping or other land uses would be very difficult, forestry offers an alternative and often complementary farm crop, instead of a competing land use.

Most hill country farms have sites that are relatively low in pasture production that could be acceptable for productive forestry. With careful site selection a forestry enterprise can be established without significantly reducing pastoral production. An example illustrated by MAF, based on land capability information determined how a 26% reduction in the grazed area of a

2.4.4 Species Selection

The major tree species selected for forestry ventures has been radiata pine. It has a number of advantages over other timber species including:

- Arguably one of the most profitable tree crops due to shorter rotation lengths, allowing an earlier realisation of returns;
- Produces a versatile timber with a wide range of end uses;
- The timber responds well to preservative treatments resulting in an extended end use;
- Very tolerant of a wide range of site and growing conditions;
- The subject of much research, and is the tree that is known most about;
- Growth and production has been extensively modelled for the majority of New Zealand sites;
- Responsive to silvicultural management, with the influences and outcomes of different management techniques being well known;
- Easy to propagate and has had major genetic improvement;
- Markets and processing facilities are well established.

There are however some disadvantages associated with the selection of radiata as a timber species, these include:

- Low natural durability compared to many hardwood species, although this problem is largely overcome with the use of preservatives;
- Unattractive;
- There is a perceived biological risk with monoculture plantations;
- An associated market risk with production dominated from one timber species.

There are however no accurate predictions of what will happen in 25-30 years time when new radiata plantings are to be harvested. Whilst alternative species have special attributes that set them aside, radiata remains the most popular planted species. This is due to the contributing factors discussed above as well as it's earlier and higher rates of return on money invested (refer Section 2.7.4).

2.4.4.1 Genetics

The objective of most silvicultural regimes is to maximise the production and the quality of the timber produced. A major component of New Zealand forestry development has been the genetic improvement of the radiata crop, resulting in faster growth, increased log straightness, less stem malformation, improved branching habits and improved crown health (MacLaren, 1993).

A distinguishing feature of radiata pine grown in New Zealand is the individual variation in individual tree growth rate and form (James, 1979). This variation is normally countered by planting more trees than are required at final harvest, removing inferior trees in one or more thinnings.

Prior to the 1960s seedlings were genetically unimproved (MacLaren, 1993). Practice at the time was to initially plant at stockings of around 1500sph. For regimes where the production objective is either pulpwood or energy the variation in form is not so important. For clearwood regimes form is very important and variation is overcome by increased planting rates. Increased stockings have an associated cost. More trees are needed at planting and more trees are pruned in the early stages of the rotation to ensure selection of form trees for final stockings. One way of improving tree form is through tree breeding.

In 1953 an intensive breeding program for radiata pine began and the first seed orchard was planted in 1957-8 by the New Zealand Forest Service. The best growth and form trees were climbed or felled in order to acquire seed. Selection concentrated on stem straightness, branch habit and absence of stem cones on the lower 18m of the stem. Vigour was not so highly regarded, however, since only dominant trees were considered, some improvement in vigour was expected (James, 1979).

The perception of the first attempts towards the improvement of tree quality through breeding were not well received. There were many accounts circulated to the effect that trees derived from seed orchard seed are no better (or even worse) than seeds from routine sources. However, results from a breeding trial at Rotoehu State Forest demonstrated the improvements in tree quality influenced by tree breeding. Radiata pine raised from seed orchard seed was compared with trees from routine seedlots. An assessment at final prune indicated that 90% of the final crop derived from seed orchard stock planted at 1500sph were of good form. In contrast the routine seed source established at the same stocking produced only 57%. These findings suggest that establishing as few as four times the final crop stocking may be all that is necessary on high quality sites managed for clearwood regimes (James, 1979).

The selection of superior trees led to superior seed quality. This was then used in seed orchards - a concentration of top quality trees grown specifically for seed production. The first seed orchards were "open-pollinated". There was no control over the origin of the pollen fertilising the female cones on the elite trees. "Control-pollinated" orchards protect the female cones from contamination and only pollen from desirable trees are used in fertilisation. This type of seed orchard has now superseded open-pollinated orchards (MacLaren, 1993).

By 1985, the expression "seed orchard" had become inadequate in describing the level of genetic improvement. Sufficient seed was now available from seed orchards for managers to select superior parents from within the seed orchard. As well as improvements in growth and form a range of special-purpose seedlots became available.

A seed certification system was then developed to provide comparative rankings of genetic gain across a seedlot. There are three distinct breeds, each with its own improvement rating:

- Growth and Form (GF) - most of the radiata pine seed used in the New Zealand forest industry is given a comparison on the GF scale. This is a general purpose breed suited to a wide range of end purposes and sites. The GF rating is not a linear scale and does not translate directly into any percentage gain. It is designed to rank seedlots for genetic quality, the higher the improvement rating the greater the genetic improvement. Currently, about 5% of the genetically improved seed is rated above GF20, with the majority rated as GF16 to GF17 (MacLaren, 1993). Higher grades are more costly and are often restricted in their distribution.

- Long Internode (LI) - offers significant clearcuttings between knot clusters from unpruned logs.

- Dothistroma Resistant (DR) - specially bred for resistance to the needle-cast disease Dothistroma.

Other breeds under development include high and low wood densities, a multinodal breed, pole production, and Christmas tree breeds.

Table 2.3: The improvement of some GF ratings.

GF rating	Percentage of "acceptable" stems on a forest site	Estimated percentage gain in volume
1	45	0
7	50	5-10
14	65	13-18
16	70	15-20
19	70	19-23
23	80	27-32
Long internode		
9	55	8-13
Dothistroma-resistant		
14	65	13-18

[Source: MacLaren, 1993]

The strong demand and shortage of supply for seed rated GF22 or higher resulted in many nurseries taking cuttings from seedlings. This was a means of multiplying the limited qualities of the genetically superior seed. These juvenile cuttings are very similar in growth and form to ordinary seedlings (Tombleson, 1991).

Physiologically aged cuttings provide an opportunity for high fertility pastoral sites. These sites tend to express malformation more readily than less fertile sites. Physiological aging refers to the "apparent" age of a cutting. A cutting from a three year old tree will show similar growth and form characteristics, and therefore has a physiological age of three years. The growth of these "aged" cuttings on fertile sites is similar to seedlings, however the advanced physiological age usually produces a tree of superior tree form and stem straightness for the first few years (Tombleson, 1991).

Physiologically aged trees in comparison with seedlings have straighter stems, less forking, smaller branch sizes, and a tidier branch habit, resulting in higher yields of knot-free timber. They are sturdier, with roots that are less likely to be distorted at planting, the "sail area" is reduced making them less vulnerable to windthrow (MacLaren, 1993). Stem straightness measurements on pruned butt logs have indicated that seedlings may have up to 30% fewer straight stems on forest sites, and up to 50% fewer straight stems on farm sites compared with field collected cuttings. STANDPAK analysis of this data indicates the superior form of the cuttings results in a 20% predicted higher recoverable volume of clear grade timber compared to seedlings (Holden, 1995).

The advantages on the fertile farm sites are lower initial stockings, resulting in an associated lower cost of pruning and thinning, and perhaps the greatest advantage is the straighter pruned stems resulting in an increased yield of clear timber (Tombleson, 1991). However, aged cuttings have disadvantages of higher palatability to both sheep and possums, increased cost of planting stock and limited availability of high GF rated cuttings (MacLaren, 1993). Further genetic improvement in tree form for very fertile sites would be particularly useful, however aged cuttings currently offer an alternative.

The genetically improved planting stock has been a very important factor in the development of farm forestry. The advantages of reducing the initial rates of establishment have provided farmers with an opportunity to improve the grazing and livestock component in the early stage of the rotation (refer Section 2.5.3.6).

Improvements in genetic performance now provide the forester with two methods of quality control, including:

- Selection of superior genetic material; and
- Selection of the best form trees in the field by means of thinning.

2.4.4.2 Alternative Species

Radiata pine has remained the most popular planted species, however there has been a strong interest shown toward alternative species. Native tree species have historically provided New Zealand with timber for special end uses requiring high standards in decorative features, dimensional stability and surface hardness. However, the declining resource and increasing conservation pressure has restricted their use.

Exotic special purpose timber species have become increasingly popular as an alternative to the slower growing indigenous species. These special purpose species will provide for New Zealand's domestic needs and for possible export. Special purpose species were defined in a 1979 New Zealand Forest Service workshop as those species capable of producing timber superior to radiata pine in either appearance, hardness, stability or natural durability (Hay, 1995).

The major special purpose species of interest include:

- Douglas-fir (*Pseudotsuga menziesii*);
- A range of Eucalyptus species;
- Cypresses (*Cupressus macrocarpa* and *Cupressus lusitanica*);

- Australian blackwood (*Acacia melanoxylon*);
- Black walnut (*Juglans nigra*).

Other species of interest have included poplars, paulownia and other deciduous hardwoods including oak, elm, European ash, black locust and walnut.

There are considerable opportunities for high returns from small forests growing well managed special purpose timber species. Special purpose species have generally been planted on a relatively small scale (Hay, 1995). These plantings have been taken up predominantly by small landowners and farmers that have had the foresight and enthusiasm to produce an alternative timber to radiata pine.

Growers need to be aware of the marketing potential of the special purpose timbers. This is especially important considering the availability and supply of both native and imported specialty timbers. An important factor will be the substitution of these timber sources as their availability declines. Growers will need to closely address the availability and continuity of supply of particular specialty timbers. Many species have specific niche markets, often these markets are small and susceptible to oversupply.

There are a number of disadvantages and risks associated with planting species other than radiata pine. The greatest disadvantages include:

- The relative lack of genetic improvement;
- Limited knowledge and modelling of the affects and outcomes of different site and management variables; and
- Generally a longer investment period associated with longer maturity period of the trees.

Planting alternative species posses a degree of uncertainty, especially considering the affects of management on final yield and crop quality. The New Zealand Forestry Research Institute has responded to this problem. A research program has been established, aimed at understanding and developing growth modelling procedures necessary for predicting growth and log qualities (as affected by site and management variables) of the main species of interest (Hay, 1995). The development of such events will allow the growers of alternative species to make the necessary management decisions with a greater degree of certainty.

2.5 FACTORS AFFECTING TREE GROWTH AND QUALITY

2.5.1 Introduction

Site selection for production forestry is one of the most important considerations in order to maximise returns from investment. Site selection is influential on both growth potential and costings e.g., transport, logging and roading. Factors that influence potential tree growth and quality are largely the environmental and physical constraints, and the variables associated with tree management on these sites. Such constraints have an impact on species suitability, growth rates, rotation lengths and management requirements (Vos & Clark, 1995).

In New Zealand forestry **site index** and **basal area level** are used as a measure of the potential productivity for a particular site. Site index is a measure of mean top height at age 20 years of the 100 largest diameter stems per hectare. Basal area level (sometimes referred to as "fertility" (refer Section 2.5.2.5)) is the area of stumps per hectare if each tree were felled at 1.4m above the ground (MacLaren, 1993). Site index is mainly determined by environmental factors such as temperature and moisture while basal area is influenced largely by soil fertility.

2.5.2 Environmental and Physical Constraints

2.5.2.1 Temperature

Radiata can tolerate a moderate range of temperature extremes. Altitude limits are approximately 500m in Otago and Southland and 700m in the North Island (Miller & Wilkinson, 1995). Outside of this range a species like Douglas-fir is likely to be more tolerant of climatic extremes than radiata (Vos & Clark, 1995).

Radiata seedlings are particularly susceptible to out of season frosts. A frost of -7 °C can cause damage if it occurs between October and May, and frosts of -13 °C can kill young trees in any month (MacLaren, 1993).

2.5.2.2 Rainfall

Radiata pine is remarkably drought tolerant, withstanding annual rainfall of 400mm or less, but requires between 600mm-1400mm for good growth (Miller & Wilkinson, 1995). However, actions of extreme weather conditions can cause permanent damage, especially during the establishment phase. A drought or flood can cause permanent wilting, through either a lack of water or because the roots are killed by a lack of oxygen (Anon. 1993).

2.5.2.3 Wind

Wind is probably the greatest single risk to a forestry investment (MacLaren,1993). High winds can cause toppling and stem breakage, and continual exposure severely reduces tree size and form (refer Section 2.5.3.2).

New Zealand weather is dominated by a flow of westerly winds and there are few locations that are not susceptible to the prevailing winds. The affects of these winds are further accentuated on unstable soils and trees on exposed ridges.

2.5.2.4 Micro-sites

On any one site, climate and soil type can vary producing a range of micro-sites. Micro-sites are largely features of different aspects, landforms and vegetative cover (refer Section 2.5.3.4).

Aspect refers to the direction that the land faces. Westerly aspects are often more exposed to the prevailing winds while northerly aspects are generally warmer and drier than those facing the south.

The changing conditions of landform from ridge tops to valley floors can influence the features of the micro-site. Ridges are generally exposed to wind, are drier, and have shallow soils due to soil erosion. Lower down (face) the slope tree growth conditions improve as soil depth and moisture improve. Dependant on the aspect to prevailing winds the face is likely to receive a degree of shelter from adjacent ridges.

The toe of a slope is generally formed by the movement of soil from the ridges and face. These sites are likely to have fertile soils, reduced wind exposure and improved soil moisture levels. However, they are more likely to experience harder frosts due to the settling of colder heavier air. A similar situation exists on flats and terraces. These sites have deep soils are generally very fertile, however they are susceptible to drainage problems and frosts.

Generally changes in micro-site conditions are likely to have little effect on the decisions of whether to plant radiata pine. They become more significant when selecting alternative species, and it is usually these species that have to be carefully matched to site conditions.

2.5.2.5 Fertility

Pinus radiata grows well in most parts of New Zealand and is relatively tolerant of low fertility. Consequently the application of fertiliser is not a routine operation on most New Zealand forests. However, there are certain regions where the use of fertilisers have greatly improved the growth rates of *Pinus radiata*.

The most common nutrient deficiencies are nitrogen (N), phosphorus (P) and boron (B). Deficiencies of potassium (K), calcium (Ca), magnesium (Mg), and copper (Cu) occur less frequently, and zinc (Zn), sulphur (S), manganese (Mn), and iron (Fe) are very rare (Mead, 1995).

Nutrient deficiencies are assessed through foliar analysis. Visual symptoms (Table 2.4) can also be used as a diagnosis of nutrient deficiencies, however these usually appear when the deficiencies are severe. Foliage analysis allows early detection and corrective measures to be taken before any significant production losses are incurred.

Table 2.4: Diagnostic symptoms and marginal foliar levels for radiata pine. (Deficient areas, usually requiring treatment, have levels below this range. Satisfactory levels are above these levels).

Deficiency	Symptoms	Marginal Foliar Levels
N	Uniform yellow-green short needles; loss of older foliage; fine branches.	1.2-1.4%
P	Dull green, short needles; loss of older foliage; spire-like crowns.	0.11-0.12%
K	Yellow needle tips (sometimes necrosis) in lower crown; loss of older foliage. Winter.	0.4-0.5%
Mg	Golden yellow needle tips, usually in older foliage of mid to upper crown. Spring.	0.07-0.10%
Ca	Resin exudation, bud death and dieback. Hooked needles.	0.10%
S	Similar to nitrogen .	80 ppm SO_4
B	Tip death and/or shoot dieback. Shoots bend over. Pith necrosis. Mid-summer to late winter.	8-12 ppm
Cu	Twisting of branches and leaders. In seedlings, drooping needles and necrosis.	2-4 ppm
Zn	Rosetting of buds. Chlorosis.	10 ppm
Mn	Pale yellow-green foliage.	10 ppm
Fe	Similar to Mn; yellow-white needles.	25-40 ppm

[Source: Mead, 1995]

An important fertility issue facing the New Zealand forest industry is the decline of *Lupinus arboreus* Sims in radiata pine stands established on the west coast sand dunes. The lupin served a dual role of providing shelter necessary for the establishment of young pine trees and increasing the presence of soil available nitrogen (Dick, 1994). The estimated nitrogen fixation rate was 160kg/ha/year, markedly reducing the requirement for applications of artificial nitrogenous fertilisers (Gadgil, 1971). Lupin blight (*Colletotrichum gloeosporioides* (Penzig)) was found to cause rapid mortality of seedlings, dieback, and stem cankering of older lupin plants. This has shortened the expected lifespan of the lupin by up to 3 years. The productivity of *Lupinus arboreus* can no longer be relied on for the provision of a large part of the nitrogen requirements in the sand dune forests (Dick, 1994). This may place an increasing demand on more expensive artificial nitrogen sources or introducing alternative legume species that are resistant to the blight.

In New Zealand basal area is generally used as a measure of site fertility and is broadly classed into low, medium or high basal area (refer Section 2.7.3.4). Farm sites are categorised as having high basal areas and will generally produce greater volumes of timber in comparison with non-farm sites (Table 2.5).

Table 2.5: The effect of site index and basal area potential on yield of radiata pine at 28 yrs (m^3/ha at harvest).

	SITE INDEX		
BASAL AREA	*18*	*26*	*34*
Low	200	340	500
Medium	230	430	600
High	340	540	640

The main difference between farm and non-farm sites is largely the nutrient store accumulated during pastoral farming, in particular phosphorus and nitrogen. Therefore, the growth response of *Pinus radiata* on a high fertility farm site is likely to differ from that of a non-farm site. Investigating the growth response of *Pinus radiata* to fertilisers used on nutrient deficient sites could be used to demonstrate what occurs on a high fertility site.

Hunter and Graham (1982), investigated the growth response of phosphorus-deficient *Pinus radiata* to various rates of superphosphate fertiliser. The general response on a low P site was an increased apparent site index and significantly increased basal area increment. On average annual height increment in 10 year old trees that received fertiliser were 27% greater than in trees that had not. Basal areas in the control plots increased by 60% between ages 3 to 6 years whereas the fertilised plots had doubled basal area over the same time span. With increasing amounts of fertiliser there was little gain in tree height and a diminishing rate of basal area increment. On the more fertile sites the fertiliser served only to increase basal area without any marked increase in height.

Ballard (1978), highlighted the use of fertilisers at establishment, particularly N and P. Phosphorus again improved basal area increment and height. The N fertiliser (60 g/seedling) improved collar diameter by 14mm and improved tree height by 27 cm over the first 3 years of growth. The establishment applications of N were effective for only 1 to 2 years, probably because of the mobility of applied N in soils i.e., leaching losses. If sustained N responses are required there appears to be little alternative to applying more frequent N applications.

Mead and Gadgill (1978), investigated the use of fertiliser in established radiata pine stands, and obtained similar results to Ballard (1978). Phosphorus deficient sites supplied with high rates of P often resulted in volume responses of about $30m^3$/ha/year. Nitrogen fertilisers also improved volumes by $8m^3$/ha/year on fertile Central North Island soils. On infertile sites in the Nelson region responses to N + P fertiliser were about $17m^3$/ha/year.

Most agricultural land will have a store of N and P accumulated from a grass and clover cover and applied superphosphate. Therefore *Pinus radiata* planted on farm sites would expect to have a growth response similar or even more vigorous than sites that have received fertiliser treatments. A farm site is likely to produce trees of greater volume, largely through increased diameter growth at a given stocking in comparison to a non-farm site.

Unfortunately, branch size and stem diameter are closely related (Knowles *et al,* 1992). As diameter increases so does the branch size, reducing tree quality. Knot size is one of the most important characteristics affecting the commercial use of wood (Brazier, 1977). This problem is further magnified when a combination of both lower stockings and high site fertility are encountered (refer Section 2.5.3.3). A measure of control for this problem is to maintain a higher tree stocking, this helps to suppress branch size, improving timber quality.

Table 2.6: Second-log branch sizes at Tikitere, 200 and 400 sph.

Stocking	Branch Index (cm)	Max. Branch (cm)	Internode Index	Branches/whorl	Whorls/log
200	7.8	9.5	0.17	5.8	9.8
400	5.5	6.5	0.22	5.5	9.1

[Source: Knowles, Hawke and MacLaren, 1992].

2.5.3 Management

Factors associated with the management (particularly silviculture) of *Pinus radiata* are very influential on tree growth and form. The early stages of management are imperative to the establishment and quality of the trees at harvest. Inappropriate management techniques will do little to optimise the potential productivity and returns from a given site.

2.5.3.1 Establishment

The management techniques employed during establishment are essential to ensure high seedling survival and uniform subsequent growth. Seedling establishment is influenced by planting techniques, site conditions - especially incidence of competing weeds (refer Section 2.5.3.4), the incidence and damage from pests and disease (refer Section 2.5.3.5), and the genetic improvement of the seedling stock (refer Section 2.4.4.1).

Planting usually occurs from June through to about August. Dry soils and areas prone to drought should be planted early in the season while in wetter, colder areas latter planting provides better establishment. Good planting techniques are essential for root and tree placement. It is important that the seedlings be planted with as little twisting and distortion of the root system as possible. Bent or twisted roots will give poor anchorage increasing the likelihood of toppling at a later date. On high fertility sites fast initial growth often leads to toppling and correct planting techniques become increasingly important(MacLaren, 1993).

2.5.3.2 Thinning

Initial and final stockings, coupled with the timing of thinning operations are important management decisions that need to be made early in the crop rotation. Standard forestry practice is to plant more trees than required for final harvest. This ensures the site is fully occupied and allows forest managers to select the best form trees (at the time of operation) for an evenly distributed final crop. Thinning concentrates the resources of the site (water, nutrients, sunlight) toward the selected trees (MacLaren, 1993). Therefore the timing and severity of thinning is very influential on early crop development, final crop quality and rotation length.

In New Zealand initial stockings have declined markedly (refer Section 2.3.3.1) and it is now normal to plant between 600-1000sph. Initial stockings of 600sph or more provide mutual protection for young trees from wind exposure. Lower stockings incur a marked reduction in height growth and are more susceptible to wind damage (MacLaren & Knowles, 1995).

The timing of thinning is important and occurs within a relatively short period of time or tree height. This is due to the rapid growth rate of radiata pine and the risks of windthrow in New Zealand (West, 1990). A late thinning, after about 14-18 metres in height, poses a greater risk of wind damage to the remaining trees (MacLaren & Knowles, 1995).

An early thinning, between the age of 3 and 6 years, means surplus trees would have had minimal influence on the final crop. With early thinning it is harder to select what will be the best trees at harvest. There is evidence to indicate that early (< age 7) selection is of limited benefit as there is a weak relationship between the vigour and form of trees at the time of selection and the size and shape of stems at maturity (MacLaren & Knowles, 1995). However, early thinning is cheaper and allows the trees to attain larger diameters due to minimal competition for the remainder of the rotation. Early thinning is usually associated with clearwood regimes (pruned butt logs) where low final stockings (200-350sph) are required.

Delayed thinning is usually associated with either a production thinning or framing regime. These regimes generally have higher stockings, producing a greater volume per hectare with better form and smaller branched trees. Production thinning requires high stockings to be maintained over a considerable period, suppressing the potential growth of the final crop trees. There is also a risk of damage to the remaining trees and site conditions that could compromise final crop quality.

2.5.3.3 Pruning

Pruning prevents the formation of large branches in the butt log. The removal of live branches slows tree growth, especially diameter (MacLaren, 1993). However, there is a trade-off between volume production and an increased product unit value from pruning (Garcia, 1990). The objective of pruning is to increase the clearwood portion of the butt log by restricting the defect core to a narrow uniform diameter. The defect core is a hypothetical cylinder in the centre of a mature pruned tree containing the defective wood formed after the occlusion of the branch stubs (MacLaren, 1993).

Pruning operations are now usually scheduled on tree size, in particular diameter over pruned stubs (DOS). DOS refers to the stem diameter over the pruned branch stubs of the largest whorl removed in that lift. The largest DOS in any one pruning lift will influence the size of the defect core. DOS is the most direct way of scheduling a pruning operation, because it is a prime determinant in clearwood production (MacLaren, 1993). A target DOS of between 13-19cm from growth model simulations (refer Section 2.7.2) is a good compromise between the need to restrict the defect core without penalising tree growth and incurring the cost of too many pruning lifts (MacLaren & Knowles, 1995).

Tree growth is directly related to the length of green crown (MacLaren, 1993). Therefore, pruning should be conducted in such a manner as to leave the same length of green crown. However, there is a trade-off between the removal of too much crown and too little. Removing too much will slow tree growth, while too little will result in more frequent pruning lifts in order to maintain the target DOS. Delayed prunings are penalised by a larger DOS, affecting the size of the defect core which may ruin the time and investment into previous pruning lifts.

Uneven DOS sizes have a significant effect on both clearwood yield and profitability. In terms of clearwood yield, pruning to 4.3m with a uniform DOS size achieves a similar or even better result than pruning to 5.8m with a DOS size varying by more than ± 2cm (Knowles, 1990b). Model simulations demonstrate that leaving 3-4m of green crown is an acceptable compromise for a typical situation (refer Section 2.7.3.3).

The above pruning technique is referred to "variable lift pruning". This is where each tree is treated as an individual and pruned according to it's height, resulting in the development of a more uniform crop. Variable lift pruning has largely superseded "fixed lift pruning" where trees are pruned to a fixed height irrespective of tree height. This results in a crop with varying lengths of green crown, so that by the next pruning the differences in tree height and diameter become much more apparent(MacLaren, 1993).

DOS sizes can be particularly difficult to control and maintain on sites with a high basal area level, e.g., ex-pastoral sites. These sites produce trees that have more vigorous diameter growth and consequent branch growth with little corresponding increased height growth in comparison to non-farm sites. These sites are likely to require more frequent pruning lifts in order to maintain a target DOS. Maintaining target DOS's becomes increasingly difficult on sites that have a combination of both a high basal area level and low site index. The resultant effect being a short tree with a large diameter. This then further restricts the amount of green crown that can be removed in any one pruning lift, leading to an increase in costs associated with more pruning lifts.

Planting higher GF seedlings or cuttings can help improve the situation on these particular sites as they have a lower DOS for a given height (MacLaren, 1993). Also, coordinating the timing of thinning with pruning operations can have a significant effect. If thinning occurs well before pruning there will be no control of branch size, and if significantly delayed the pruned crop trees will be suppressed by the more competitive unpruned or partially pruned element (MacLaren & Knowles, 1995).

Tombleson *et al* (1990) further examined branch size in relation to stocking. On examining forest stands there is little overlap of individual tree crowns. If it is assumed that branch diameter is a function of branch length; and branches stop growing when they come within close proximity of another tree, it can be shown that branch diameter is a function of stocking at time of crown closure. Site index also influences branch size, a possible explanation for this is the more rapid height growth at high site indices. This causes a more rapid rise of the green crown and hence the branches become moribund at an earlier age and are smaller relative to final branch size for lower site indices. MacLaren *et al* (1995) have observed that there is an associated increased height increment with stocking rate that starts from a very young age. This information suggests that a delay in thinning could be used in order to help suppress branch size and diameter increment, while encouraging height growth. Thus giving the forest manager a greater opportunity to control DOS size.

2.5.3.4 Weed Control

Weed control is essential for high uniform seedling survival rate, and in certain instances, improved silvicultural access and reduced fire risk. Weeds of major concern include the woody weeds, in particular gorse, blackberry, broom, buddleia, and bracken fern. Grass and herbaceous species can be strongly competitive for moisture and nutrients in all parts of the country, but the effect is greater in dry areas. Weed competition trials have demonstrated that grass and herbaceous weeds are generally a problem with early establishment. While after 2-3 years woody weeds have the largest effect on tree stem volume, particularly tree height, due largely to competition for available light (Davenhill *et al*, 1996). Preliminary results from herbicide trials on fertile sites have demonstrated the larger the weed free spots the greater the overall growth response from radiata. A spot diameter of 1.5-1.6m, or twice the expected height of the pasture is recommended. However favourable growth responses are still experienced up to around 4m (Anon, 1996b).

The development of oversowing techniques used in forest cutover has provided the forest industry with a new innovated site management approach. The oversowing mixture can improve weed control and introducing legumes can improve soil nitrogen levels, significantly improving the overall site productivity. Oversowing offers a biological weed control and can provide understorey grazing where livestock are available. Although oversowing can reduce the amount of herbicide used on some sites it is unlikely to be a substitute for pre-plant and post-plant spot spraying which is necessary to reduce competition (West, 1995).

Generally, most sites will require some form of site preparation prior to planting. The necessary preparation will depend on the condition of the site and the existence of any competing weeds. The extent of weed control could range from merely a heavy grazing on pastoral land to the extensive use of mechanical and herbicide preparation on harvested forest cutover. Post planting, the seedlings are likely to require further releasing in order to allow the seedlings time to over-top and dominate the surrounding regrowth.

2.5.3.5 Pest and Disease

The onset of disease can be caused from agencies or stress factors such as living organisms including fungi, bacteria, viruses, insects and large animals. Non living agencies such as drought, flood, frost, fire, careless use of herbicides, machinery and stock damage, mineral deficiencies and excesses, and poor planting practices can also lead to premature death or slower than usual growth.

Gadgill *et al* (1995), discusses the range of pest and diseases found in New Zealand. There are very few serious insect pests or major diseases in New Zealand's introduced conifers. Fortunately, New Zealand is generally free of the major northern hemisphere pests and diseases that could be potentially catastrophic to the forest industry.

The insect pests of particular note that affect *Pinus radiata* seedlings include soil insects or insects originating from competing weeds. However, the young trees only suffer little more than a temporary setback in growth. The most important pests of mature pine are *Sirex noctilio* and the common forest looper (*Pseudocoremia suavis*). They only appear to be serious in trees grown under stress and can be largely avoided under appropriate management regimes. Outbreaks of other insects are usually rare and are of little consequence.

There are a number of other pests other than insects that can cause appreciable damage amongst radiata pine. Young seedlings are susceptible to damage from rabbits, hares and possums. Older trees are susceptible to browsing damages by sheep and cattle until the bark becomes corky (or fissured). Deer and goats can cause more serious damages as they can strip bark from mature trees. There are a number of chemical paint products that can deter animals from browsing the trees, however they are not usually successful over extended periods.

Fungi are the most important disease agents of trees and have varied symptoms of infection. The three main diseases of concern among New Zealand's pine plantations include ***Dothistroma pini***, *Cyclaneusma* spp. and *Armillaria* spp. Sirex transmitted the fungus ***Amylostereum areolatum*** (a wilt disease of pines) that caused considerable damage in over-stocked stands during the 1940s and 1950s. However the biological control of Sirex and changes in silvicultural practices have bought this disease under control.

The most important disease of pines in New Zealand is Dothistroma needle-blight. The fungus causes a loss in growth directly proportional to the amount of green crown affected. Radiata pine develops resistant to the disease at about 15 years of age, younger plantations can be controlled with the aerial application of copper fungicide.

Cyclaneusma needle-cast affects tree needles of one year or older and is most common in trees in the 6-20 year age class. Infected tree needles are cast in the autumn and spring, causing a loss in tree growth. There are no economically effective control solutions except tree selection at thinning and a program of tree breeding (MacLaren, 1993).

Armelleria causes serious root-rot and can lead to heavy loses in the first five years of growth. Mortality diminishes as the trees become older, however, there is a reduction in growth and susceptibility to wind throw.

New Zealand continually monitors levels of insects and fungi populations that have already established. There is also relatively strict quarantine procedures to prevent the introduction of new overseas ones. The quarantine procedures operate at three levels including offshore (to keep the problem from the border), border interception and surveillance for early detection (Gadgill *et a,l* 1995).

2.5.3.6 Livestock

Although there are a number of advantages of maintaining a managed understorey (refer Section 2.4.3) there are a few considerations that have to be taken into account, these include:

- Timing the re-introduction of grazing stock after planting;
- The class of stock; and
- The declining grazing potential as the trees age.

Radiata pine is not especially palatable to grazing stock, however, they will browse if they are hungry enough. Generally stock can be re-introduced when the leading shoots are out of reach. However, the trees are still susceptible to stock damage including branch breakage, bark stripping and toppling. MacLaren (1993) outlines some grazing management tips

- Sheep can commence grazing after about a year with extreme care. Trees are usually relatively safe from sheep after 3 years of age;
- Cattle can be successfully grazed among younger pines. However, care should be taken until about age 8 when the tree bark becomes corky.

As trees mature they begin to influence pasture quantity and quality, and therefore animal performance. This is due to the shading affects of the tree canopy having a direct consequence on the underlying pastures ability to intercept light (Knowles *et al*, 1992). Pasture composition deteriorates as the proportion of ryegrass and clover components decrease, and less palatable grasses and weeds increase (MacLaren, 1993).

As pasture production and quality declines with increased tree age and stocking so do the stock numbers per hectare that can be grazed. There is also a decline in animal performance as a result of the deteriorating pasture composition, an increase in gastro-intestinal parasites and an increase in litter intake. The extent of the reduction in carrying capacity throughout the rotation is influenced by the type of management regime and in particular stems per hectare. The Tikitere grazing trial suggests that grazing was not worthwhile after age 9 in the 400sph, in contrast grazing the 100sph was still useful at age 18 (Knowles *et al*, 1992).

Although there is significant grazing opportunities available at lower stockings, suggesting that lower than normal stockings may be preferable on farm sites. However, even when the grazing component is included in calculations the higher stems per hectare are more profitable than the lower stockings (MacLaren, 1993) (refer Section 2.4.2).

2.6 FOREST MENSURATION

2.6.1 Introduction

Forest mensuration is the measurement of individual trees and forests, providing quantitative information about what is managed and how it changes with time (Carron, 1968). An even aged stand shows a regular change in production, which increases to a maximum value then declines

(Ovington, 1957, as cited by Newbould, 1967). A stand, as defined by British Forest Association (1953, as cited by Carron, 1968), is an aggregation of trees, sufficiently uniform in composition and age, or defined by natural or artificial boundaries, to be regarded as a unit for silvicultural or management purposes. A forest comprises a number of such stands aggregated for some purpose of management (Carron, 1968). It is at the stand level that data collection needs to be increasingly precise and detailed.

The measurement of tree growth is an important aspect of forest management. There are three main types of assessment carried out in plantation forests, including silvicultural inventory, mid-rotation inventory, and pre-harvest inventory. Silvicultural and mid-rotation inventory are generally termed management inventory and only require simple measures of tree variables. A pre-harvest inventory requires a more detailed assessment of stem quality to provide estimates of yield by log grade types (Gordon & Lawrence, 1995).

Silvicultural inventory is used to plan, schedule and control silvicultural operations. It also provides a measure of quality control to ensure silvicultural standards are adhered to. A mid-rotation inventory is used to update stand records, and is useful for providing reference points for predicting future growth and yield. Management inventory provides adequate information for general estimates of log product volumes, however, for a more detailed estimate a pre-harvest inventory is more appropriate. A pre-harvest inventory is used in the planning process for harvest operations and assists with the marketing of the forest produce (Gordon & Lawrence, 1995). This inventory data also provides the raw data for the configuration and validation of new and existing growth models.

2.6.2 Measurement of Trees

Diameter and height are the two main parameters involved with tree measurements. They are relatively easy non destructive measures that can be taken in order to estimate tree volumes and growth. Diameters measured include stem diameter - diameter at breast height (DBH), diameter over stubs (DOS), upper stem diameter and branch diameter. Height measurements include stem height, pruned height, green crown height, and merchantable height. In forest inventory the most commonly measured variables are stocking, basal area and height (Fischer, 1995a).

Breast height in New Zealand is defined as 1.4m above firm ground after vegetation has been removed, measured on the uphill side of the tree when on sloping ground (Goulding, 1995). The DBH can be measured with either calipers or a diameter tape to the nearest tenth of a centimetre. The DBH is used to calculate the basal area (cross-sectional area of the stem at breast height).

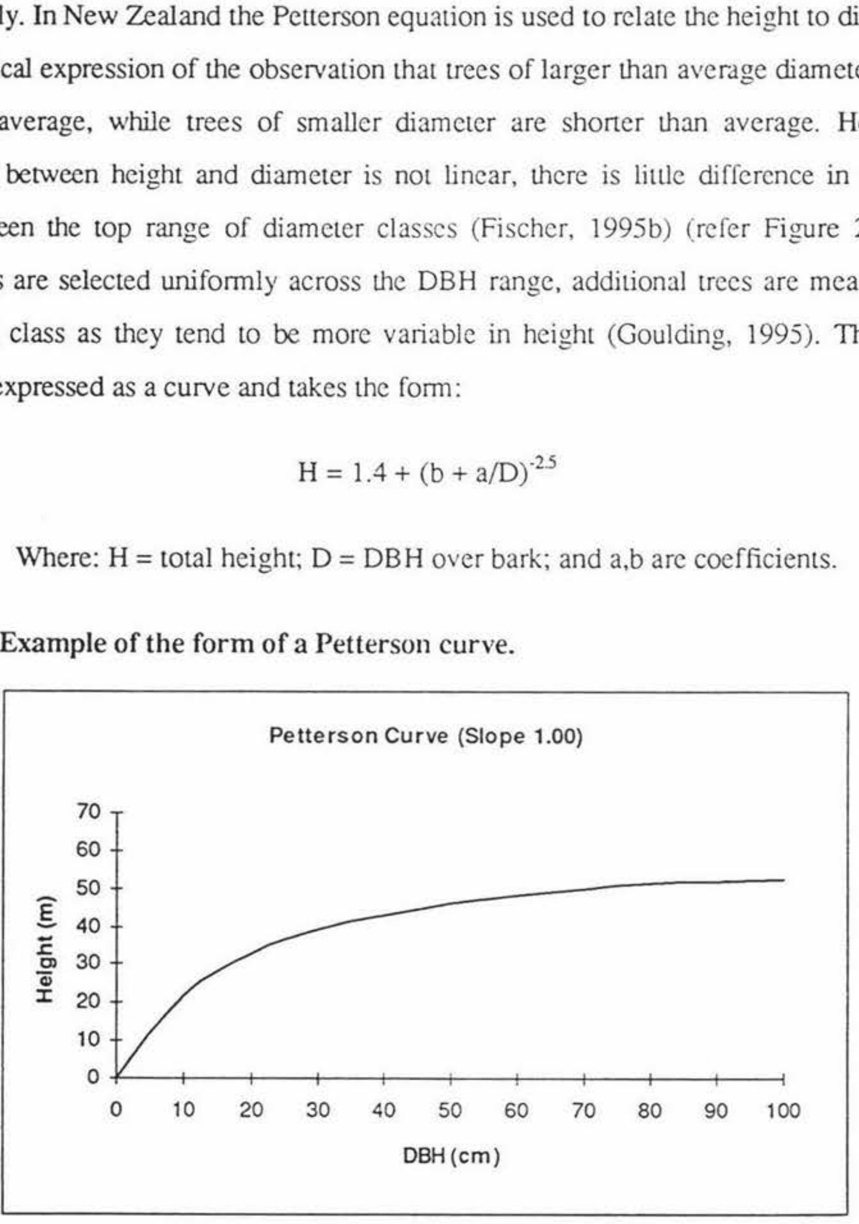
Tree height may be estimated, measured directly (by climbing with a tape, or raising a pole alongside the tree), or measured indirectly (by the use of trigonometry and the measurement of two angles and a distance). Indirect measurements require an upper and lower angle, a datum height and a distance from the tree. A clinometer is used to measure angles to the horizontal. The Suunto (drum pendulum) is probably the most dominantly used clinometer in New Zealand forestry inventory.

Height measurements are a difficult and time consuming task, the use of an indirect measure may be more appropriate. A sample of trees can be measured for both DBH and height and a regression equation fitted to these data and used to predict the heights for those trees measured for DBH only. In New Zealand the Petterson equation is used to relate the height to diameter. It is a mathematical expression of the observation that trees of larger than average diameter tend to be taller than average, while trees of smaller diameter are shorter than average. However, the relationship between height and diameter is not linear, there is little difference in the average height between the top range of diameter classes (Fischer, 1995b) (refer Figure 2.3). Height sample trees are selected uniformly across the DBH range, additional trees are measured in the larger DBH class as they tend to be more variable in height (Goulding, 1995). The Petterson equation is expressed as a curve and takes the form:

$$H = 1.4 + (b + a/D)^{-2.5}$$

Where: H = total height; D = DBH over bark; and a,b are coefficients.

Figure 2.3: Example of the form of a Petterson curve.



[Source: Fischer, 1995b].

The Peterson equation is also used in the computer growth model STANDPAK (refer Section 2.7.3). In the Diameter Distributions module the projected basal area distribution is predicted into diameter classes using a Weibull function (a diameter distribution equation), the Petterson equation is then used to predict tree heights in each of the diameter classes (Fischer, 1995b).

The Weibull distribution is fitted to the minimum, mean and variance of the tree basal areas, and takes the form:

$$F(x) = 1 - e^{-\alpha(x-\gamma)^{\beta}}$$

Where: $F(x)$ = the proportion of stems contained below a DBH of x cm; α, β, γ are constants defining the shape, scale and location of the distribution (Anon. 1994b).

2.6.3 Sampling Techniques

Measurements should be unbiased and precise, in that the average of repeated measurements should tend towards the actual value and that repeated measurements will be concentrated in a narrow range (Fischer, 1995b). Measuring or counting a whole stand of trees is usually inappropriate, so often only a proportion (as little as 1-2%) of the total area is sampled. If the sampling design is correct the information collected should be representative of the whole stand.

Most commonly in forest inventory, the population (the entity on which the inventory is carried out) is deemed to consist of an aggregate of sample units that can be measured for some information (Goulding & Lawrence, 1992). These units are usually plots of a defined size, usually 0.04 to 0.10 hectares (Fischer, 1995a). The procedures adopted for locating the sample units (plots) within a population are based on the principles of random sampling. However, because random sampling is often difficult to manage, some form of systematic approach is more commonly used (Goulding & Lawrence, 1992).

Simple random sampling has a perceived disadvantage that the sample may not comprehensively cover the entire area occupied by the population (Fischer, 1995b). In systematic sampling individual units are selected on a systematic and predictable basis. However, if the population units are randomly distributed the sampling strategy that selects the samples at regular intervals can be thought of as random sampling (Goulding & Lawrence, 1992). Systematic sampling allows all parts of the population to be represented and the precision of the parameters estimated is usually high (Philip, 1994). This is particularly important because the characteristics of a stand are not completely dependant of geographic position (Fischer, 1995a). Bias can occur if the pattern of variance within a population matches the pattern of systematic sampling e.g., systematic sample aligned across ridges may fail to sample the valleys. To overcome such a problem a population can be divided into strata and then sampled accordingly (stratified random sampling).

The sampling units or plots are either strip (transect) or bounded plots. In all plots the dimensions are corrected for slope in order to give a horizontal area. Transect plots are advantageous in rough conditions, with poor access, high variability and when the number of trees are sparse. They are usually 100m long with 2.0m or 2.5m either side of the transect and are a good indicator of conditions throughout the stand, especially where changes occur in a striated manner (Goulding & Lawrence, 1992). This form of sampling may also take the form of a structured walk (MacLaren, 1996).

Bounded plots are either circular or diamond in shape and enclose a fixed area of the stand being sampled. In a relatively uniform stand fewer plots are required to obtain a given level of precision in comparison with transect plots (Goulding & Lawrence, 1992). Permanent sample plots are used for the repeated measure of the same trees. They are used where the sampler is interested in obtaining the best estimate of the current growing stock and the change since the last inventory (Philip, 1994).

2.6.4 Permanent Sample Plots

The establishment of Permanent Sample Plots (PSPs) provide a means of assessing stand growth and yield. Models are then constructed using this data to predict future growth, silvicultural scheduling and post operational assessments. They are considered "permanent" because the same stems are measured repeatedly over time.

The PSP data base system at the Forest Research Institute (FRI) is committed to the long-term management of high quality data and strict standards have been established for the collection of growth data from PSPs (Ellis & Dunlop, 1991). Data requirements are changing, in line with trends towards more intensive silvicultural practices and forest planning. This requires a need to collect relatively accurate estimates of stem wood production since this is commonly the largest component of forest production (Newbould, 1967).

Growth modelling requires data representing a broad range of responses. New Zealand has a range of environmental conditions. This has led to extensive sampling to cover the variety of growth relationships that exist. PSPs have been established around New Zealand since the 1920s in order to measure and compare stand variables and treatments.

There are two distinct classes of Permanent Sample Plot:

Growth and Yield Plots:

These plots are treated in the same manner as the surrounding stand. They are designed for the continuous monitoring of growth within a forest under different silvicultural regimes. These plots provide the basic data used for growth modelling (Pilaar and Dunlop, 1989), and can be used to test existing computer growth models or to create new ones (Dean, 1989).

Experimental Plots:

These plots are designed to study various tree species and tree or crop responses to different management strategies (eg. establishment, fertiliser treatment, pruning, thinning). The majority of these plots are established in standard replicated trials for statistical analysis. Other examples of experimental plots include "Nelder trials", in these trials trees are planted radially and are designed to study density effects. "Timberbelt plots" are summarised by length (kilometres) rather than area.

Experimental plots are treated separately from the remainder of the stand. They usually require uniform sites which limit the use of such trials in most forests. Generally, experimental plots are not representative of the surrounding stand, however they are used to develop data used in growth model development (Pilaar and Dunlop, 1989).

2.7 ANALYSIS OF FORESTRY INVESTMENT

2.7.1 Introduction

Forestry is a long term investment involving the sacrifice of certain immediate returns for uncertain future benefits. Therefore it is important that reliable physical and financial data be obtained to assess the benefits of such long term investments. Reliable information is necessary to determine the possible outcomes of an investment and aid in the decision making process. To determine the financial performance of a forestry investment project there is a need to:

- Predict the yield and quality from a stand of trees;

- Determine the financial, physical and management resources needed in the project and determine the revenues received from it; and
- Assess the levels of risk associated with the investment.

2.7.2 Growth Modelling

The ability to predict the future growth and yield from a stand of trees is a very important step in assessing the feasibility of a forestry investment. Comparisons can be made with existing stands of trees within a region or previous production from the site. However, this information could be misleading because previous sites were planted with genetically inferior trees and experienced different silvicultural management. Using this kind of information can pose further problems if there is not an accurate representation of the chosen site. However, it does give a gauge on achievable levels of production. The most reliable means of predicting growth and yield is to use computer simulated growth modelling procedures developed by the New Zealand Forestry Research Institute.

A forestry investment project is not only constrained by financial outcomes, physical constraints affecting growth and quality of production are equally important in the investment process. There are an endless combination of silvicultural practices, the choice of which is influenced by site factors, location and financial circumstances. Therefore, there is a need to accurately predict the future effects of current management decisions, especially on the outcomes of yield and quality.

Ideally the assessment of total volume and quality will be based on mensuration data, reflecting the effects of disease, damage, and management operations such as pruning and thinning. While certain management and investment decisions can be made at the stand level, most long-term "strategic" decisions require the consideration of future developments. This requires the exploration of different management strategies due to the changing status of the forest through time. Growth models can be used in this instance to explore and identify trade-offs between alternative strategies in relation to timber quality and quantity, costs and returns. Models such as these can be used for the planning and monitoring of a stand and help answer the "what-if" questions to formulate a desired strategy.

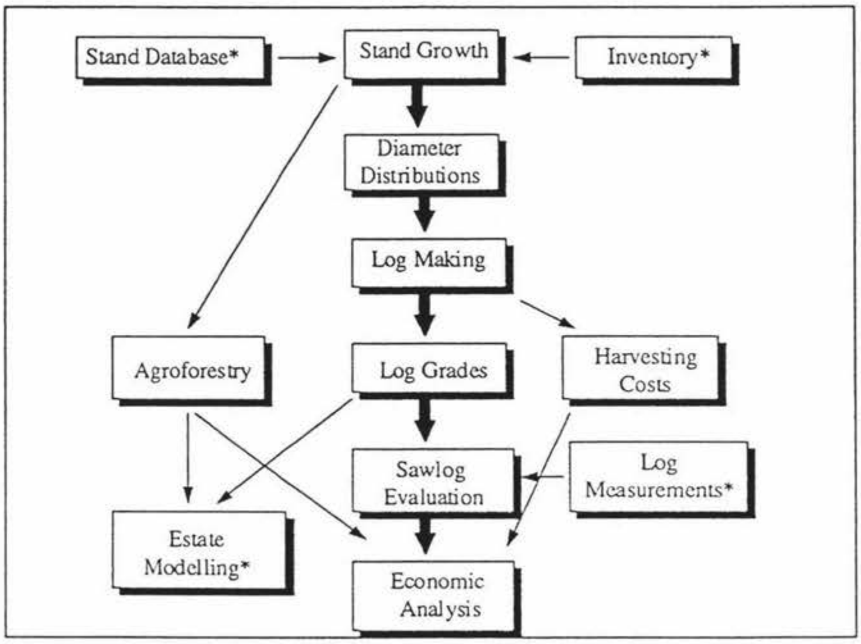
A forest growth model describes and portrays the development of tree crops as they increase in age, or as time changes (Philip, 1994). A growth model is a set of mathematical equations which predict the development of tree crops overtime and are usually programmed as part of computer-based forest management system. There are a range of computer models available, however, radiata pine is usually managed in even aged stands and the use of stand growth models are found to be adequate for most purposes. A stand growth model predicts development in terms of stand and per hectare variables such as crop heights, number of stems, and basal area per hectare (Goulding, 1995). STANDPAK is an example of such a model.

2.7.3 STANDPAK

STANDPAK is a stand evaluation package developed by the NZFRI. It simulates the growth and quality of radiata pine stands, calculating yield by log quality classes (log grades). It can also estimate the green-sawn timber out-turn and can be used for both long and short term plantation management planning, including:

- The calculation of log volumes, log qualities, piece size assortments and understorey livestock production for a range of rotation ages and management systems.
- Help decide how many stems to prune, to what height, when to carry out the operation, how many times to thin, when and to what stocking.
- Schedule the timing of pruning and thinning operations for maximum return and assists with planning best use of capital and labour.
- Enable managers to value their logs through the sawing process and to test future price scenarios.
- Help decide what type of land to buy or sell, whether forestry should be combined with agriculture (Anon, 1994b).

Figure 2.4: STANDPAK modules (* Other software applications).



[Source: Anon, 1994b].

STANDPAK incorporates many years of measurements in thousands of sample plots and hundreds of replicated trials. It is used throughout the New Zealand forest industry and is used as an evaluation tool, at the stand level only for alternative silvicultural strategies (James, 1990) (refer Figure 2.4). Examples of it's use have included:

- Analysing the pattern of growth of thinned and pruned stands (Garcia, 1990); pruning evaluations in clearwood regimes (Knowles, 1990a) and the optimisation of final crop stockings (MacLaren, 1990).
- Investigating the spacing and thinning effects in agroforestry (Knowles, 1990b).
- Investigating the contentious issue of trade offs between early revenue from production thinning at the expense of later revenues at clearfelling (West, 1990).
- Response of radiata pine branch characteristics to site and stocking (Tombleson *et al*, 1990);
- Comparing the profitability and timber grade recovery from improved radiata pine breeds (Carson, 1990).

Examples such as these can be used to validate STANDPAK against real situations, and as new information is developed and deficiencies identified the appropriate corrections can be made.

2.7.3.1 Development

STANDPAK was developed as a consequence of moves by the New Zealand Forest Service to bring some coherence to New Zealand radiata pine silviculture. James (1990), discusses the development of the early computer-based model systems. In 1979 a Radiata Pine Task Force, made of a mixture of scientists and foresters, was assembled and the regimes of the time were surveyed. The first report of the Task Force (Williams, 1982) found nearly 70 distinct silvicultural schedules. There were wide variations in the aspects of spacing, and the timing and intensity of pruning and thinning. The lack of an objective basis for predicting the quantitative and qualitative results of any treatment made attempts to compare similar schedules difficult. The results of the Task Force produced the first-generation computer-based silvicultural stand model SILMOD (Whiteside and Sutton, 1983). The model predicted the size, quality and value, silvicultural treatments and rotation lengths for a range of processing operations for radiata stands on almost any New Zealand site. SILMOD was enhanced by a subsequent Task Force, the result being STANDPAK.

In addition to defining the forestry component a grazing package had been constructed and incorporated into the existing silvicultural simulation models. The package predicts the pruning and thinning debris from any silvicultural operation, the rate at which this debris decays, the reduction in pasture growth due to shading at any date in a given regime, the reduction in quality of the pasture and the resultant costs and returns from the understorey livestock (Cox *et al,*1988).

STANDPAK is based on a large data-set of both monitoring plots and replicated trials. Much of the information used in the development of STANDPAK has come from Permanent Sample Plots (PSPs). Inventory data is collected and used to create and continually up grade new and existing models.

2.7.3.2 Growth Models

Beekhuis (1966), produced the first generation of mathematical stand growth models. This was a variable-density yield model with separate graphically derived functions for height, standing basal area and stems per hectare development (Goulding, 1995).

Goulding discusses further developments of second and third generation stand growth models. The second generation of models were based on statistical analysis of data from PSPs measured up until 1973. The result of this was a Kaingaroa Growth Model (KGM1), this was then modified to allow the use of regional site, top height and age curves to produce a model KGM2 which could be applied nationwide. Similar models were then developed for regions with differing growth patterns. These were stand growth models with functions for height, basal area increment and mortality in stems per hectare. Additional functions were added that predicted the basal area of mortality and thinnings, and the reduction in growth due to the loss of site occupancy immediately after thinning.

The third generation stand growth models are based on a state-space model comprising a set of stochastic differential equations. The differential equations describe the changes in stand variables such as basal area, stocking and top height. The state-space approach uses a sufficient number of variables that describe the "state" of the stand at any given time so that future states are described by the current state and future actions, and the quantities of interest, such as volumes, can be derived from the values of the state variables (Garcia, 1979). In other words, the state variables summarise the historical events affecting the future development of the stand (Garcia, 1984). A stochastic model incorporates uncertainty in the outcome by generating a random variable or variables from a prescribed probability function, and adjusts the prediction by including the effect of this stochastic element (Philip, 1994). The rates of change in stand parameters of top height, standing basal area and stems per hectare are predicted over time on the assumption that future development is determined by the values of the stand at any one time (Goulding, 1995). The model parameters are simultaneously estimated using maximum likelihood techniques, under specific assumptions about the random variation in the model (Garcia, 1984).

A "stand volume generator" was developed to predict the sizes, volumes and numbers of log products at any age given the output of a stand growth model. A Weibull function is used to generate a DBH frequency distribution using individual tree breast-height basal area frequency distributions. This is then used to construct a height DBH curve and used to predict tree height at a generated DBH. The stem breakage and stem taper is predicted for the tree in the midpoint of each class. A user defined cutting strategy is then applied to cut the trees into logs. The log grade out-turn is then classified by diameter, length and quality indices such as defect core, wood density, branch size sweep and internode length.

There are now a range of growth models each with a significant difference in the pattern of growth. These cover the major bio-geo-climatic regions across New Zealand. Perhaps one of the most important developments in stand modelling was the development of a model EARLY (West *et al*, 1982). This model predicts the effects of pruning and early thinning on the growth of radiata pine on forest and ex-pastoral sites.

2.7.3.3 EARLY

West *et al* (1982) used data from 24 silvicultural trials in the North Island to derive a computer-based growth model EARLY. There was a need to develop a model that could account for the effects of a wide range of silvicultural regimes that could compromise between minimising DOS and maintaining tree growth. EARLY was developed to quantify more accurately the effects of heavy thinning and green pruning. The model is used to predict stand growth up until mean height 18m, after this point one of the other regional stand growth models are chosen. The findings of West *et al* (1982) are outlined below:

- Pruning will generally reduce basal area increment;
- Tree stocking strongly influences the relationship between basal area increment and mean green crown length;
- Increases in green crown length have a diminishing contribution to basal area increment at higher stockings;
- The length of green crown active in the growing tree is related to tree stocking; and
- Basal area increment after thinning was found to be in proportion to the stocking and green crown.

Deriving the total length of green crown per hectare (mean crown length x stems/ha = km crown/ha), the stocking, and crown length relationship was the major variable for growth prediction, explaining both the pruning and thinning affects. When pruning results in the removal of "active" crown (below approximately 2.8km/ha), the reduction in basal area increment is directly proportional to the reduction in grown length. The drop in basal area increment is even more evident in trees that had severe prunings and high stockings. They were found to drop below the general relationship of basal area increment to crown/ha. When "partially active" crown (2.8 - 4.5 km/ha) is removed the reduction is less, and the removal of "inactive" crown (approximately above 4.5km/ha) the reduction in basal area increment is negligible. When trees are grown in a selective clearwood regime the pruned crop element is reduced in proportion to the basal area of the following element. Therefore delaying thinning can be expected to reduce the increment of the crop trees (West *et al* 1982). This further supports the prescribed regime in Section 2.5.3.3 for dealing with sites that have high basal area increments and low site indices.

West *et al* (1982) also found that height increment was not significantly affected by pruning or thinning treatments, so height growth can be simulated with existing site index curves. However, some individual spacing and stocking trials were examined, tree heights greater than 4m were observed as having a slight but consistent trend toward reduced height increment at lower stockings. This finding was also observed by Knowles *et al* (1992) and MacLaren *et al* (1995) who found that tree height was positively correlated with final crop stocking in certain circumstances.

West *et al* (1982) also found farm sites to have a larger basal area increment than forest sites. For example a crop standing at 2.5km of crown/ha on a forest site will grow approximately 3.2m^2/ha/year of basal area, while a farm site will grow approximately 5.1m^2/ha/year, a difference of around 40%. The EARLY model was then modified and extended to predict basal area at three levels of increment, low, medium and high (West *et al*, 1987). The particular level of basal area increment occurring on any given site seemed to be correlated with the fertility of that site. The basal area growth on most forest sites could be predicted using the standard or "medium" function, while the "high" function predicted the growth of trees on improved pasture. The "low" function was reserved for sites on grossly infertile and/or dry sites.

Although New Zealand has a relatively good coverage there is considerable variation in growth patterns within a region and even within a given site. Careful validation is therefore necessary to ensure that the models are not misused.

2.7.3.4 Growth Models Suitable For Farm Sites

Using EARLY allows the tree grower to determine the trade off between tree growth and pruning to achieve a desired DOS (Knowles *et al*, 1987). Farm sites are recognised as having improved growth rates, validation by Knowles and Koehler (1984) indicated that tree growth on a range of farm sites could be predicted using the high basal area function.

Mid-rotation growth modelling on farm sites has been limited to the older agroforestry trials. The Kiangaroa growth model (KGM2) and the Hawkes Bay growth model (NAPIRAD) were found to accurately predict the growth on a range of farm sites (West & Dean, 1988). Although there was little difference between the results West and Dean considered the growth model's structure and age. The KGM2 is representative of the 1975 data base and growth modelling expertise, whereas NAPIRAD incorporates the newer "state space" theory of growth with improved data. It was concluded that NAPIRAD is probably a more robust model to use when testing a range of stockings.

2.7.4 Investment Analysis

Once reasonable yields of log grade out turns have been determined economic analysis can be used to assess the feasibility of forestry development. Project evaluation is critical for selecting the most desirable investment options. A form of cost benefit methodology is necessary to determine the physical and financial resources needed in the project and the returns received from it.

Discounted cashflow analysis (DCF) is one of the most common means for appraising long term projects such as forestry. DCF is designed to assess the worth of a project, taking account of the timing as well as the amount of cash flows. The key assumption in DCF is that a sum of money today is worth more than that same sum in the future, because money can be invested to produce a larger sum in the future. In order to make comparisons between competing projects all costs and returns must be expressed in present day dollars. It is accepted practice to freeze financial data because of the difficulty associated with predicting the long term effects of inflation on costs and prices (Anon. 1994c).

Comparisons between investment projects involve discounting the costs and returns at a given discount rate, the reverse of compounding. This is done in order to compare projects at the beginning of the investment rather than at the end. Net Present Value (NPV) and Internal Rate of Return (IRR) are the two most common indicators applied when DCF analysis is used to evaluate projects (Anon, 1994c).

2.7.4.1 Net Present Value (NPV)

NPV is the sum of the discounted future revenues less the sum of the discounted future costs. In general a positive NPV indicates that the project is profitable and a negative NPV indicates a loss at the particular discount rate. When a number of projects are being evaluated the best proposition is the one with the highest NPV, at a particular discount rate (Fraser, 1995).

NPV is highly dependant on the choice of discount rate, it is also important that the same discount rate be used for all discounting in any one particular evaluation (Anon. 1994c). The choice of discount rate should generally reflect the forgone rate of return on the marginal project displaced by the investment in question i.e., the opportunity cost of capital (Fraser, 1995).

There are two simple ways used to determine an estimate of an appropriate discount rate, these include the cost of borrowing money and the return on alternative investments. If money is borrowed to finance the project then the lending interest rate can be used as the discount rate.

Return on alternative investments follows a similar principle, except the rate of return on money invested is used as the discount rate.

2.7.4.2 Internal Rate Of Return (IRR)

The IRR is the discount rate at which discounted costs equal discounted revenues, i.e., the rate at which NPV equals zero. The IRR is the same as the "interest rate of the investment" (MacLaren, 1993). In general, projects with an IRR higher than a predetermined discount rate are accepted, while those with a lower rate are rejected (Fraser, 1995). Provided all costs and returns are expressed in current dollar terms, and costs and returns move similarly with inflation the IRR is a real rate i.e., the rate can be achieved over and above inflation (van Rossen, 1995).

Most forestry investment analysis focus on the rate of return required or being achieved by the project. This is largely due to the difficulty of finding an acceptable discount rate. Also society expects a return on capital invested and forestry must provide a return on capital comparable to that being achieved in other sectors of the economy, or risk being denied access to capital altogether (Fisher, 1996).

2.7.4.3 Problems Associated With DCF Analysis

DCF analysis is an aid to the decision making process, not a substitute for it. The limitations arise in particular from the difficulty with data projection. While it is impossible to predict when, where and for what price the New Zealand forest or agricultural industries will be selling their produce in 25-30 years time it is possible to make some predictions.

Some of the problems associated with the use of DCF analysis include the choice of an acceptable discount rate and the selection of an acceptable return on investment. Despite the apparent acceptance of the opportunity cost as an appropriate means for selecting a discount rate, there is unfortunately no other simple and non-controversial way of determining an actual number. The discount rate used in New Zealand forestry has tracked closely around 6-8% over the past 25 years (Fischer, 1996). The choice of discount rate is largely a perception of an investors attitude towards risk (refer Section 2.7.5).

The choice of discount rate for economic analysis can have a considerable impact on the choice of forest regime and the financial results achieved. An increasing discount rate places an increased importance on early returns and a reduction in growing costs. An increased discount rate favours a low initial stocking, early thinning to waste, low pruning and a shorter rotation length (Knowles, 1990; MacLaren, 1990; West, 1990; Knowles & West, 1988). This is because costs are reduced and returns are realised earlier and therefore they are not as heavily influenced by time. As the discount rate decreases optimum stocking usually increases, indicative of the fact that the second and higher order logs become increasingly important as the trees become taller (MacLaren, 1990).

A stand is presumed to be financially mature when the increase financial yield drops below the required rate of return (Fischer,1996). Optimum rotation length varies between 25-35 years depending on discount rate and site index, and is relatively insensitive to final stocking and timber prices (MacLaren, 1990). Knowles (1990b), demonstrated that a discount rate of 10% showed pruning above 5.8m to be unprofitable, however pruning between 3.1m and 5.8m was more profitable than not pruning at all. Higher pruning is profitable at a lower discount rate (6%), longer rotations (30 years) and higher timber prices.

Similar to the problem of selecting an appropriate discount rate is to accept an appropriate rate of return on investment. Investors commonly seek returns in excess of 7% (8-10% most quoted), while domestic investments are often accepted from 4% to 7% (Fischer, 1996). The decision on the level of return is again the perception of risk and is not always overridden by economic criteria (e.g., sentimental value of land to a farming family). Typically a well located and managed forestry investment can achieve a rate of return within the range of 8-12% (van Rossen, 1995).

Historical data suggests that 4% per annum is an appropriate base discount rate to use for secure long term investments in the modern world. Despite this fact the rate used in New Zealand forestry valuation will normally exceed 4% (Fischer, 1996). This is due to expected rates of return from forestry and in certain instances the addition of a risk factor. The value of this risk factor is again an investor preference and takes account of their attitudes towards the risk of the investment proposal.

The main problem associated with using IRR is that it gives no indication of the dollar return on investment and takes little account of the risks involved. For example, an attractive investment option may be one that involves a large investment with a low rate of return versuse a smaller investment with high rates of return. Using IRR as a sole determinant for project selection in this case may contrast results based on NPV. A prime example is the comparison of farming with forestry. When comparing a farming with a forestry venture consideration has to be given to the two quite different cashflows, both in terms of scale and timing. Irregularities can occur when IRR is used, farming often generates a higher IRR but involves a much smaller investment, resulting in a lower NPV as this is the value of the investment after the specified discount rate has been earned. Farming returns can be represented as an annuity and will respond differently to discount rate as opposed to a lump sum payment such as forestry. Forestry NPV is therefore more sensitive to discount rate than is agriculture (Knowles & West, 1988). However, the use of NPV with an appropriate discount rate will give a better indication of maximising profit from a given area of land than will IRR (MacLaren, 1993). The choice of IRR over NPV will rely on the preferences or goals of the investor or landowners. Is it the return on capital that is the overriding factor or the revenue at maturity. In a farming situation there may be no opportunity of expanding into other areas or ventures other than those associated with the land. For a particular farming situation there is a known return on capital. This rate of return can be used as the discount rate in order to investigate the opportunities forestry may offer as an alternative landuse.

The use of DCF is a very contentious issue and involves very important decisions to be made early on that affect the future events of any investment project. The DCF process is subject to these early assumptions and given the long term nature of a forestry investment raises the concern over the choice of acceptable discount rates, IRRs and NPVs. This then ultimately leads to the selection or rejection of the investment proposal. There are, however, methods that can be employed to make allowances for this. Risk analysis can be used to measure the sensitivity of certain key elements to change that may affect the outcome of an investment proposal. Risk analysis can further aid in the decision making process.

2.7.5 Risk

A crop of trees represents 25-30 years of accumulated value. Over this time it is susceptible to both economic and environmental variability. A project can be accepted based on it's financial and technical feasibility. However, over time there is likely to be potential variation with respects to costs and revenues over and above inflation trends. Some of these risks can be accounted for in DCF analysis through the choice of higher discount and interest rates for an acceptance or rejection level of a proposed project. Risk analysis can measure the possibility of changes in an accepted or known occurrence. The appropriate adjustments can be made to costs and revenues to measure their effects. For example, what happens if the projected yields and stumpage are not attained, or if tending costs are exceeded? These questions can be addressed in a form of a sensitivity analysis.

The risks associated with forestry include:

- Management Risk - the risk associated with the performance of forest management, including timely silviculture the ultimately affects timber yield and quality.

- Market Risk - the variability of future market conditions in the future.
- Fire - from natural causes, negligence and arson.
- Wind Damage - causing stem deformation and toppling.
- Pest and Diseases - from already existent ones and the potential introduction of new ones.
- Financial Risk - from the changes in the financial circumstances of the investor or other partners (van Rossen, 1995).

Risk can be classified as business risk or financial risk (Gabriel & Baker, 1980). Business risk incorporates production risk (which impact on yields) and market risk (which impact on input and output prices). This is reflected in the variability of the net cashflows of the business. Financial risk is reflected in the added variability of net cashflows to owner equity. It is essentially the risk of being unable to meet prior claims on the business e.g., debt servicing (Martin, 1994).

2.7.5.1 Managing Risk

The objective of risk management is to avoid vulnerable situations while still achieving the highest possible returns for the owners of equity (Martin, 1994). Many of the production risks associated with forestry can be minimised through the use of appropriate management techniques including site selection, correct planting techniques and timely silvicultural management. The financial risks are harder to predict and the use of sensitivity analysis can give the investor an idea as to how conditions of the investment may change.

Since the deregulation of the New Zealand economy the economic environment facing pastoral farmers has changed dramatically (Lattimore & Tyler, 1990). With the removal of input and output subsidies the farmers are now fully exposed to the conditions of the market. This has lead to an increased exposure to the elements of risk especially market uncertainty. Farmers have now taken measures against certain risk factors in order to protect their business.

Risk management strategies can be classified as production, marketing and financial (Barry & Fraser, 1976; Sonka & Patrick, 1984). Production responses include the selection of enterprises with a low yield variability or diversification into alternative enterprises. A marketing strategy may include the selection of an enterprise with a low expected price variability and spreading product sales over time. A financial response may include matching payment structures with cashflows.

Although there are a number of risk reducing strategies not all of these are appropriate or available to the farmer. Hill country sheep and beef properties are relatively restricted to a choice of enterprise diversification. Forestry is one option and can be evaluated against other enterprises using a known return on capital. The major concern of a forestry investment is the profile of it's cashflow, this is especially important if the project is taken on as a sole investor. There is little income generated from the project until final harvest. During the first 8-10 years of the forestry venture there are considerable cash demands on establishment and silvicultural operations. Failure to meet these costs may result in an inability to maintain timely silvicultural management that will ultimately affect the profitability of the venture. Investors need to be aware of the cashflow demands of the project and accommodate them into the financial plan. This becomes increasingly important when forestry development is taken up in conjunction with farming, especially the labour requirements, the timing of there costs and the potential loss in productivity from the land in trees. The problem is cashflow and the ability of the farm to generate income over and above prior commitments. In a farming situation there is room to minimise these cashflow problems by using farm labour and utilisising grazing opportunities in about the first third of the rotation. Estate modelling procedures can help identify periods where there is an increasing strain on farm generated income (refer Section 2.7.6).

A landowner seeking to invest in forestry can minimise their risk and cashflow demands through the formation of partnerships, joint ventures and/or the sale of cutting rights. A partnership or joint venture is a contractual arrangement that can be set up in a manner so that both the growing costs and associated risks of the venture are shared. The sacrifice of this arrangement is that a share of the final harvest value is forgone by the landowner in order to pay the investor. It is also possible to exit early from a forestry investment through the sale of cutting rights at an associated cost of a forgone final harvest value.

DCF, growth modelling and risk analysis are useful for comparing alternative courses of action rather than providing an absolute measure of their outcome. Due to the time frame and cashflow profile of forestry investments the results of any project evaluation rely heavily on the accuracy of the inputed data to obtain useful and meaningful results for the decision maker.

2.7.6 Estate Modelling

Forest estate models are the modern form of the forest working plan that address the forest as a whole. A forest is a potential stream of future wood production with a range of options on how it can be managed and how much wood can be used at various times. A stand is an element of a forest and supplies wood to the usage system for only a brief period where as a forest can maintain supply for an indeterminate period. Stand management is intermittent, irreversible and quickly effected while forest management may be continuous, reversible, dealing in tendencies rather than specific results that have immediate as well as long term effects (Allison, 1995).

On an individual stand basis it is not difficult to determine optimal silvicultural regimes and rotation ages. Maintaining this rigid application of stand prescriptions may be far from optimal and produce unacceptable results for a forest as a whole. A project may be profitable in its entirety but not feasible when considering the allocation of physical and financial resources. There are likely to be fluctuations in annual timber production, revenues, and in labour, equipment and financial requirements for both harvesting and silvicultural operations (Garcia, 1995). Estate modelling provides a facility for simulating and evaluating the different effects of forest management, assisting in the planning and identification of preferable management strategies given the objectives and constraints of the system.

When forestry is combined with agriculture there is a mix of two distinctly different cashflows. There are key periods of cashflow for both the whole farm and forestry system. This is especially important considering the prior commitments that the farm cashflows have to satisfy, especially debt servicing. An Agroforestry Estate Model (AEM) has been designed to show the effects of a sustained planting and felling program on a farm's physical and financial flows - such as livestock carrying capacity, labour requirements, and cash flows for up to 100 years. This can then illustrate the physical and financial consequences of an agroforestry project compared to farming (Knowles & Middlemiss, 1992). AEM is useful for analysing sustained forestry, however, simple cashflow spreadsheets can be set up in order to identify cashflow demands, as well as financially evaluate forestry diversification. This form of analysis can be simple and affective, considering that the majority of forestry planted on farm sites has occurred in large one off or periodic plantings as funds become available.

2.8 SUMMARY

Forestry planted on high fertility sites, characteristic of farm sites, is potentially high producing, especially in the production of pruned butt logs. The increased fertility associated with these sites produces trees of larger diameters in comparison with similar regimes on traditional medium fertility forest sites. However, there are often problems associated with tree quality, in particular branching characteristics and stem malformations. This suggests that farm sites require different silvicultural techniques to those exhibited on traditional forest sites.

The increased diameter growth is also associated with increased branch sizes that can often make target DOS sizes hard to maintain in a clearwood regime. Maintaining a crop DOS of between 13-19cm and pruning to a crown length remaining of 3-4m at each lift has been identified as a good compromise between restricting the defect core without unduly penalising tree growth (MacLaren & Knowles, 1995). Farm sites are usually managed at the upper DOS and lower crown length limits. Generally, less fertile sites have lighter green crowns (i.e., smaller branches, fewer and smaller needles) and require greater lengths of crown to avoid substantial growth losses (MacLaren, 1993).

Modelling procedures using STANDPAK can optimise the variables of crown length and DOS site for given site conditions. EARLY and NAPIRAD provide the best growth model combinations for farm sites (West & Dean, 1988). However, the information used to derive these models may not specifically simulate growth for all farm site conditions. The use of site specific inventory data from existing trees can provide the necessary variables for accurately configuring the existing STANDPAK growth models and components. For example, EARLY has basal level adjustments that can be used to modify a particular sites fertility. The level of adjustment will vary between sites, so the use of inventory data, in particular basal area derived from DBH and stocking, can improve the accuracy in selection of appropriate basal area levels.

The problems associated with maintaining a defect core and restricting the number of pruning operations is further escalated on sites that have high fertility levels and low site indices. These sites have large diameter trees with little or no increased height growth, and are likely to require more pruning operations if 3m of crown is to left at each lift. Certain silvicultural techniques can be administered to reduce the number of required prunings, including increased stocking, delayed thinning, and increasing the severity of pruning. These interactions will suppress diameter growth and allow an increased control over target DOS. This type of interaction is likely to see basal area increments fall below a general basal area increment to crown height relationship, that is the reduced basal area increment will be more evident under this type of regime (West *et al*, 1982). In extreme cases severe prunings could grossly affect crop tree development or even cause problems with mortality.

However, trees that demonstrate a large DBH to height ratio are generally above this relationship (West *et al* 1982). This would suggest that a more severe pruning could be administered to trees managed on a farm site without the same detrimental consequences of suppressed tree growth to those managed on medium fertility forest sites. In fact a number of trees pruned under set height regimes were likely to have experienced prunings outside of this 3-4m crown length remaining realm.

Forestry development on farms can pose a number of problems in comparison to traditional forest sites. There are problems associated with silvicultural management decisions and using appropriate growth modelling procedures to quantify management affects. Using existing stand inventory data to configure existing STANDPAK growth models and components can improve the accuracy associated with modelling procedures. A Massey University farm property will be used in this research project to configure existing STANDPAK components. These configurations will be used to develop appropriate silvicultural regimes specific to the given site conditions, in particular the of low site index and high basal area potential.

Chapter Three: STANDPAK Configuration

3.1 INTRODUCTION

The objective of this section is to configure STANDPAK using existing growth models to best simulate the growth of a *Pinus radiata* stand at Massey Universities hill country farm, Tuapaka. The resultant configurations will be used to investigate the feasibility of forestry development applicable to the Tuapaka sheep and beef hill country unit.

STANDPAK has a range of growth models designed for a range of regional site conditions. However, for many regions outside of the Central North Island and Bay of Plenty, and in particular farm sites, growth models are unavailable. Therefore it is often necessary to configure existing STANDPAK growth models in order to simulate *Pinus radiata* growth for particular site conditions.

Tuapaka Farm is located south-east of the Manawatu River, on State Highway 57A, 13 km from Palmerston North. Altitude ranges from 60 to 340m above sea level. Average annual rainfall is 1500mm. The property has two distinguishing landforms, terrace flats adjacent to the State Highway and a hill block extending up into the flanks of the Tararua Range. The property is currently divided into two production units. A bull beef unit occupies 111 ha of terrace flats while a sheep and beef unit occupies 365ha of hill country (Zhi Liu *et al*, 1991).

The Tuapaka hill unit has a prominent scarp between 80-150m altitude separating it from the terrace flats. This scarpment is predominantly Halcombe hill and steepland soils (Pollok and McLaughlin, 1986). Zhi Liu *et al*, (1991) identified this area of the property as predominantly land use capability classes VI and VII. The scarp is classified as moderately steep to steep (25-35°), susceptible to erosion (in particular tunnel gully erosion), and as a consequence pasture production is low. Although soil erosion is not a major problem on this property Zhi Liu *et al*, (1991) have prescribed grazing under spaced tree planting and/or production forestry as an erosion control measure. On smaller areas consisting of steep gullies (>35°, class VIII) protection forestry has been prescribed.

The scarpment has been targeted for forestry development due to it's land use limitations. The STANDPAK modelling system will be configured using information obtained from an existing stand of *Pinus radiata* planted on this scarp. In 1973 a 12.5ha forest block was planted at around 1500sph. The stand was left unmanaged until it was thinned to waste in June 1990 to an average stocking of 290sph. The above information plus collected field inventory data was used in a configuration procedure using STANDPAK version 6.0 licensed to Massey University. The configuration procedure was used to determine model configurations using the growth models EARLY and NAPIRAD to best simulate the current growth conditions of the 12.5ha Tuapaka stand.

3.2 STANDPAK INPUTS

Given the wide variation within many stands it is often more accurate to obtain data from the stand under consideration. The "Guidelines for Field Estimation of STANDPAK Inputs" provided the necessary sampling and mensuration techniques for the data collection (MacLaren, 1996). Prior to sampling the stand for the field estimations it is often necessary to have an approximation of the variance and mean of the population. This provides the necessary information for determining the sample size required for the degree of precision in the final estimate (Fischer, 1995b). This preliminary information is collected from a pilot inventory.

In June 1995 the Forest Research Institute established four permanent sample plots (PSPs) in the Tuapaka stand. The height and DBH information taken from these plots was used as the pilot data to determine the optimum sample size consistent with achieving the required level of precision (refer Section 3.2.3).

3.2.1 Establishing Permanent Sample Plots on Tuapaka

Standards defined by Dean (1989), Ellis and Dunlop (1991) were used for the establishment and measurement of the PSPs. The procedures used were as follows.

3.2.1.1 Plot Location

The four plots were located in order to be representative of the stratum of the stand being sampled. The plots were established at least 15m in from the edge of the stand in order to remove edge effects. Tracks or gaps in the stand and exposed ridges were also avoided.

3.2.1.2 Plot Shape and Size

When the location of a plot was established, a tanalised marker peg was driven in, and labelled with tags for later identification. Circular plots were used due to their ease of establishment.

Approximately 20-25 trees are required throughout the life of the plot. More trees may be present if the plot has not yet been thinned to the final stocking. Therefore the size of the plot should be determined on the number of trees per hectare at final stocking or at the end of the plot life.

Plot areas were corrected for slope so that they are the correct size on the horizontal plane. The Tuapaka PSPs were 0.067ha (3) and 0.05ha (1). Tree stockings ranged between 17 and 21. These plot sizes are slightly below the minimum recommended in Table 3.1 in order to minimise the edge effects of the stand.

Table 3.1: Recommended plot size.

Final stocking (sph)	Plot size (ha)	Radius (m)
>600	0.04	11.28
300-600	0.08	15.96
200-300	0.10	17.84
<200	0.20	25.23

[Source: Ellis & Dunlop, 1991].

3.2.1.3 Plot Layout:

Plots were surveyed off in order to fix boundaries with all surveyed bearings and distances recorded. Starting at the plot centre peg a tape measure was run out (radius adjusted for slope). Certain trees were clearly inside the plot, and others clearly outside. For trees on the plot boundary, the tape is held at the same height on the tree as the position of the tape on the centre peg. The tree is included in the plot if more than half of the tree diameter is within the circle.

3.2.1.4 Tree Numbering:

Tree numbering began with the tree closest to magnetic north and proceeded tree by tree in a clockwise direction. The numbered trees tags are visible from the centre peg and placed 2cm above breast height (defined as 1.4m). This gives a reference point for the measurement of tree diameter at breast height (DBH). Alternatively a paint band at breast height could be used on each tree. It is often useful to have a map showing the exact location of each tree in the plot, as the tags can fade or fall off. This provides the ability to identify the position of every tree in the plot should it be neglected during its life.

3.2.1.5 Plot Measurement

It is important to use standard measurement techniques, so that data from different sources is comparable. The four PSPs were measured for DBH, mean crop height and crown height. During the data collection process the data recorder repeated back measurements to ensure they were heard correctly, reducing the possibility of errors.

Diameter

DBH was recorded for every tree in the plot using a girth tape and the details of diameter were recorded to the nearest millimetre.

Height

Height measurements are very time consuming, consequently sampling was limited to 10 trees per plot. These were selected to evenly cover the diameter range in the plot. Only live trees of normal form (i.e., not forked), not leaning and without broken or dead tops were selected. These sample trees were selected at the first measurement. A Suunto clinometer was used to measure the upper (top of the tree) and lower angles (in degrees) of inclination. A range finder was used to measure the slope distance from the tree. It is often difficult to precisely determine ground level at a distance from the tree. Consequently a datum point (using a survey staff) is necessary to measure the lower angle and slope distance. Tree height was then calculated using the above inputs in the following height formulae:

$$H = d \cos B (\tan A - \tan B) + c$$

where: A = upper angle (degrees)

B = lower angle (degrees)

d = slope distance (m)

c = datum height (m)

H = tree height (m)

Tree height was measured to the nearest 0.1m.

3.2.2 Results from the Pilot Inventory

The pilot inventory supplied the following data (refer Appendix One):

- 72 trees were measured for DBH with a mean ($\bar{x}$) of 39.8cm and standard deviation (s) of 6.7cm;
- 42 trees were measured for height with a mean ($\bar{x}$) of 22.4m and a standard deviation (s) of 2.1m;
- the stocking of the stand ranged between 254-340sph, average stocking was estimated to be around 290sph.

3.2.3 Field Estimation of the STANDPAK Inputs

The results from the pilot inventory provided the necessary information for further sampling in the collection of the field estimations for the STANDPAK inputs.

3.2.3.1 Sample Size

In general, it is better to maximise the number of plots and minimise the number of trees per plot to obtain greatest precision. This means that, if possible, there should be only one tree per plot (MacLaren, 1996). The formula that calculates the number of plots required in the main assessment is outlined below:

$$n = \left(\frac{100\,ts}{d\,\bar{x}} \right)^2$$

where: n = number of plots required;

d = the desired Probable Limit of Error (PLE) (%);

$\bar{x}$ = an estimate of the sample mean value;

s^2 = variance of the estimated sample mean value;

t = the appropriate value of t (refer Appendix One).

The Probable Limits of Error (PLE) is a term peculiar to New Zealand Forestry. The PLE refers to the confidence limits expressed as a percentage of the estimated mean. For example, a PLE of

10% at the 95% probability level implies that the true mean is likely to lie within 10% of the estimated mean 95 times out of 100.

When n has been calculated, it is necessary to determine a more accurate value of t from the t-table. The correct value of t depends on the value of n, which is required to calculate the "degrees of freedom" (n-1) used in the t-table. This new value was then used to recalculate a new value of n, a number of iterations were necessary until there was no change in the value of n.

A high level of precision was sought for the estimation of the stand height and DBH parameters. The PLE used for the inventory were 2.5% for the DBH and 5.0% for the height. These PLE were chosen to ensure sufficient samples were measured to obtain a good representation of the stand. It was more feasible to obtain a higher level of accuracy for DBH because it was a less time consuming variable to measure and formulae are available that can determine height from DBH.

Using the above formula the number of plots necessary to achieve the PLE at the 95% confidence level was calculated to be 60 plot heights and 180 plot DBHs.

3.2.3.2 Sampling

The sampling design and strategy used in locating the PSPs was considered inappropriate for the collection of field estimates necessary for the STANDPAK configuration. PSPs are established by the FRI for the collection and monitoring of *Pinus radiata* growth. The information collected from these plots is then used to develop future growth models for farm sites. PSPs are not always a true representation of stand growth because they are located within a stand so as to eliminate the bias of edge affects and any other site irregularities. Therefore a "structured walk" was considered a more appropriate sampling strategy for the Tuapaka inventory.

A "structured walk" is a form of systematic sampling. Systematic sampling involves the regular spacing of transect lines to ensure even coverage of a stand. The plots are then located at regular intervals along these transects (Goulding & Lawrence, 1992). The "structured walk" takes the form of a triangle, set out in such a manner so as to sample all parts of the stand (MacLaren, 1996). This sampling technique was considered necessary because of the inherent variability of the stand caused by edge affects.

The "structured walk" was designed in such a manner to ensure an even coverage of the 12.5ha forest block. The triangular walk began from an easy point of access and followed a predetermined map route through the stand. The 60 height and 180 DBH measurements were then taken at regular intervals along the route of the "structured walk".

Heights were calculated using the necessary height formulae and input data. A Suunto clinometer was used for angle measurements and a fibreglass measuring tape used to measure the horizontal distance from the tree. A fibreglass diameter tape was used to measure DBH. The collection of these field estimations was carried out in August 1996.

3.2.3.3 Tree Measurements

The results from the Tuapaka inventory were as follows:

- 180 trees were measured for DBH with a mean ($\bar{x}$) of 43.0cm (basal area 42.19m^2) and standard deviation (s) of 5.9cm;

- 60 trees were measured for height with a mean ($\bar{x}$) of 25.6m and a standard deviation (s) of 4.0m;

These results were then used to help configure existing STANDPAK growth models to best simulate the growth of the stand.

3.3 STANDPAK CONFIGURATION

The STANDPAK modules "Stand Growth", "Diameter Distributions", "Log Making" and "Log Grading" were used in the configuration and analysis process. The STANDPAK user guide was used as a guide in configuring each module (Anon, 1994b). The first step was to configure the "Stand Growth" module to best simulate the growth of the current stand. This information was then used in subsequent modules to grow the stand through to maturity. At harvest the resultant volume by log grade out turn was then assessed and valued.

3.3.1 "Stand Growth"

"Stand Growth" is a growth simulation program that is used to generate yield tables and explore the effects of altering silvicultural regimes. The module is made up of a number of main menu options including "Set Models", "Initial Stand", "Treatments" and "Grow".

3.3.1.1 "Set Models"

"Set Models" is used to specify the growth model, height model and tables for stand volume and monthly growth. This module provides access to the details of the various models that can help determine whether or not a given model or table is applicable to the given site or region. The combination of the EARLY and NAPIRAD growth models are recommended for use on farm sites (West & Dean, 1988). The EARLY growth model was used for the early growth set and then switched to NAPIRAD for the later growth set (refer Section 3.3.1.3).

The EARLY growth model has a selection of functions and adjustments, including basal area increment level, crown height function, a basal area increment adjustment and a DOS adjustment for each pruning lift (not applicable in this case). The level of basal area growth can be selected from a range of low, medium and high, with a ±20% level of adjustment within each increment. Unlike some of the growth models EARLY does not maintain a mandatory set of default models and tables. EARLY can be used in combination with any of the height models, stand volume and growth functions. NAPIRAD uses a mandatory height model (26).

3.3.1.2 "Initial Stand"

This is the starting point of the growth simulation and requires data for site index, establishment and starting date, stand height, stocking and basal area. The first step in the process was to estimate a site index for the Tuapaka site. "Initial Stand" has a built in calculator that allows the conversion between some of the data items displayed e.g., height can be calculated given site index and age. This calculator was then used to estimate a site index from the field estimates for mean crop height and age. The site index for Tuapaka was estimated to be 23 and was consistent with FRI site index estimations from the PSP data. This site index value was used for all subsequent simulations.

The "Initial Stand" was started at age 4 (minimum starting age in EARLY) because silvicultural treatments can not pre-date the age of the stand. This approach is necessary in order to simulate the affects of a high initial stocking (1500sph) and relatively late thinning (age 17 years). Initiating the stand at age 4 allows the early and later growth model sets to be configured to best simulate the growth of the current stand estimated from the field inventory data.

At this point the initial stocking, estimated final stocking and site index were inputed. The remaining stand heights (i.e., mean, mean top and predominant mean height) and basal area were estimated using the conversion calculator.

3.3.1.3 "Stand Treatments" and "Grow"

The next step was to input the stand treatments. The "Treatments" option allows a sequence of silvicultural treatments and simulation directives to be specified. The Tuapaka block had only one silvicultural treatment. The date and final stocking of the thinning were entered. The other directives stipulated at this point are the timing of the "Switch" to the later growth model set and the end rotation date (age 32.). The final step in the "Stand Growth" module is to select "Grow" from the main menu starting the simulation.

3.3.1.4 Model Configurations

The configuration process has began modelling a relatively unfamiliar site, however, some assessments of the site conditions can be made at this point. The site is ex-pastoral, of high fertility and therefore has a high basal area increment potential.

The process of configuration began combining EARLY with a number of different height models, stand volume, monthly growth, DOS and crown functions. The high basal area increment adjustment factor and the timing of the "Switch" directive to the later set of growth functions were also varied. The later growth set of NAPIRAD and height model 26 were also varied with different combinations of stand volume and monthly growth functions.

A number of different configurations were tested. At age 23.2 the height and basal area growth simulations were compared with the field inventory estimations. The major problem in the configuration process was the continual under prediction of basal area between the simulation and field estimates. The simulation that closest estimated the field inventory data was achieved using the following configurations.

- Growth Model (early set): EARLY (23); high basal area increment +20%; standard DOS function; and Beekuis crown function;
- Height model 26; stand volume function 22; monthly growth function 6 (proportionates the seasonal growth into each month);
- Growth Model (later set): NAPIRAD (9);
- Height model 26 (mandatory); stand volume function 22; monthly growth function 6; and the timing of the switch to the later set was at mean top height 18m.

The chosen height model, stand volume and monthly growth functions are all derived from growth data sets from the Hawkes Bay region. Combining these models with both the early and later growth sets gave the best simulation.

The above configurations estimated mean height at 25.7m (field estimate 25.6m) and basal area at 39.72m^2 (field estimate 42.19m^2) (refer Appendix One). These model configurations were then used to grow the stand through to maturity to attain log grades and yields necessary for further analysis. Prior to growing the Tuapaka stand through to maturity the stand parameter basal area was changed (age 23.2) in the "Treatments" option "change stand values" to that estimated in the field.

The remaining modules in STANDPAK including the "Diameter Distributions", "Log Making" and "Log Grading", were used to predict and assess the yields by log grade and the resulting value of the stand.

3.3.2 "Diameter Distributions"

"Diameter Distributions" calculates stand diameter distributions and average tree heights given stand age, basal area, mean top height and stocking. The main menu options include "Tables", "Stand Details", and "Distributions".

3.3.2.1 "Tables"

In order to generate diameter distributions a Weibull and monthly growth adjustment table are required. The "Tables" menu offers a set of Weibull tables with equations for predicting the variance of tree basal area and the slope of the tree height/DBH curve. Weibull table 13, representing Hawkes Bay data, was selected for the current and future simulations.

The monthly growth adjustment determines the growth adjusted age from year and month. This is necessary to fit the Weibull distribution to a stand at any point during the year. This has been previously selected in the "Stand Growth" module and is a default table in "Diameter Distributions".

3.3.2.2 "Stand Details" and "Distributions"

In the "Stand Details" menu an automatic clearfelling strategy was selected with six clearfell dates in annual increments starting at age 25. This was done in order to determine the optimum harvest age. The stand diameter distributions were then estimated using the "Distributions" menu option.

3.3.3 "Log Making"

The "Log Making" module cuts logs from trees belonging to one or more stand diameter distributions. Log quality variables measuring defect core, branch size, internode length, wood density and sweep are assigned to each log. The main menu options used in this module are "Tables", "Patterns", "Log Qualities" and "Cut Logs".

3.3.3.1 "Tables"

The "Tables" option was used to set the volume, taper and breakage tables. The tree volume and taper tables are used to estimate log dimensions and volumes. The breakage table estimates tree break heights on felling. There is currently no harvest information available for the Tuapaka stand. However, there are volume and taper tables that apply to *Pinus radiata* in the Santoft forest and region. These tree volume (212) and taper tables (212) were then selected. A no breakage table (2) was selected because there is little known about the breakage that could occur on the current site. The possibility of breakage occurring at harvest is compensated for in an estimated loss due to malformation (refer Section 3.3.3.2).

3.3.3.2 "Patterns"

A preferential log cutting strategy was created in the "Patterns" menu that produced an assortment of logs ready for grading in the "Log Grading" module (Table 3.2). The specification defines the limits for log dimensions and the maximum number of logs which may be cut to the specification. The logs are cut by these defined rules between the stump height (0.3m) and the break height in the tree. During the cutting process a log will be cut from the tree if it meets the requirements for a log specification. The preferential strategy means that if a tree fails to meet the requirements of a specification the next log specification is tried. The amount of waste between the logs is minimised as far as possible and if no further logs can be cut from a tree the remainder is all waste.

Table 3.2: Log Cutting Pattern.

Log Specifications	Pruned / Unpruned	Min. Length (m)	Max. Length (m)	Min. SED (mm)	Max. Logs
1	P	4	6.1	300	1
2	U	4	6.1	100	99

Although the current Tuapaka stand is unpruned a pruned specification was entered for future simulations. The second log specification is a general "catch-all" category with the smallest minimum SED in the log grade specifications and 99 as the maximum number of logs. This is to ensure that the maximum number of logs can be cut (Table 3.3) from a single tree.

The volume of each log was reduced by 3.0% due to malformation. This value was chosen to compensate for possible deformations that could be expected from growing trees on a farm site and damages that occur during harvest.

3.3.3.3 "Log Qualities" and "Cut Logs"

Log qualities are the physical properties of the log and are divided into site and regime dependent types. The site dependant qualities include sweep, internode index and basic wood density. The regime dependant qualities include branch index, maximum branch and defect core. "Log Qualities" allows levels of adjustments to be set for these physical properties.

The site dependant qualities are influenced by variations in stand site parameters such as site index. There was little information available about the Tuapaka site and its influences on these qualities, therefore a medium default value was accepted for the site dependant log quality parameters.

Regime dependant qualities are influenced by the regime type. The current stand was not assessed as part of a pre-harvest inventory so very little was known about the stand qualities. Similarly, for future simulations, the affects of proposed regimes can not be quantified so default values were accepted for the regime qualities.

The final step in the "Log Making" module is to cut the logs using the "Cut Log" option. The logs cut from each tree are assigned log quality variables.

3.3.4 "Log Grading"

The "Log Grading" module was used to grade the logs generated from "Log Making". The grades can be defined in terms of small end diameter, large end diameter, length, sweep, branch size, internode length, and whether the log is pruned or unpruned. The main menu options used in this module include "Specify Grades" and "Grade Logs".

3.3.4.1 "Specify Grades" and "Grade Logs"

The logs were graded using the "Specify Grades" menu to New Zealand domestic log grade specifications (Table 3.3). The logs are tested against each grade in the order in which they are specified. The grades were therefore entered according to value, the most valuable first and the least valuable last. Any log that did not meet any of the grade criteria was regarded as waste.

Table 3.3: New Zealand Domestic Log Grade Specifications.

Log Grade	Pruned or Unpruned	Small End Diameter (mm)	Lengths (m)	Maximum Branch (mm)	Sweep Class
P1	P	400+	4.0-6.1	NA	1
P2	P	300-399	4.0-6.1	NA	1
S1	U	400+	4.0-6.1	60	1
S2	U	300-399	4.0-6.1	60	1
S3	U	200-299	4.0-6.1	60	1
L1	U	400+	4.0-6.1	140	1
L2	U	300-399	4.0-6.1	140	1
L3	U	200-299	4.0-6.1	140	1
PULP	U	100+	4.0-6.1	NA	2

[Source: Anon, 1996c].

Default percentages were accepted for log volume down-graded to waste and to the lowest grade (Table 3.4) in the "Options" menu. Although the result from the percentage downgrade and malformation loss (set in "Log Making") are cumulative there is some expected loss in quality due to growing the trees on a high fertility site.

Table 3.4: Percentages Downgraded.

Log Grades	% Downgraded to lowest grade	% Downgraded to waste
Pruned	2	0
Unpruned	4	2

The log grades were then combined into different aggregations and used in an economic evaluation of the Tuapaka stand, using current New Zealand log prices (Table 3.5). The final step was to use the "Grade Logs" menu that allowed the Yield Table to be viewed.

Table 3.5: Indicative Log Prices for New Zealand Domestic Grades.

Log Grade	NZ$/tonne "at mill"	Average Price
P1	148-210	180
P2	111-162	136
S1	90-99	95
S2	70-88	80
L1/L2	56-85	71
S3/L3	58-66	62
PULP	35-55	45

[Source: Edmonds, 1996].

3.3.5 Prediction of Volume by Log Grade

The projected yield by log grade from the STANDPAK simulation is outlined in Table 3.6 (refer Appendix One). The net pre-tax returns from the stand ($/ha) were calculated using the log grade by volume data, their corresponding values and the harvest and transport costing outlined in Appendix Two.

Table 3.6: Projected log grade yields (m^3/ha) and net harvest value ($/ha) from Tuapaka.

AGE	S1	S2	S3/L3	L1/L2	PULP	Total	*DBH	Net $/ha
25	52.9	138.0	116.5	43.6	82.7	433.8	45.7	15,038
26	72.0	153.0	105.9	58.6	82.3	471.9	47.0	17,307
27	96.1	154.4	104.5	69.8	85.6	510.4	48.2	19,344
28	117.1	156.4	105.9	88.3	80.8	548.5	49.3	21,637
29	137.5	158.4	96.1	108.3	87.1	587.4	50.4	23,538
30	156.9	154.8	96.9	123.9	91.8	624.3	51.4	25,260

[* DBH at final harvest (cm)].

The results from the analysis are:

- Volume increasing with age;
- S1 Grade increasing with age;

- Value increasing with age.

The increasing total volume corresponds to an increasing volume of S1 and L1/L2 log grades. This result principally reflects the increased diameter growth that is occurring with age. The increased diameter growth produces a greater volume of timber especially in the larger diameter logs in the lower portion of the tree. After age 28 years there is a notable decrease in the S3/L3 grades and a corresponding increase in the volume of L1/L2 grades. The increasing diameter growth has resulted in a proportion of the smaller diameter S3/L3 logs attaining larger small end diameters of the next log grade category.

Maintaining the high stocking late into the rotation has had the effect of decreasing the total volume that could have been realised had thinning occurred earlier. However, the late thinning has improved the quality of the log grade out turn. The high stocking has suppressed branch formation producing a larger than expected proportion of S1 and S2 grade logs. At age 28 years the Tuapaka stand has an estimated net pre-tax value of $21,637/ha, equating to a total stand value of around $270,000. The income generated from this 12.5ha stand of trees may be available for financing current and future forestry development on Tuapaka.

3.4 GENERAL DISCUSSION

One major limitation has been identified in the use of STANDPAK for the current and future simulations. The software currently licensed to Massey has no allowance for the use of genetically improved planting stock. The current improvement is GF7. Future plantings will use improved GF material, improving site index and tree form. This improvement can not be measured with the current STANDPAK program. Using GF7 planting stock for future simulations will give an appreciation to the difficulties associated with silvicultural management on difficult sites, such as those conditions experienced on Tuapaka. The silvicultural management options identified to overcome these site constraints will be those of a worst case scenario and therefore could be improved upon with improved genetic stock.

Further difficulties were identified in the application of STANDPAK on current stand conditions. These included the prediction or estimation of quality parameters, losses due to malformation and percentage downgrades. The collected field inventory data provided the necessary information for the growth conditions of the stand. It was not a pre-harvest inventory so little is know about the harvest characteristics of the site. However, the estimates used are believed to be reasonable representatives of the current site conditions.

The model configurations developed for the STANDPAK simulation of stand growth and production will form the basis for investigating future forestry development. STANDPAK will be used to model the silvicultural options available for the given site conditions experienced on the Tuapaka sheep and beef hill country unit.

Chapter Four: Silvicultural Regimes

4.1 INTRODUCTION

This section will investigate and model a range of silvicultural options for the current Tuapaka stands and the preferred options for future plantings. The STANDPAK configurations developed in the previous section will form the basis for simulating this forestry development.

Recent *Pinus radiata* plantings have taken place in 1993 (10.8ha), 1994 (6.1ha) and 1995 (1.9ha). These were planted at 1000sph with GF 16 and 17 seedlings. A total area of 31.3ha has been planted, with future plantings expected to increase to around 68.0ha. The majority (48.1ha) of the current and future forestry development will take place on the scarpment described in Chapter 3.0.

4.2 STANDPAK INPUTS

STANDPAK will be used to simulate and develop suitable silvicultural regimes for the Tuapaka site. The approach will be to investigate two distinct regimes. A low cost and input regime with a lower final return (i.e., framing regime) versus an intensely managed regime with greater final value (i.e., clearwood regime).

The simulated regimes will be selected having considered attributes of their economic criteria, in particular NPV, IRR, final harvest value and the required silvicultural management. The timing and extent of the silvicultural operations will influence cashflow commitments, final crop production and value. There is no single solution or "standard regime" that satisfies all site variations. However, the approach of this report will be to analyse STANDPAK simulations of fairly typical regimes that could be prescribed for fertile pasture sites. Subsequent simulations will investigate available silvicultural options that simulate suitable regimes for the Tuapaka site conditions.

The STANDPAK configurations set for each module in the previous Chapter will be used for the following clearwood and framing regime simulations. This includes the adjustment to the growth model sets, the log cutting, and the log grading specifications.

In addition to the previous modules used in the configuration process the "Economic Analysis" module will be added to compare the financial aspects of each regime simulation. The "Treatments" option of the "Stand Growth" module will be used to implement the required silvicultural treatments.

4.2.1 "Stand Growth"

In the "Stand Growth" module the "Treatments" option was used to set the pruning and thinning directives, the switch models and end rotation directives were left the same.

The pruning directives were specified by prescribing the number of stems to prune and pruned height. The pruned height was specified as a length of green crown remaining. The scheduling of each pruning operation was specified by a target DOS. All stand ages were specified by calendar dates made up of a year and month. When using the EARLY growth model, DOS can be used to specify time. The corresponding stand age is calculated when the crop DOS matches the specified target DOS of 19cm (refer Section 4.3). The height of the DOS whorl and diameter of maximum branch were set to zero. This allows the EARLY growth model to calculate an estimate for DOS height at each prune.

The thinning intensity was specified by entering a residual stocking (after thinning) and using the thin to waste least pruned option. This option selectively thins the least-pruned elements of the stand first. The different regime simulations were grown through to maturity using the previously set configurations. These regime simulations were then compared using the "Economic Analysis" module.

4.2.2 "Economic Analysis"

The "Economic Analysis" module performs a discounted cashflow analysis for a number of removals. Of particular note will be the pre tax NPV, IRR and net revenue for the removals from the of the different silvicultural simulations. The economic analysis is performed for the removals specified in the "Diameter Distributions" module. The "Economic Analysis" does not distinguish between costs and revenues which occur at different times within the same year. This module is made up of a number of main menu options, including "Initial Data", "Costs", "Revenues", and "Analysis" that are to be used for the proposed simulations.

4.2.2.1 "Initial Data"

Under the "Initial Data" menu the "General Info" form was selected. In this form the "earliest age of stand management" was entered as zero (i.e., planting). An 8% discount rate was used as the rate at which all cashflows were discounted. The "area in addition to planted area", "initial and final land value", and the "percentages for sensitivity analysis" were set to zero because they were not necessary for a comparison betwwen the forestry regimes.

An 8% discount rate was chosen because it was considered to be an acceptable return on investment and to give a fair comparison between the different silvicultural regimes that are to be simulated. For example a high discount rate (10%) favours early thinning to waste, low final stockings, lower pruning heights and shorter rotations. In contrast 6% favours higher prunings, longer rotations and higher timber prices. An 8% discount rate would not be as biased toward either of the above silvicultural management techniques, therefore giving a fairer indication to a favourable management option.

4.2.2.2 "Costs" and "Revenues"

The "Costs" and "Revenues" menu options allow a library of cost and revenue data to be maintained. A cost and revenue item was created for the Tuapaka site.

The "Costs" menu is made up of treatment, growing, logging, and administrative costs. All the costings were interpreted from the Lincoln Financial Budget Manual (Anon. 1996c) (refer Appendix Two).

The treatment costs are associated with treatments entered in the "Treatments" form of the "Stand Growth" module. The treatment costs will include the pruning and thinning operations. The growing costs are in addition to the treatments from "Stand Growth" e.g., planting, pre and post planting weed control costs. These costs were calculated on a per tree basis and entered in the form on a per hectare basis.

The logging costs consist of felling and extraction, transport to market, logging overheads and roading. The roading costs are entered on a per hectare basis while the remaining logging costs were based on a volume removed per hectare (m^3/ha) at harvest. The terrain on which Tuapaka have developed their forestry may require cable logging, therefore a felling and extraction cost of \$20.00/m^3 was used. Transport to market was costed out at a flat rate of \$25.00/m^3 for all log classes, this equated to a transport cost of carting all produce to Wellington harbour. This cartage cost was assumed because of the uncertainty associated with the location of log processing facilities by the end of the crop rotation. A relatively low roading cost of $400/ha was assumed because Tuapaka already has a well established gravelled access track along the enscarpement. This track should only require upgrading in order to accommodate heavier vehicles and maintenance once it is installed.

The administrative costs can be entered as an annual charge and allows overheads to be entered as an individual cost in a specified year. In the following simulations an annual administration, insurance and pest control fee were entered.

In the "Revenues" menu a list of log prices can be created for the log grades entered in the "Log Grading" module. The revenues were set according to the indicative log prices for New Zealand domestic grades (refer Table 3.5).

4.2.2.3 "Analysis"

"Analysis" performs the economic analysis displaying a report of the results. The results include prices and yield data, cashflow analysis of treatments, clearfelling expenses, a discounted cashflow analysis (including NPV, IRR and a break even stumpage price), and a sensitivity analysis (if selected).

4.3 CLEARWOOD REGIMES

Pruning produces a knot-free clearwood log from the lower portion of the tree. This higher grade timber fetches a higher price premium in comparison to unpruned logs. A clearwood regime has a more demanding cashflow requirement and slows the diameter growth of the tree. However, the advantage of pruning is the production of quality clearwood timber, improving the income at harvest in comparison to a framing regime. In order to attain higher grade clearwood it is necessary to administer timely silvicultural management. The timing and extent of these expenses are very influential on the time value of the money invested and therefore the success of the forestry project.

The STANDPAK outputs from the clearwood regimes simulated in this section are outlined in further detail in Appendix Three.

The objective of pruning is to maximise the production of clearwood through the restriction of the defect core size. The timing and extent of thinning then allows this potential to be realised. Pruning operations are now usually scheduled on DOS because it is a prime determinant of the size of the defect core. The extent of each pruning operation is determined by the length of green crown remaining. This allows individual trees to be pruned on their own merits, unlike fixed lift pruning regimes that were prescribed to the whole stand.

However, a fixed lift clearwood regime was investigated in order to assess the affects of scheduling silvicultural regimes based on tree height. Of particular note is the affect on crop DOS and consequence size of the defect core. A fixed lift regime ignores the variability in individual tree height, with trees being pruned to fixed heights in usually 3 lifts. This is an older style of silvicultural managment administered to early New Zealand clearwood regimes and has been largely superseded by the CRL method.

The fixed lift regime was simulated to schedule 3 fixed lift prunes to 2.2m, 4.2m and 6.0m. These occurred at 5.8, 7.5 and 9.1 years of age. A thin to waste leaving 350sph was scheduled at the second prune. The pruning operations were based on MCH so as to leave an average CRL of about 2.8m.

The major consequence of a pruning scheduled by MCH involving fixed lifts was the lack of control over crop DOS. Crop DOS varied between 20.0 and 24.7cm largely because of the lack of control over branch size and diameter growth. The crop DOS is not uniform so the largest crop DOS attained in any one lift (i.e., 24.7cm) will determine the size of the defect core.

Although this simulation produced a very good final volume (769m^3/ha), having a large crop DOS will be penalised by a reduction in the total clearwood produced. Therefore, it is likely that a large proportion of the pruned logs would be severely downgraded. Scheduling the fixed lifts earlier to reduce crop DOS would result in the removal of too much green crown, especially in the smaller trees of the stand. This then results in a greater variability in individual tree diameter and heights by the next pruning operation (MacLaren, 1993).

There are, however, trade-offs between minimising the size of the defect core, restricting tree growth and the required number of prunings. A small target DOS is harder to maintain and achieves little if subsequent lifts attain larger DOS sizes. Maintaining a small DOS can be penalised by either the tree being revisited too often or being pruned too severely at each pruning lift. This will result in increased silvicultural costs and reduced volume growth.

There are a number of factors that affect the decision on target DOS size (usually 13-19cm) and crown length remaining (CRL) (3-4m). These include site characteristics (especially fertility), the cost of extra pruning lifts and the associated reductions in tree growth. On fertile sites pruning is usually scheduled at the higher end of the DOS range (19cm) and trees are pruned harder (CRL

3m) in order to control DOS and minimise the number of required prunings (MacLaren, 1993). It is therefore necessary to select a regime that is manageable for the given site conditions.

The objective of the STANDPAK simulations is to produce a uniformly pruned tree crop that maximises the amount of quality clearwood without unduly restricting tree growth. This is to be achieved by timely silvicultural management. The necessary pruning operations will be prescibed in order to restrict and maintain a uniform defect core. Thinning will be timed to allow the potential clearwood production to be realised. An important feature inselecting a regime will be to minimise the cashflow demands, especially the number of scheduled pruning operations. The aim being to administer between 3-4 pruning operations.

4.3.1 A Standard Regime (Regime 1)

Fertile sites, in particular farm sites often require different silvicultural treatments to those prescribed within the forestry industry. As a consequence a typical clearwood regime prescribed for fertile farm sites was followed (MacLaren, 1993). This simulation involved an initial planting density of 1000sph, an early thinning to waste, a target DOS of 19cm, pruning to a CRL of 3m and a final crop stocking of 350sph.

This simulation required an unrealistic number of prunings in order to maintain the target DOS (19cm). The first pruning operation commenced at age 4.7 years at an average mean crop height (MCH) of 3.9m, 380sph were selected for pruning. Ten pruning operations were necessary over the next 6 years. The final pruning operation occurred at age 10.2 years at an average MCH (pruned element) of 9.9m. At the second pruning operation 350sph were selected for future management. The stand was thinned once at age 6 years (fifth pruning) to the final crop stocking.

The resultant volume from this stand at age 28 years was 772m^3, with a net pre-tax value of \$42,600/ha. Although this is a respectable yield this particular regime has a pre-tax NPV of around \$840/ha at an 8% discount rate. This is low (refer Table 4.3) and is a reflection of the number of prunings required in order to maintain the prescribed directives.

4.3.2 Management Options

Ten pruning operations were regarded as excessive and costly, especially if contract labour is to be employed. However, the number of required pruning lifts can be manipulated through silvicultural management. In particular, the removal of more green crown at each pruning lift and delaying the thinning operation.

The first option investigated was to simulate a pruning that removed more of the trees green crown in the earlier stages of growth. This was achieved by reducing the CRL.

4.3.2.1 Reducing Green Crown Length (Regime 2)

Fertile farm sites produce trees that have vigorous diameter growth and consequent branch growth with little corresponding increase in height growth. The removal of green crown slows tree growth, in particular diameter growth (MacLaren, 1993). Therefore, reducing the amount of green crown remaining at each pruning lift should not only give a higher pruned height but suppress diameter growth and subsequent branch development. This will give an increased control over DOS size and should have the affect of delaying the scheduled pruning operations. Delaying pruning should allow the tree to attain an increased height so that by the next scheduled pruning an increased pruned height can be administered. This should reduce the required number pruning operations.

In "Regime 2" the green crown length was reduced from 3.0m to 2.0m for the first pruning lift and to 2.5m for the second pruning lift. This had the affect of reducing the required number of pruning operations to 5. The age and height of the first pruning were identical (i.e., 4.7 years and 3.9m), however average lift height was 1.9m compared to 0.9m for the standard regime.

Pruning the trees harder resulted in the delay of subsequent pruning operations. The second prune was not necessary until an age of 6.4 years when the tree was at a MCH of 5.7m versus 4.9 years and 4.1m for the standard regime. At the second prune the stand was pruned to an average CRL of 2.5m, this corresponded to an average pruned height of 3.2m versus 1.1m for the second pruning lift of the standard regime. The remaining pruning lifts were pruned to an average CRL of about 3.0m The final pruning lift occurred at age 10 years, corressponding to a MCH of 9.8m. The stand was thinned to a final stocking of 350sph at the second prune.

Pruning heavily in the first two pruning operations reduced DBH and branch size. For example, at a stand age of 10 years this simulation had an average DBH of 25.2cm and a maximum branch size at DOS height (5.5m) of 5.9cm (varied between 5.9 and 6.1cm for previous pruning operations). In contrast the standard regime had a DBH of 26.1cm and a maximum branch size of 6.0cm (DOS height 5.7m) that had varied between 6.0 and 6.4cm for previous prunes.

The resultant volume from this stand at age 28 years was 767m^3, with a net pre-tax value of $42,300/ha. The most significant change was the improved NPV, a reflection of the reduction in silvicultural costs. The NPV increased to $2266/ha, an improvement of almost $1,400/ha.

4.3.2.2 Delayed Thinning (Regime 3)

A delayed thinning will maintain the initial plant density for longer into the rotation than was experienced in regimes 1 and 2. This effectively increases the stocking and with an increased stocking there is an associated increase in height increment that begins form an early age (MacLaren *et al*, 1995). Branch growth is also suppressed as they come into contact with trees in close proximity (Tombleson *et al*, 1990). Therefore a delayed thinning is expected to have a resultant affect of improved height increment, while further suppressing both diameter growth and branch development.

Combining a delayed thinning with the removal of more green crown at pruning is proposed to give further control over DOS, delaying the pruning schedule. The delayed pruning schedule, complemented with the proposed increase in height increment should allow the tree to be pruned to an increased height at each lift. This is expected to further reduce the number of scheduled pruning operations.

The "Regime 3" simulation delayed thinning until the third pruning lift. The resultant affect was that only 4 pruning operations were necessary. The later thinning delayed the third pruning operation to age 8.4 years versus 7.8 years for regime 2. At this age the stand is taller allowing the stand to be pruned to an average CRL of 3.0m, this corresponded to an average pruned height of 5.0m. The stand received a final prune at age 10.2 years at a MCH of 10.2m versus 10.1 years and 9.8m.

The delayed thinning further suppressed both branch size and diameter increment during early stand growth. At about age 10 years the delayed thinned stand had a DBH of 23.5cm and a maximum branch diameter (at DOS height 5.2m) of 5.5cm. Maintaining a higher stocking later into the rotation also increased MCH by 0.4m at 10.1 years.

The resultant volume from this stand at age 28 years was 755m^3, with a net pre-tax value of $41,439/ha. Final volume and consequently value have been suppressed in comparison with the previous regimes. However, NPV is further improved to $2,475/ha, an increase of almost $200/ha over the 5 pruning regime (Regime 2).

4.3.2.3 Reducing the Ratio of the Pruned Element (Regime 4)

Reducing the length of green crown and delaying thinning has been the trend of the simulations so far. The observation made to this point is that the unpruned trees are having and increased influence on the pruned element of the stand. The presence of the unpruned trees has increased the competition between the pruned and unpruned element. So far only final crop stockings involving 350sph have been investigated, the best simulation being a 4 pruning regime. The proposal is to further increase the competition experienced by the pruned element within the stand. This will be achieved by selecting fewer trees for pruning during early stand growth and as a consequence a lower final stocking. This will effectively reduce the ratio of the pruned to unpruned element within the stand, and therefore increase competition. This is proposed to further suppress diameter and branch growth, while further encouraging height increment growth of the pruned element.

A regime was developed that scheduled 3 pruning operations. This was achieved through a reduced selection ratio of the initial pruned element to around 300sph and removing more green crown at the second pruning lift. This simulation was pruned to a CRL of 2.2m at the second prune versus 2.5m in Regime 3.

This simulation had a much higher ratio of unchecked trees. The unpruned trees have influenced the pruned element by further suppressing branch and diameter growth. In this simulation 330sph were selected for the first prune and 300sph at the second and third prunings. The second prune occurred at a similar age (6.5 years), however, more green crown was removed leaving a CRL of 2.2m. This corresponded to an average pruned height of 3.8m. The third and final pruning was scheduled at age 9.2 years, allowing the stand to be pruned to 6m leaving a CRL of 3.2m. A thin to waste leaving 300sph was also scheduled at the third prune.

This simulation further suppressed both branch and diameter size of the pruned element. At the final prune maximum branch size had been suppressed to 5.3cm. The DBH and MCH were 20.5cm and 9.2m.

The resultant volume produced in this simulation at age 28 years was 698m^3/ha, with a net pre-tax value of $39,461/ha. The decline in final volume and value is largely a reflection of the declined final crop stocking (refer Section 4.3.3.2). However, the NPV has further improved to

$2,681/ha, an increase of just over $200/ha over the 4 pruning regime (Regime 3). The improvement in NPV is a reflection of the reduced silvicultural costs associated with maintaining a lower final crop stocking (refer Section 4.3.3.2).

4.3.3 Alternative Regimes

Simulations so far have involved regimes with initial stockings of 1000sph and final crop stockings of between 300-350sph. This section will investigate alternative regimes, in particular the variation of stocking (both initial and final). The consequences of these different management options will be simulated, especially the affects on silvicultural management.

4.3.3.1 Initial Stockings (Regimes 5 and 6)

Two regimes involving initial stockings of 1200sph and 800sph were investigated in order to assess any benefits from planting at higher or lower densities.

Planting at 1200sph is expected to further increase competition within the stand. This is proposed to be beneficial in allowing more trees to be selected for pruning, allowing a higher final stocking to be attained and maintaining a 3 lift pruning schedule.

Simulations involving an initial stocking of 1200sph resulted in the development of a regime that maintained 3 prunings while attaining higher final crop stockings of 350-400sph (Regime 5). Having an initial stocking of 1200sph meant a higher proportion of unchecked trees could be maintained through to thinning. This had a similar affect to the simulation of Regime 4 in Section 4.3.2.3. Branch and diameter size were suppressed, the resultant affect being a delay in the pruning schedule necessary to maintain a crop DOS of 19cm.

At a final crop stocking of 350sph the first prune was scheduled at age 4.7 years, leaving a CRL of 2.0m (1.9m pruned height). The second pruning operation was scheduled at age 6.9 years, leaving a CRL of 2.5m (3.8m pruned height). The third and final pruning operation was scheduled at age 9.9 years, leaving a CRL of 4.0m. A thin to waste leaving the 350sph was scheduled at the third prune.

At the final prune maximum branch size at DOS height had been suppressed to 5.0cm and had varied between 5.0 and 5.9cm for previous operations. The DBH and MCH at the final prune were 20.1cm and 10.0m. The resultant volume produced from this simulation at age 28 years was 733m^3/ha, with a net pre-tax value of $40,187/ha and NPV of $2,512/ha.

Similar results were achieved with a final crop stocking of 400sph. The first prune occurred at age 4.7 years, second at 6.7years and the third at 9.7 years. The maximum branch size varied between 5.0 and 5.9cm. DBH and MCH were 19.8cm and 9.6 at the third prune. The resultant volume produced form this simulation was 767m^3/ha, with a net pre-tax value of $39,913/ha and NPV of $2,356/ha.

Planting at an initial stocking of 1200sph gives further control over DOS. This has been beneficial to silvicultural management allowing higher final crop stockings to be attained with only 3 pruning operations.

Simulations involving an initial stocking of 800sph resulted in regimes with similar affects to those of an early thinning in previous simulations. Two simulations were tested, both involved a final crop stocking of 350sph. The first simulation involved a late thinning at age 8.1 years (fourth prune) and required 5 pruning operations, the last at age 9.5 years (Regime 6 Table 4.3). The second simulation involved an earlier thinning at age 5.9 years (second prune) and required 6 prunings, the last at age 9.6 years.

In both of these simulations there was a loss in the control over DOS. Diameter growth improved and as a consequence so did branch size. Both of these regimes produced similar results, about 760m^3/ha with a final value of around $42,000. However, because of the additional prunings NPV had declined to $2,327/ha for the 5 pruning regime and $2,027/ha for the 6 pruning regime.

4.3.3.2 Varying Final Stocking

Four final crop stockings were investigated including 400, 350, 300 and 270sph. Regime 3 was used to analyse the 4 final crop stockings in order to assess the affects of maintaining different stocking regimes on the Tuapaka site. Regime 3 was used because a similar management schedule could be maintained for all the final stockings. The results of major interest are the affects on final volume, value and NPV. Comparing NPV will give an appreciation of the change in volume and value, and the additional costs associated with pruning extra trees. The results from these simulations are summarised in Table 4.1.

Table 4.1: The affects of final crop stocking on projected production, silvicultural costs and value at harvest.

Final Stocking (sph)	Volume (m^3/ha)	Net Income ($/ha)	*Silvicultural Costs ($/ha)	NPV $/ha
400	794.5	42,303	2,503	2,380
350	754.9	41,439	2,211	2,475
300	704.2	39,623	1,918	2,432
270	674.9	38,342	1,776	2,374

[*Includes the costs of the pruning and thinning operations].

As final crop stocking increases so to does the total volume, harvest value and silvicultural costs (pruning and thinning). NPV increases with increased stockings, however it declines above stockings of 350sph. After this point the increase in volume and value does not compensate for the increased costs associated with silvicultural management. An optimal final crop stocking appears to lie between 300-350sph.

As final crop stockings increase log quality improves in the higher portion of the tree, especially the S3/L3 log grade. This is a reflection of the suppressed branch size caused at higher stockings. Although total volume and log quality generally improves with an increase in stocking there is a diminishing return at harvest from the higher value P1 log grade (refer Table 4.2). There is a notable decline in the proportion of P1 logs above a final stocking of 350sph, however the total production of P1 and P2 logs remains relatively unchanged. This is influenced largely by the suppression in diameter growth caused at higher stocking. The suppressed diameter growth will have resulted in a decline in the average SED of the P1 grade logs. Therefore, reducing the proportion of logs attaining the necessary SED in the P1 category.

Table 4.2: Projected log grades as affected by final stocking.

SPH	P1	P2	S1	S2	S3/L3	L1/L2	Pulp	*DBH (cm)
400	189.0	94.5	1.6	6.7	138.0	227.8	137.0	51.2
350	202.4	69.5	1.5	4.9	115.9	229.9	130.7	53.4
300	209.5	45.6	1.5	3.4	92.5	224.0	127.7	55.7
270	213.7	31.3	1.4	2.7	61.5	228.9	135.3	57.6

[*DBH at harvest].

4.3.4 General Discussion

The six clearwood regimes investigated have been bought forward for further discussion, and include the following regimes:

Regime 1. A standard regime, 380sph selected in first prune, involved an early thin to final stocking 350sph at the second prune, stand pruned to a 3m CRL, and target DOS 19cm.

Regime 2. Identical to regime 1, except more green crown was removed at the first prune (2.0m CRL) and second prune (2.5m CRL).

Regime 3. This regime combined regime 2 with a delayed thinning (at the third prune), increasing the competition between the pruned and unpruned element of the stand.

Regime 4. This regime further increased competition by removing more green crown at the second prune (CRL 2.2m) and reduced the ratio of the pruned to unpruned element. This was achieved by selecting 330sph at first prune and a lower final crop stocking of 300sph.

Regime 5. This regime involved a higher initial stocking of 1200sph.

Regime 6. This regime involved a lower initial stocking 800sph.

The results form the six clearwood regimes (including the standard regime) are displayed in the following table.

Table 4.3: Results from the STANDPAK simulations for the clearwood regimes.

Regime No.	1	2	3	4	5	6
Planting density (sph)	1000	1000	1000	1000	1200	800
Final crop stocking (sph)	350	350	350	300	350	350
No. of prunes	10	5	4	3	3	5
DBH at last prune (cm)	26.1	25.2	23.5	20.5	20.1	23.6
Branch size at last prune (cm)	6.0	5.9	5.5	5.3	5.0	5.9
MCH at last prune (m)	9.9	9.8	10.2	9.2	10.0	9.2
DBH at harvest (cm)	54.1	53.9	53.4	55.5	52.6	53.6
Merchantable volume (m^3/ha)	772	767	755	698	733	761
Net harvest value ($/ha)	42,600	42,300	41,400	39,500	40,200	41,800
NPV ($/ha @ 8% DR*)	840	2,226	2,475	2,681	2,512	2,327

[*Discount Rate].

The general trend through regimes 1 to 4 is to delay the scheduled thinning operation and remove more green crown at each pruning lift. This has relatively unaffected the time horizon over which the pruning operations have occurred. The first pruning occurs at around stand age 4.7 years, while the final pruning occurs between stand age 9.2 and 10.2 years.

Delaying thinning and removing more green crown has resulted in an increase in competition between the pruned and unpruned element of the stand. The increased competition has resulted in suppressed branch sizes in the DOS whorl, suppression in diameter growth and improved height growth. The affect produced by suppressed branch and diameter growth delays the necessary pruning operations for the stand. In combination with the fact that the tree is now taller at each pruning lift the corressponding pruned height can be increased. This therefore, reduces the number of pruning lifts necessary to reach a 6m height. This is reflected in the improvement in NPV as the number of prunings decrease.

Pruning below about 3.0m of CRL produces a warning message in the "Stand Growth" module of STANDPAK. This relates to the large amount of crown removed. Crown length is the current predictor for basal area increment in the EARLY growth model and removing this amount of green crown could adversely affect tree growth. However, the crown length does not take into account the needle density, needle retention, or width of crown. These are all factors affecting the amount of foliage and photosynthetic capacity of the tree (McInnes, 1997). McInnes further suggests that, in general, trees with larger stem diameters tend to have greater amounts of foliage. For example a stand from a Taradale farm site that produced shorter fatter trees had greater amounts of foliage for a given crown length compared to trees grown on more traditional forest sites. These results suggest trees on high basal area sites can be pruned to lower CRL without the same effects as those on less fertile sites. The CRL left on higher fertility sites is likely to have greater amounts of foliage per unit of crown length and hence greater photosynthetic capacity.

Planting at higher initial stockings results in higher final stockings that can be pruned in 3 lifts. Planting 1200sph means that the unpruned competitive element is increased, allowing more stems to be pruned. Increasing the final stocking increases volume at harvest in comparison to Regime 4. However, the NPV has declined because of the additional costs early in the rotation associated with purchasing, planting, and releasing the extra seedlings. In contrast, planting at a lower initial stocking reduces the competition affect, increases the number of prunings and reduces the NPV in comparison with Regimes 3 and 4.

Increasing crop competition between the pruned and unpruned element has come at a sacrifice. The final harvest volume and value has declined. However, the number of pruning operations has significantly reduced and as a consequence the NPV has improved.

Regime 5 has a suppressed final volume in comparison with the other regimes of similar final stocking. This is due to a suppressed diameter growth at final harvest, caused by crop competition during the early stages of growth. There is also a notable decline in the proportion of the P1 log grade, a reflection on the reduced diameter at harvest (refer Table 4.4). In this regime the increased competition and costs suffered early in the rotation are not compensated by higher final crop stocking and volume. This is evident when comparing the NPVs with Regime 4 (refer Table 4.3).

Table 4.4: Summary of log grade out turns for the different clearwood regimes.

Regime No.	1	2	3	4	5	6
P1	213.1	210.0	202.4	206.1	188.7	206.1
P2	65.4	66.6	69.5	46.9	74.8	68.0
S1	1.4	1.5	1.5	2.0	2.8	1.5
S2	4.2	4.4	4.9	4.3	9.3	4.7
S3/L3	113.2	114.0	115.9	95.0	120.6	115.0
L1/L2	236.0	234.2	229.9	226.9	222.7	232.1
Pulp	138.9	136.5	130.7	117.3	113.9	133.4
Total	772.2	767.1	754.9	698.4	732.8	760.9

The selection process for the most appropriate clearwood regime was driven largely by cashflow criteria, in particular the number of required pruning lifts to attain a 6m height. The number of pruning operations and the extent of the silvicultural costs early in the rotation are reflected by the NPV values for each regime. The extent of the costs associated with early stand management is especially important considering the likely cashflow constraints involved with the running of the Tuapaka property. Regimes that involved more than 4 prunings were not considered as an option. Although in some instances these regimes have higher yields and values at harvest the number of pruning operations are excessive and costly. This is especially evident when the time value of the money invested is taken into consideration (refer to NPVs Table 4.3).

This leaves the regimes that involve 3 and 4 pruning operations. Again consideration is given to the cashflow requirements of each regime. A forestry regime involving 3 pruning lifts is likely to be more manageable than those that involve more pruning lifts. This is especially important considering possible cashflow constraints associated with running a farm business and the requirements of organising timely silvicultural management. This is increasingly important if contract labour needs to be organised. Selecting the 3 pruning regime requires a lower final stocking. This is necessary to achieve 3 pruning lifts. Although final harvest volume is lower the diameter growth per tree has improved, compensating for early growth suppression. This is reflected in the relative proportion of P1 log grades produced versus the 350sph regimes (refer Table 4.4). Given the Tuapaka site conditions and the financial and physical implications of all the clearwood simulations the 3 pruning regime (Regime 4) appears to be the most appropriate.

4.4 FRAMING REGIMES

This option was primarily investigated as an alternative to pruning. A framing regime would involve a simpler management structure, and reduce the cashflow demand by eliminating the major silvicultural costs i.e., pruning. This would then place less demand on farm generated income. However, the disadvantage associated with framing regimes is the lower final returns from the tree crop. This is associated with the production of no high value pruned logs.

The STANDPAK outputs from the framing regimes simulated in this section are outlined in further detail in Appendix Four.

4.4.1 Regime Options

An initial stocking of 1000sph was tested varying the timing of a once over thinning to waste. A production thin was not considered in these regimes because of the marginal returns associated with such a venture. STANDPAK was used in order to simulate the affect of varying thinning dates on final production and log grade out turn. The variation of thinning date was entered into the "Treatments" menu of the "Stand Growth" module. The "Economic Analysis" module was then used to assess the financial affects.

Thinning was to be scheduled late in the rotation, but to occur before a mean crop height of 14m. This approach was taken in order to improve timber quality through suppressed branch development (i.e., a late thinning) and minimise the possible risks from windthrow that can occur above a crop height of 14-18m (i.e., thinning before a height of 14m) (MacLaren & Knowles, 1995). This is especially important considering the windy climate experienced in the Manawatu (Burgess, 1986). A high final crop stocking of 400sph was chosen with the expectation of reducing branch size while still attaining respectable log diameters at a clearfell age of 28 years.

Two regimes were simulated using an initial stocking of 1000sph and 3 alternatives simulated using an initial stocking of 800sph. These regimes were all thinned to a final stocking of 400sph.

The regime simulations are outlined as follows:

Table 4.5: Outline of the management for the framing regimes.

Regime No.	1	2	3	4	5
Initial Stocking (sph)	1000	1000	800	800	800
MCH at thinning (m)	12.0	9.0	7.0	12.0	9.0
Age at thinning (years)	12.6	10.0	8.0	12.5	9.9

4.4.2 Results

The results from the STANDPAK analysis are summarised in Table 4.6.

Table 4.6: Summary of results from the STANDPAK simulations for the framing regimes.

Regime No.	1	2	3	4	5	12.5ha
S1	65.6	44.0	18.4	38.6	24.7	117.1
S2	75.5	41.1	13.5	48.4	25.3	156.4
S3/L3	135.6	126.9	105.6	131.3	122.5	105.9
L1/L2	421.9	517.3	569.9	502.8	565.6	88.3
Pulp	88.6	108.8	167.5	91.6	118.9	80.8
Total	787.2	837.3	874.8	812.8	857.0	548.5
*DBH	51.5	53.2	55.1	52.5	53.9	49.3
Net $/ha	18,797	18,846	17,610	18,524	18,509	15,026
NPV $/ha	1,100	1,082	1,038	1,196	1,157	NA

[*DBH at final harvest].

In general, a delayed thinning (MCH 12m) suppresses DBH and final volume at harvest in comparison to the earlier thinned regimes. There is however, an improvement in the volume of S1 and S2 logs produced. This trend is also noted between the 1000 and 800sph regimes. The improvement in log quality is a result of the suppressed branch development caused by higher initial stockings or a delay in thinning. Combining both of these management strategies (i.e., Regime 1) further improves log quality, reflected in the volume of S1 and S2 logs produced.

The log grade out turn from the 12.5ha Tuapaka *Pinus radiata* block was used to contrast the extremes of a high initial stocking and a very late thinning. These results show a drastic improvement in log quality. However, this improvement in quality is at the expense of a large decrease in volume. Using the same costs as for the other regimes, the improvement in log quality does not compensate for the loss in volume. Regime 3 was simulated in order to contrast a low initial stocking and an earlier thinning. The result was an increased volume at the expense of log quality. This regime has a contrasting affect to the current Tuapaka stand, the increase in volume has not compensated for the decline in log quality.

4.4.3 General Discussion

In general the timing of thinning is relatively forgiving on final crop value, except at the extremes. With a late thinning (i.e., age 17 years for the 12.5ha stand) log grade quality is improved and total volume is reduced. An early thinning (i.e., less than 8 years of age) improves total volume, however log grade quality is affected. These extremes show the influence of stocking on the suppression of branch and diameter growth. With higher stockings and delayed thinnings the decline in volume is attributed to a decline in DBH at harvest. Regime 3 has a DBH at harvest of 55.1cm, in contrast the 12.5ha Tuapaka block has a DBH of 49.3cm.

Although total volume is important, these stands have a decreased proportion of total volume in the higher valued S1 and S2 log grades. Perhaps the most important influence in selecting an appropriate framing regime for Tuapaka is the volume distribution amongst the log grades. With a framing regime there are no P1 or P2 logs produced, therefore the total volume produced from the stand is distributed amongst a smaller spectrum of log grades. This means the framing regime is targeting a smaller range of the total log grade market, and is possibly prone to more market risks. Therefore it is considered to be important to select a regime that produces a higher volume of S1 and S2 grade logs giving a better distribution of volume amongst all the log classes, spreading the possible market risk. Given that the current Tuapaka plantings have been planted at 1000sph the regime that best fits the above criteria is regime 1, the later thinning option.

4.5 REGIMES FOR FURTHER ANALYSIS

A pruning and framing regime have been selected from the STANDPAK simulations to contrast the demands on both management and cashflow requirements. These regimes will be investigated further to assess and compare their final returns at harvest and their respective returns on investment. The two regimes chosen for the Tuapaka site are summarised below.

- Clearwood regime: 1000sph initial stocking, 3 pruning lifts, target DOS 19cm, thinned to waste at the final pruning lift to a final crop stocking of 300sph, rotation length 28 years.

- Framing regime: 1000sph initial stocking, thinned to waste at a mean crop height of 12m to a final crop stocking of 400sph, rotation length 28 years.

The physical and financial outputs from these regimes are summarised in Table 4.7.

Table 4.7: Summary of the physical and financial analysis (pre-tax) for the chosen regimes.

	FRAMING	CLEARWOOD
Merchantable Volume	787m³/ha	698m³/ha
Net Harvest Value	$18,797/ha	$39,461/ha
Establishment Costs	$650/ha	$650/ha
Silvicultural Costs	$350/ha	$1,408/ha
Total Funds Required*	$1,000/ha	$2,058/ha
NPV (@ 8% DR)	$1,100/ha	$2,681/ha
IRR	11.2%	12.1%

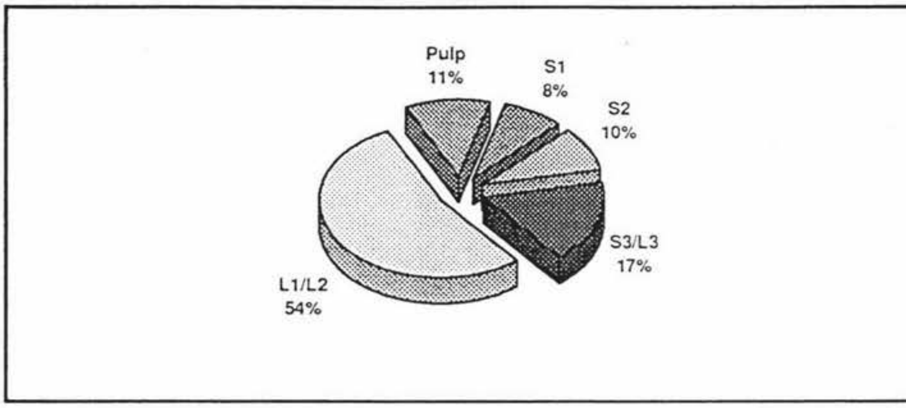
[*Excludes administration, insurance and harvest costs].

These regimes have different cashflow and management commitments. The framing regime requires about $1,000/ha over the length of the rotation. Of this, $650/ha is required for establishment and $350/ha for a thinning to waste. The clearwood regime requires about $2,000/ha. An additional $1,000/ha is required for silvicultural inputs, particularly pruning.

However, the clearwood regime is rewarded by an improvement in log quality and increased return at harvest. Although the total yield is reduced the additional investment required earlier in the rotation is reflected in the proportion of higher valued pruned logs produced. The clearwood regime produces a merchantable yield of 698m³/ha with a net pre-tax value of $39,461/ha. In contrast the framing regime yields 787m³/ha at a value of $18,797/ha. Figure 4.1 and Figure 4.2 show the relative proportion of logs in each log grade class.

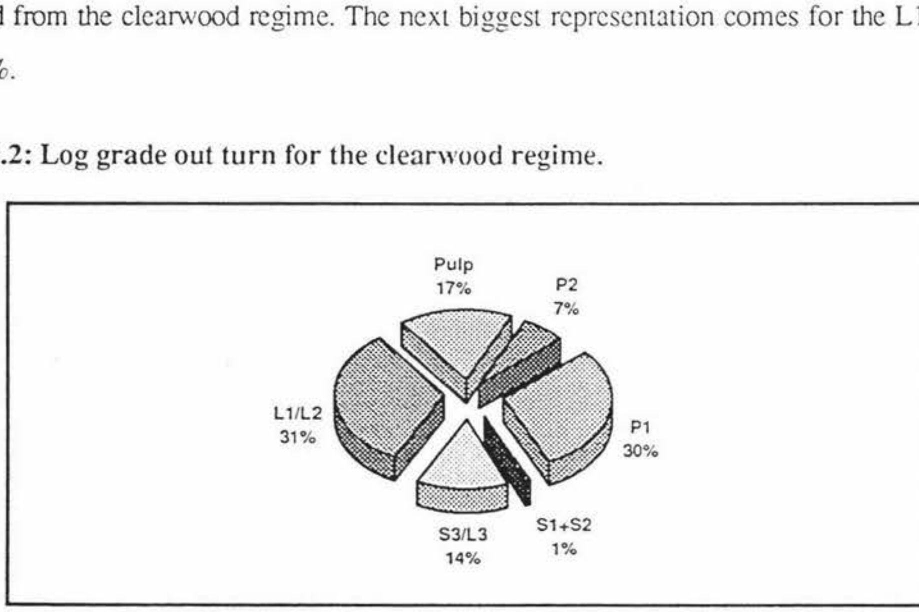
The largest proportion of logs in the framing regime come from the L1/L2 log class with 54%. This log class has a value of $71/m³. The higher value S1 ($95/m³) and S2 ($80/m³) only make up 18% of the total produced.

Figure 4.1: Log grade out turn for the framing regime.



In contrast the high value P1 ($180/m^3) and P2 ($136/m^3) logs make up 37% of the total volume produced from the clearwood regime. The next biggest representation comes for the L1/L2 grade with 31%.

Figure 4.2: Log grade out turn for the clearwood regime.



The clearwood regime has a similar pre-tax internal rate of return to the framing regime (12.1% vs 11.2%). However, the clearwood regime has a better return on investment with a pre-tax NPV of $2,681/ha at an 8% discount rate. In contrast the framing regime has an NPV of $1,100/ha. This is a reflection of the difference today between the investment required for each regime and the returns received at harvest. The clearwood regime requires a larger investment (i.e., silvicultural management) but produces a much larger return at harvest than does the framing regime.

The timing and extent of expenditure required during a rotation are very important to the success of a forestry project. Failure to meet or delaying the costs necessary for silvicultural management could result in a loss in potential returns. The cashflow demands become increasingly important if more than one stand of trees requires a prescribed silvicultural operation in the same year.

For Tuapaka the cash demands will need to be identified. This is particularly important considering that the farming enterprise will have to satisfy on farm commitments as well as financing the forestry development. The timing of Tuapaka's recent plantings are such that a number of stands will require silvicultural management in the same year.

Discounted cashflow techniques will be used in Chapter 5 to identify the physical and financial consequences of the farm forestry project. In particular the timing of the cashflows and the returns on investment. The regimes identified in this section will provide the management requirements and log grade yields for further project analysis.

Chapter Five: Tuapaka Forestry Analysis

5.1 INTRODUCTION

This chapter will analyse the current and future forestry options available for Tuapaka. This will involve the following:

- A cash budget analysis of the financial situation for the current livestock policy.
- An economic evaluation of the current forestry development with respects to managing a clearwood and framing regime.
- Investigating the future planting options available for the Tuapaka forestry development.

The silvicultural schedules developed in Chapter 4 will be used for the forestry development analysis. The objective will be to investigate the cashflows involved, particularly the timing and extent of cash required for further expansion. Of special importance will be the rates of return from the respective regimes and the future scale of forestry development, given that a source of project financing could come from the untended 12.5ha stand.

5.2 CURRENT FARMING SITUATION

5.2.1 Tuapaka Livestock Policy

Tuapaka is currently (1996/97 season) carrying a total of 3628 stock units at a stocking rate of 11.2 stock units/ha (effective area 324.5ha). The current sheep to cattle ratio is about 50:50, consisting of 1930 sheep (1835 stock units) and 366 cattle (1793 stock units).

The sheep operation is run with the aim of selling lambs onto the Christmas market with the latest being sold in January. In the 1996/97 season there were 1015 mixed age ewes, 442 two tooth ewes, 455 replacement ewe hoggets and 18 Romney and Suffolk rams. The lambing percentage is 115%.

There are presently two cattle policies being run on the farm. The first involves breeding cows with progeny sold as weaners. There are currently 69 mixed age cows and 18 rising one year heifers. The calving percentage is around 85%. A bull beef finishing policy currently runs 194 rising one year bulls, purchased annually and kept for a minimum of one year. About 110 are sold at 200kg carcass weight, the remainder are wintered and sold as rising three year olds at a carcass weight of around 266kg.

5.2.2 Cash Budget Analysis

The 1996/97 season figures were collected from the Massey University Farms Administration (pers. comm. Grant and MacDonald, 1997). A cash budget was then established for the year ending 30th June 1997 (refer Appendix Five). The financial information was then compared with a Ministry of Agriculture (MAF) North Island hill country sheep and beef model farm in the Wanganui-Rangitikei-Manawatu district (Anon. 1997a). This was done to give an appreciation of the current farming environment at Tuapaka. The MAF model farm is based on a property that has an effective area of 373ha, running 2,727 sheep stock units and 849 cattle stock units. This equates to a total of 3,576 stock units, at a stocking rate of 9.58 stock units/ha. The financial results forecasted for the 1996/97 season were based on farmer expectations and intentions in November 1996 (Anon. 1997a).

The results from the Tuapaka cash budget are summarised below.

Table 5.1:Tuapaka cash budget summary.

	Total	($/ha)	Monitor Farm ($/ha)
Net Farm Income	$108,137	$334/ha	$349/ha
Total Farm Expenses	$108,622	$335/ha	$284/ha
Effective Farm Surplus	$-485	$-1/ha	$65/ha
Net Taxable Income	-$13,985	$-43/ha	-

Tuapaka produced a net farm income of $108,137, or $334/ha (Table 5.1). This is comparable with the value forecasted from the model farm ($349/ha). However, the major difference between the two is total farm expenses. Tuapaka has a total farm expenditure of $335/ha, $51/ha more than the model farm. This expenditure is largely influenced by Tuapaka's fertiliser inputs, which totalled $24,640 for the 1996/97 season. This equates to $76/ha, $47/ha more than the model farm. Tuapaka repair and maintenance expenditure is also high in comparison with the model farm. High farm expenditure on Tuapaka has resulted in a low effective farm surplus (EFS) in comparison to the model farm (Table 5.1). However, this is not an unfamiliar situation and is comparable with similar sheep and beef hill country farms in the district over the past few seasons (Anon. 1997a). Although the current financial conditions are marginally sustainable, Tuapaka is well placed to take advantage of any improvement in price, primarily because of the current policy of maintaining fertiliser inputs. This may provide a farm surplus available for forestry investment.

5.3 CURRENT FORESTRY EVALUATION

5.3.1 Introduction

This section will investigate the silvicultural options available for the current 31.3ha of plantations on Tuapaka. The costs and benefits from these regimes will be forecasted overtime in order to assess the time value of money invested. A discounted cashflow analysis is used to determine the internal rate of return (IRR) and current value (NPV)of the respective regimes.

The forestry development on Tuapaka involves a number of different aged stands. This does not simply involve the analysis of one stand of trees over one rotation length as is the case of many forestry prospecti. For the purposes of a project evaluation it is necessary to take a window of time involved in the investment period (i.e., fix a starting and end point for the project). This is necessary for an economic evaluation of the current forestry development using discounted cashflow techniques (pers. comm. Shadbolt, 1997). The cashflow analysis will be setup over a 28 year time horizon i.e., the equivalent of one rotation length. This will begin in 1993 (when the first of the new plantings began) and end in 2021 (when the first of the new plantings are to be harvested). The procedures involved with the economic evaluation of the Tuapaka forestry diversification are outlined in the following sections.

5.3.2 Financial Information

A forestry cashflow spreadsheet was setup using Microsoft Excel, and forecasted over a 28 year time horizon (refer Appendix Five). The costs and returns used in the project analysis are based in 1996 dollars and are not inflation adjusted. This is the same as assuming that inflation will effect costs and returns in a similar manner. Therefore the financial results expressed in this project are the real returns that can be expected from the forestry development.

The planting program on Tuapaka has resulted in plantations of various ages at the beginning and at the end of the 28 year time horizon. These trees have a value within the project, even though the income from their harvest is yet to be realised. The financial data required for the project evaluation, including the valuation of unharvested trees are outlined in this section.

5.3.2.1 Annual Costs

These costs include insurance, administration, and pest control. These costs total $30/ha/year throughout the duration of the rotation.

Fire insurance is based on expected tree crop value and increases annually, this is expected to range from $5-$25 over the rotation length of the stand. Pest control and the administrative costs peak early in the rotation and decrease thereafter. A total annual cost of $30/ha is therefore assumed to be a reasonable estimate for the duration of the forestry project.

5.3.2.2 Forest Management

The silvicultural costs are the same as those in the STANDPAK simulations (Chapter 4) and are outlined in Table 5.2.

Table 5.2: Silvicultural costs and the year in which they occur.

	Cost $/stem	Cost $/ha	Year Cost Incurred
Seedling Purchase	$0.20	$200	0
Planting	$0.25	$250	0
Releasing	$0.20	$200	0
Prune 1	$1.10	$363	4
Prune 2	$1.35	$405	6
Prune 3	$1.70	$510	9
Thinning (Clearwood)	-	$130	9
Thinning (Framing)	-	$350	12

The establishment costs are the same for both regimes as they are both planted at an initial stocking of 1000sph. The difference between the two regimes is the additional silvicultural costs associated with the clearwood regime in years 4-9. The thinning costs are different for each as the framing regime involves a later thin and requires a selection to be made. The clearwood regime involves the thinning of younger trees with the selection of trees already decided upon in earlier pruning management. The silvicultural scheduling has been taken from the STANDPAK simulations for the respective regimes and occur in the prescribed year from the date of planting.

5.3.2.3 Harvest Costs

The harvest costs are the same as those used in the STANDPAK analysis. They include $20/$m^3$ for logging and loading, $25/$m^3$ for transport, and $400/ha for roading. An additional cost brought into the project evaluation is a commission cost for marketing and selling the logs produced. The commission is assessed at 5% of the pre tax revenue received from the stand.

5.3.2.4 Land and Tree Valuation

In order to evaluate the forestry development on Tuapaka as an investment project the land and trees involved in the project need to be valued. New and existing plantations were brought at the start of the project and sold at year 28.

Although Tuapaka is freehold, land designated for forestry has an opportunity cost associated with it, based on income from farming for example. The property has a current land valuation of around $1,620/ha, based on $150 per stock unit (pers. comm. Grant, 1997). The land identified for forestry development is largely land use capability classes VI to VII, and consequently has a lower livestock performance than the remainder of the property. For the investment analysis the land to be planted into trees has been valued at $1,000/ha, and is considered a reasonable value given these constraints.

The purchase price of the land is entered in the year in which a designated area of the property becomes planted, it is then sold for the same value at the end of the project term. The purchase and sale of the land in the project is not taxable.

The project term begins in 1993 at year zero with 12.5ha of trees 8 years from harvest. Existing plantations (land value excluded) were valued by discounting the pre tax harvest revenue at a set discount rate to the year in which they enter the project (refer Appendix Five). The NPV of the 12.5ha of standing trees is estimated at $125,272 at an 8% discount rate. This value is entered into the project at year zero. This discount rate was chosen because it was considered an acceptable return on investment, and necessary to give a fair comparison between the clearwood and framing regimes.

For the project evaluation purposes the tax paid at harvest for this particular stand is tax at the marginal rate on the difference between the harvest revenue less the purchase price in year zero.

However, this is not the tax that will be paid by Tuapaka in year 2001. The post tax revenue received by Tuapaka will be the full harvest value less taxation at the marginal tax rate.

A similar method was used to value the unharvested trees in year 28 (refer Appendix Five). The pre tax cashflows associated with one hectare of trees were discounted at a rate of 8%. The corresponding NPVs for each stand were then established by multiplying the unharvested area by the appropriate NPV/ha. These values were then used as the sale price of the trees in year 28 of the project evaluation.

5.3.2.5 Tax Legislation

Current New Zealand tax legislation allows virtually all expenditure on forestry establishment and ongoing costs to be deductible against other New Zealand income. The costs of forest establishment such as planting, pruning, thinning and overheads including insurance are deductible against income from other sources in the year in which they are incurred. The forest management costs and overheads will cause the forest to return a loss if there is no associated harvest revenue in that particular year. This loss can be applied to reduce other taxable income. This means that if the forest owner is in a position to fully utilise the possible tax benefits the actual costs incurred in the forestry project are reduced by the marginal tax rate.

If the forest owner is unable to utilise the tax benefits in the year of occurrence, the credits not previously deducted can be accumulated into a "Cost of Bush" account. This "Cost of Bush" account is not deductible for taxation purposes until assessable income is derived from the sale of timber.

5.3.3 Project Evaluation

The clearwood and framing regimes were evaluated and compared using the a discounted cashflow technique for the 28 year time horizon (refer Appendix Five). The cashflows from the livestock were excluded in these calculations.

Table 5.3: Summary of the pre and post tax returns (utilising tax benefits) for a clearwood and framing regimes (planted area 31.3ha).

	Clearwood	Framing
IRR (pre tax)	9.11%	7.61%
IRR (post tax)	7.78%	6.18%
NPV @ 8% DR* (pre tax)	$30,827	$(7,432)
NPV @ 5.4% DR* (post tax)	$79,434	$18,248

[*Discount Rate].

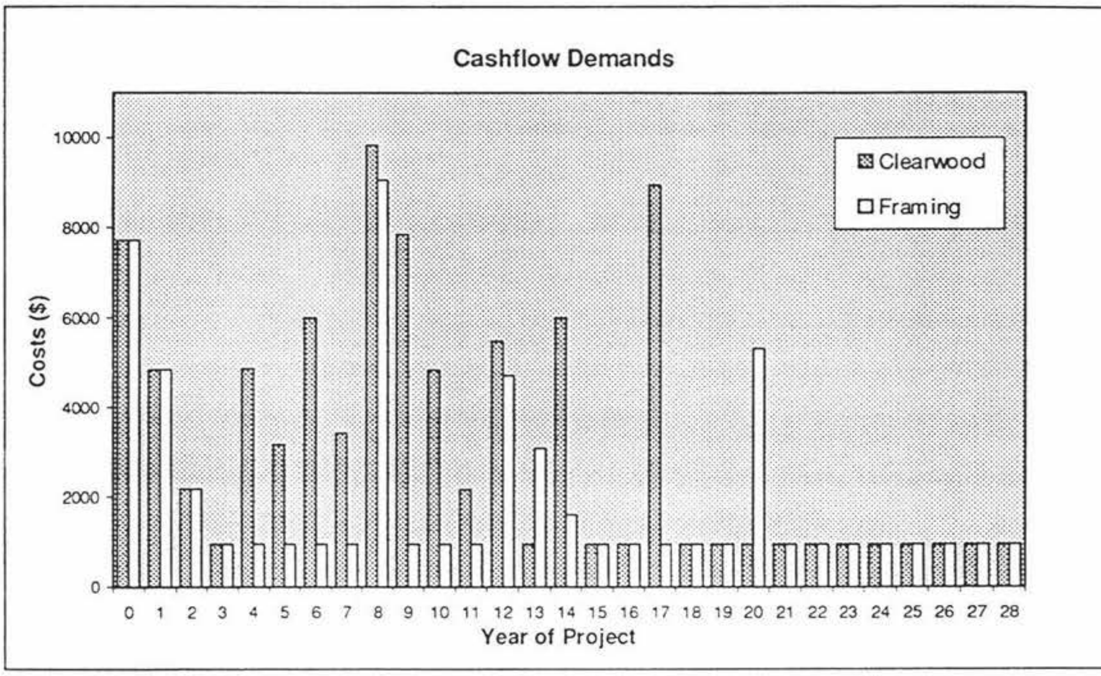
The 31.3ha clearwood regime has an IRR of 9.11% pre tax, and 7.78% post tax (Table 5.3). This project has a pre tax value in year 28 of $1,152,897 arising from total funds invested of $247,921 over the full term. The NPV of this project is $30,827 pre tax and $79,434 post tax, using pre and post tax discount rates of 8.0% and 5.36%.

The two discount rates are different pre and post tax because the tax payments made in the post tax cashflow require the discount rate to reflect interest on the tax credits at the marginal tax rate. This means the actual discount rate used on the post tax cashflow is the pre tax discount rate less the marginal tax rate (i.e., $i(1-t)$ where i = the pre tax discount rate and t = marginal tax rate) (Lawrence, 1991).

The framing regime has an IRR of 7.61% pre tax, and 6.18% post tax. This project has a pre tax value in year 28 of $645,783 arising from total funds invested of $214,806 over the full term. The NPV of this project is $-7,432 pre tax and $18,248 post tax. The total value of these projects include a pre tax revenue of $244,091 received in year 8 (2001).

The actual costs incurred by Tuapaka (land value excluded) over the duration of clearwood project total $91,349. The annual costs range between $939 and $9,834. Crucial demands on cashflow are experienced at establishment and during silvicultural management (years 0-17), where the costs range from $2,174 through to $9,834 (refer Figure 5.1). The pre tax value of the trees produced in this project total $1,121,597, of which $484,864 is unharvested.

Figure 5.1: Cashflow requirements for the clearwood and framing regimes.



The total costs incurred in the framing regime were $58,234. The annual costs ranged between $939 and $9,064. However, the cashflow demand is different from that of the clearwood regime. The crucial demands on cashflow are experienced at establishment, and during thinning where the costs range from $2,174 to $9,064 (refer Figure 5.1). The pre tax value of the trees produced in this project total $614,483, of which $203,971 is unharvested.

The post tax calculations used in this analysis were based on the ability to fully utilise the tax benefits. A post tax financial analysis for each regime was investigated for investors that were not in a position to utilise tax credits in the year of occurrence. This results in a delay in the taxation benefit as it is carried forward until such time as significant revenue is derived. The post tax IRR for the clearwood and framing regimes are 7.34% and 5.84% respectively. The resulting IRRs are about 0.3% to 0.5% lower than those calculated with tax benefits. Without tax benefits in the year of occurrence the NPVs have dropped to $66,936 and $10,892 for the clearwood and framing regimes respectively. This was calculated at a post tax discount rate of 5.36%.

5.3.4 General Discussion

The clearwood regime has given the better returns on investment. The clearwood option has a post tax IRR of 7.78%, in contrast the framing regime has an IRR of 6.18%. This is a 1.60% difference and is very significant if large sums of money are invested into a project. The clearwood regime requires a larger scale of investment over the term of the project in comparison to the framing regime. However, the higher demand on cashflow is rewarded with increased returns at harvest and better returns on investment.

Taxation significantly improves the profitability of these forestry ventures. However, under the current farming conditions, Tuapaka is not in a position to fully utilise the available tax credits. Tuapaka is therefore likely to experience a return on investment of between 7.24% and 7.78% should the clearwood regime be implemented. The IRR achievable will depend on the profitability of the livestock enterprise over the period of the project, in order to utilise the taxation benefits. However it should be noted that the current tax legislation may change during the 28 year duration of the project.

Tuapaka is in the position of realising revenue early in the term of the project. In year 8 (2001) 12.5ha of unpruned trees planted in 1973 will mature. This is expected to produce a pre tax return of $244,091, which equates to $163,541 post tax at a marginal tax rate (33%). This revenue may be available to finance the development of the existing immature plantations. For example $91,349 is required to finance silvicultural costs associated with a clearwood regime over 28 years. This means the remaining $72,000 may be available to finance future plantings on the remaining area of Tuapaka identified for conversion to forestry.

5.4 FUTURE FORESTRY DEVELOPMENT

This section will investigate increasing the scale of the clearwood forestry investment on Tuapaka to a total area of 68ha. The additional 36.7ha will be planted in annual increments from 1998, finishing in 2004. In year 2001 the 12.5ha of harvested trees will be assumed to be replanted and managed under a clearwood regime. The plantings will be coordinated on a per paddock basis, the proposed planting schedule is outlined in Table 5.4.

Table 5.4: Proposed new planting schedule by year and area.

Year	1998	1999	2000	2002	2003	2004
Area	6.7ha	5.3ha	5.0ha	7.0ha	10.1ha	2.6ha

5.4.1 Project Evaluation

The financial indicators from this project are summarised in the following Table (refer Appendix Five).

Table 5.5: Summary of the pre and post (utilising tax benefits) tax (planted area 68ha).

	Clearwood (68ha)
IRR (pre tax)	9.40%
IRR (post tax)	8.18%
NPV @ 8% DR* (pre tax)	$54,227
NPV @ 5.4% DR* (post tax)	$131,632

[*Discount Rate].

The 68ha option has an IRR of 9.40% pre tax, and 8.18% post tax, resulting in a pre tax value in year 28 of $1,859,849 from total funds invested of $383,292. The NPV of this project is $54,227 pre tax and $131,632 post tax.

The actual costs incurred by Tuapaka over the duration of this project total $190,020. The annual costs now range between $2,174 and $15,553. Crucial demands on cashflow are experienced in years 6, 8-11, and 14-17 where the costs range from around $10,000 through to $15,500. The pre tax value of the trees produced in this project total $1,791,849.

Taxation has a significant effect on the profitability of the forestry venture. If the tax benefits are unable to be utilised the post tax IRR drops 0.74% to 7.44%, and the project NPV drops around $30,000 to $100,352. The IRR achievable in this project is likely to range between 7.44%-8.18%, depending on the profitability of the livestock enterprises.

An important consideration for this planting program is the ability of the project owner to meet the underlying cashflow demands. Total costs incurred are around $190,00. In year 8 of the project a post tax revenue of $164,000 is received that could be made available for financing the expansion. This would leave the project with a deficit of $27,000 if it were to be solely financed from this source. The feasibility of increasing to this scale of forestry development has not been investigated. However, the 68ha option appears to be more profitable than the 31.3ha project. Increasing the scale of investment has improved the rates of return and the worth of the project in year 28.

Chapter Six: Discussion and Conclusions

6.1 INTRODUCTION

The forest industry has become increasingly popular as an investment option for land owners and private investors. Predicted returns from forestry compare favourably with other land based investment options resulting in an increasing rate of conversion of farmland into forestry, particularly hill country sheep and beef properties. This conversion has occurred through farmers establishing small woodlots and private investors buying properties for forestry investment purposes.

The expansion of forestry onto farmland introduces the need to investigate and evaluate appropriate forest management opportunities, particularly the silvicultural management of *Pinus radiata*.

Massey University currently has 31.3ha of *Pinus radiata* planted at Tuapaka, this equates to about 10% of the farm in forestry. Of this total 31.3ha, 12.5ha is nearing maturity, the remaining trees are now reaching a stage where decisions on silvicultural management are necessary. The objectives of this study were to develop an understanding of how *Pinus radiata* grows and behaves, especially on high fertile sites characteristic of farmland. The appreciation of these characteristics were utilised to investigate and evaluate silvicultural options available for Tuapaka. This was achieved with the use of the New Zealand Forestry Research Institutes stand evaluation package - STANDPAK. However, before these objectives were addressed it was necessary to configure existing growth models that have been primarily derived from traditional forest site data.

6.2 STANDPAK CONFIGURATION

STANDPAK simulates the growth and quality of *Pinus radiata* stands, and calculates yield by log quality class. New Zealand has a relatively good regional growth model coverage. However, considerable variation can exist in growth patterns within regions and even within a given site. Many regions outside of the Central North Island and Bay of Plenty, and in particular farm sites are limited to the use of existing growth models.

It is often more accurate to use existing stand data to configure STANDPAK for specific site conditions, rather than to accept the default values for existing growth models and quality parameters (MacLaren, 1996). This information can be collected from a stand under consideration using forest inventory methods. A 12.5ha stand of unpruned trees planted in 1973 on Tuapaka provided the necessary stand variables of mean crop height (MCH), diameter at breast height (DBH), and crop stocking for the configuration process. The permanent sample plots established in 1995 by the Forest Research Institute provided the necessary pilot data for the inventory.

The Tuapaka site has been under improved pasture and has had regular applications of superphosphate so is expected to be a high basal area site. On high fertility sites *Pinus radiata* grows and behaves differently to how it does on traditional medium fertility forest sites. The potential productivity from farm sites is high, largely due to it's improved fertility. Trees grown on high fertility sites generally have larger diameters, and are therefore classified as high basal area sites.

6.2.1 Site Index

Site index at Tuapaka, estimated from height data collected from permanent sample plots and the field inventory data, was 23m. This is lower than expected. Estimates for similar sites in the Manawatu are around 28m (pers. comm. Haggitt, 1997). This result may be a combination of site exposure and lack of early weed control. It is known that continual exposure to windy conditions and early weed suppression can incur marked reductions in height growth (MacLaren & Knowles, 1995; Davenhill *et al*, 1996).

The Manawatu region is characterised by a windy climate, especially on the hills and in exposed places near the Manawatu Gorge. Although the extent of wind exposure on Tuapaka is unknown it is situated near the Manawatu gorge on the flanks of the Tararua range, which is a high wind run area (Burgess, 1986). Therefore site exposure is expected to be a problem on Tuapaka and a major contributing factor to reduced height growth. In addition, prior to the planting of the 12.5ha block there were problems associated with gorse control (pers. comm. Grant, 1997). Again the extent of the possible weed suppression is unknown, but it is likely to have contributed to reduced height growth early in the rotation.

6.2.2 Basal Area

STANDPAK simulations using the growth models EARLY and NAPIRAD were expected to give the best combination for simulating *Pinus radiata* on farm sites. Previous work suggests that using EARLY with a high basal area function in combination with NAPIRAD accurately predict the growth of radiata pine on farm sites (Knowles & Koehler, 1984; West & Dean, 1988; Knowles *et al*, 1987). EARLY has a function that allows the basal area increment of a particular site to be adjusted. The level of basal area increment is a measure of a sites fertility level, and is simply categorised into high, medium and low. Farm sites are recognised as having improved growth rates, especially basal area increment and EARLY allows an adjustment to be made of between ±20% within each basal area category.

In order to accurately configure the EARLY and NAPIRAD growth models, in particular the basal area adjustment, it was necessary to collect field data from the existing 12.5ha Tuapaka stand. The collected data consisted of MCH, mean DBH, and mean crop stocking. This was used to help make the appropriate growth model adjustments in order to best simulate the current stand conditions. The major difficulty with the simulation process was the continual under prediction of basal area at age 23 years, the closest simulation obtained used the high basal area function +20%. The result was a basal area of $39.72m^2$, compared to the field estimate of $42.19m^2$, a 6% difference.

The previous site occupancy of gorse could again be a contributing factor to the under prediction of basal area. Gorse is a nitrogenous plant, increasing the presence of soil available nitrogen. The application of N is well documented as improving radiata pine growth, in particular basal area (Ballard, 1978; Mead & Cadgill, 1978). Therefore the availability of soil N may have improved the basal area increment of the stand, especially in the early stages of growth. The extent of this basal area increment is unknown. However, because of the improved pasture and sustained fertiliser program on Tuapaka, the use of the high +20% adjustment in EARLY is expected to be an acceptable configuration for the site conditions.

6.3 ESTABLISHING SILVICULTURAL REGIMES

The STANDPAK configurations were subsequently used to develop silvicultural regimes appropriate to Tuapaka site conditions. The objective was to develop two regimes including a clearwood and framing option. Although growing *Pinus radiata* on a high fertility sites offers an opportunity to increase site productivity there are often problems associated with tree quality. Tree diameter and branch size are closely related, the larger associated branches can often result in the production of inferior quality logs.

The combined influence of site index and basal area increment affect tree growth and decisions on silvicultural management. There is no single solution or "standard regime" that satisfies all site variations. For example, Southland farm sites tend to have low site indices, usually below 24m, and are consequently difficult to manage, especially when a target DOS is to be maintained. In contrast, parts of Northland with high site indices and low basal area are relatively easy to manage. This is largely a reflection of site fertility. High fertility sites produce trees that have more vigorous diameter growth and consequent branch growth with little corresponding increased height growth in comparison to non-farm sites. Therefore, clearwood regimes for farm sites tend to remove more green crown and schedule pruning operations toward the larger end of the optimum DOS range (MacLaren, 1993).

Site index also influences branch size. A possible explanation for this is the greater height growth at high site indices causes an accelerated rise of the green crown, hence branches become moribund at an earlier age and are therefore smaller relative to final branch size for lower site indices (Tombleson *et al*, 1990). Problems with silvicultural management can be compounded when a forest site has the combination of a low site index and high basal area. The result is a short tree with a large diameter. This restricts the amount of green crown that can be removed in any one pruning lift, leading to an increased cost associated with more pruning operations. The Tuapaka site was identified as having a similar problem, site index was estimated to be 23m with a high +20% basal area increment level.

6.3.1 Clearwood

The objectives for establishing an appropriate clearwood regime were to maximise the production of clearwood without adversely affecting final harvest yields. This was achieved through timely silvicultural management that restricted and maintained a uniform defect core. An important feature of designing such a regime was to minimise the cashflow demands associated with the silvicultural management, in particular the number of pruning operations.

Maintaining a crop DOS of 19cm on the Tuapaka site was expected to be difficult, because of a combination of a low site index and high basal area increment. This was typified by the number of pruning operations (10) required to reach a 6m pruned height involving a crown length remaining (CRL) of 3m. The number of pruning lifts required were then manipulated through:

- Reducing the length of green crown at each lift;
- Delayed thinning; and
- Maintaining a high proportion of unpruned trees through to thinning.

Tree growth is directly related to the crown length remaining; reducing crown length generally reduces basal area increment. When pruning results in the removal of "active" crown the reduction in basal area increment is directly proportional to the reduction in crown length (West *et al*, 1982). This suggests that the removal of more green crown (i.e., reducing the CRL) will reduce the trees basal area increment, giving an increased control over target DOS at each pruning lift. The consequences of removing more green crown i.e., 2.0-2.5m CRL for the first and second prunes, was a reduction in the number of required prunings to 5. However, a more conventional regime involving 3 pruning lifts was sought.

The timing of thinning also has a significant influence on tree growth. If thinning occurs well before pruning there will be less control over branch size, and if significantly delayed the pruned crop trees will be suppressed by the more competitive unpruned or partially pruned element (MacLaren & Knowles, 1995). Tombleson *et al* (1990), further examined branch size in relation to stocking. Examination of forest stands reveals that there is little overlap of individual tree crowns. If it is assumed that branch diameter is a function of branch length; and branches stop growing when they come within close proximity of another tree it can be shown that branch diameter is a function of stocking at time of crown closure. This suggests that a delay in thinning (i.e., maintaining a higher stocking later into the rotation) will further suppress basal area increment and branch growth. When trees are grown in a selective clearwood regime the pruned crop element is reduced in proportion to the basal area increment of the following element (West *et al*, 1982). Delaying thinning until the third prune reduced the required prunings to 4 operations. This was a result of an increased control over diameter growth and consequent DOS sizes.

It was recognised that reducing the CRL and delaying thinning has had some form of competitive effect between the pruned and unpruned followers of the stand. The suggestion that the pruned element is reduced in proportion to the basal area increment of the following element by West *et al* (1982) was investigated using STANDPAK. This was achieved by reducing the final stocking of the pruned element from 350sph to 300sph. The CRL for the second prune was also reduced to 2.2m. Combining these two actions further reduced basal area increment and branch size at each pruning lift allowing pruning to 6m with 3 pruning lifts.

Secondary benefits associated with delayed thinning and an increased proportion of the unpruned element was increased height growth. The height of the pruned element increased at each age increment in comparison to the early thinned, higher final stocked regimes. This may be explained by the observation that tree heights greater than 4m have a slight but consistent tendency to have reduced height increment at lower stockings (West *et al*, 1982). Tree height is positively correlated with final crop stocking and there is an associated increased height increment with stocking rate that begins from a very young age in certain circumstances (MacLaren *et al*, 1995).

A reduced CRL at each pruning lift, and increasing the proportion of the unpruned following element (i.e., delaying thinning and decreasing the pruned element) has resulted in a suppressed basal area increment, branch size, and a slight increase in height growth of the pruned stand element. The consequent control over DOS and the slight increase in height growth has allowed the silvicultural management to be delayed for each pruning lift. The tree is taller at each subsequent lift allowing the pruned height to be increased. This allows a 6m high prune to be achieved in 3 pruning lifts.

Pruning to below about 3.0m of CRL produces a warning message in the "Stand Growth" module of STANDPAK. This is a result of the large amount of crown removed at pruning. However, the crown length does not take into account the needle density, needle retention, or width of crown. These are all factors affecting the amount of foliage and photosynthetic capacity of the tree. In general, trees with larger stem diameters tend to have greater amounts of foliage for a given crown length (McInnes, 1997). Also, West *et al* (1982), observed that trees demonstrating a large DBH to height ratio generally have an improved basal area increment to crown height ratio. This suggests that trees grown on high basal area sites can be pruned to a lower CRL without the same detrimental effects as those on less fertile sites. This is due to the CRL having a greater amount of foliage per unit of crown length and hence a greater photosynthetic capacity. The first and second pruning lifts in the 3 pruning regime may not have been as harsh as a 2.0m and 2.2m CRL would suggest considering that this CRL is likely to contain a greater needle mass. The first prune was effectively a half height prune which is often prescribed for the first pruning lift (MacLaren, 1993).

The objective of the clearwood regime was to minimise the required number of prunings to preferably 3 operations. However, there is a trade off between restricting the number of pruning operations and adversely affecting final crop production. The selection of an appropriate regime was considered largely on cashflow criteria, in particular the number of prunings required to attain a 6m height. The pre tax NPVs at the 1ha stand level for each of the regimes were used as the selection criteria. NPV was used because it reflects the combination of both a respectable final harvest revenue and the costs associated with silvicultural management, in particular the number of pruning operations. For example, the regimes that produce larger volumes and net harvest revenues do not necessarily produce the best NPVs. Often the increased revenue does not compensate for the increased silvicultural costs associated with the high number of pruning lifts required. Revisiting the stand numerous times is reflected by the poorer NPVs attained in these regimes.

The STANDPAK simulations identified the 3 pruning clearwood regime as being a good compromise between final harvest value and the number of required prunes. This regime produced a final harvest volume of 698m^3/ha with a net revenue of $39,500/ha. Of the total volume produced 37% was graded in the higher valued P1/P2 log class.

6.3.2 Framing

A framing regime was also investigated to assess any benefits of managing a regime that had lower silvicultural costs. Obvious disadvantages from implementing this regime, include a lower final harvest revenue. However, the objective was to produce a regime that maximised net revenue at harvest and maintained crop quality through suppressed branch development.

From the previous simulations it is known that crop stocking can be used to suppress branch size. Assuming that branch diameter is a function of branch length and that branches stop growing when in close proximity to another tree, the timing of thinning and final crop stocking will have a significant affect on tree growth, in particular branch development. However, thinning should not be delayed as late as a MCH of 14-18m height because of the risks associated with windthrow (MacLaren & Knowles, 1995). There is also a trade of between final crop stocking and final volume. Although branch development is restricted with delayed thinning and high final stocking the improvement in quality may not compensate the restriction in potential volume growth.

The STANDPAK simulations identified a framing regime involving a final crop stocking of 400sph thinned at age 12.6 years as being a good compromise between restricting branch size and attaining respectable log diameters at harvest. This regime produced a final harvest volume of 787m^3/ha with a net revenue of $18,800/ha and NPV of $1,100/ha.

6.4 LIMITATIONS

6.4.1 Quality Parameters

The STANDPAK configurations are believed to be reasonably accurate for predicting tree heights, basal area, and stand volumes, however, it is difficult to substantiate potential log quality parameters. The most accurate predictions of these qualities can be obtained from either a preharvest inventory assessment or from existing harvest data. The 12.5ha stand under consideration is about 5-6 years out from harvest and there is currently no hard data on the potential log quality parameters.

For the purposes of the research medium default values were used for the site dependent (sweep, internode index, and wood density) and regime dependent qualities (branch index, maximum branch, and defect core). Combinations of both high fertility and exposure on Tuapaka are likely to see these parameters differ from the above medium values. Especially the regime dependent qualities associated with branching and the site dependent qualities of sweep that are particularly susceptible to the described site conditions.

6.4.2 Genetic Improvement

The STANDPAK version used in this research allows a genetic improvement of GF7. Current and future Tuapaka plantings will use genetic stock of higher potential, improving both site productivity and tree form. Current plantings are GF16 and GF17. This improvement can potentially improve volume production by 5-10%. Utilising higher GF stock will further improve this potential (MacLaren, 1993). Physiologically aged cuttings can improve tree growth and form on farm sites (Tombleson, 1991). Using cuttings with similar GF is predicted to give a 20% higher recoverable volume of clear grade timber compared to seedlings (Holden, 1995). However, the scarcity of available stock and the associated higher costs are often a deterrent to planting.

There are also management implications associated with using genetically improved stock. Using improved growth and form trees effectively improves site index. This will allow the silvicultural management constraints of high stocking, delayed thinning, and harsh prunings to be modified on

Tuapaka. The modifications are likely to see the severity of these silvicultural prescriptions reduced, improving early tree growth and final harvest revenues.

Given these arguments the final STANDPAK outputs can be considered conservative. There are implications of both genetic improvement as well as management interactions that will improve volume production. Improved growth and form will not only improve silvicultural management conditions but tree and subsequent log qualities. However, the extent and the corresponding returns associated with improved volumes and quality are difficult to quantify under the current modelling conditions.

6.4.3 Modelling Considerations

Farm sites have different growth characteristics to those on traditional forest sites, and often require different silvicultural management strategies. Current modelling procedures may not adequately describe the potential benefits from growing and managing *Pinus radiata* on high basal area sites.

EARLY in combination with NAPIRAD is currently the recommended option for modelling on farm sites (West & Dean, 1988). However, growth modelling procedures, particularly later growth sets specific to farm sites can be improved. Currently EARLY allows basal area levels to be adjusted while the later growth model sets have no basal area adjustments. Using STANDPAK in only one run is unlikely to adequately account for the inherently variability of growth that often occurs in farm woodlots, especially on exposed ridges and gully floors. There are modelling procedures that can take account of this. These include modelling the inherent site variations separately. If site variations are significant enough they may be modelled to give upper and lower bounds for the STANDPAK data outputs. This would give an appreciation for the required range of silvicultural management and production potentials from a given site, especially farm sites that readily exhibit these extremities.

The success of the prescribed silvicultural management strategies will be improved by monitoring stand growth. Continual updating stand conditions, especially during early growth, will aid in optimising STANDPAK management prescriptions. The monitoring and collection of stand details will help improve and validate the STANDPAK configuration. The current model configurations used in the clearwood simulation predict a 37% log grade out turn by volume for P1/P2 class logs. Denis Hocking, a farm forester from Bulls, is producing 40-50% of his log grade out turn in the P1/P2 classes (pers. comm. Hocking, 1997). This suggests the current configurations may be underpredicted log grade out turns on Tuapaka. Therefore validation is a necessary process to ensure that stand growth is accurately simulated.

The current growth and log grade out turns have not been validated against other stand data from the Tuapaka site. This is because the current stands are too young to accurately measure for growth variables and no harvest data is currently available. The validation process is also limited by the current genetic improvement (GF 7) available in STANDPAK. These are important issues concerning both the management and production potentials on the Tuapaka, and farm sites in general.. The potential production benefits and management issues associated with farm sites need to be considered in the configuration process as well as in the development of future growth models.

The current silvicultural prescriptions identified in this project are based on the average tree at the 1ha level, and extremities of management will exist. However, for forestry analysis purposes, where it is necessary to develop an appreciation of the required management and potential production, outputs using expected (or average) results give an understanding of the site characteristics being dealt with.

6.5 ECONOMIC ANALYSIS AT THE ESTATE LEVEL

Having developed a clearwood and framing regime for Tuapaka it was then necessary to analyse the financial implications of implementing these regimes at the estate level. Of particular importance were the physical and financial resources needed in the project and the returns received from it. The Tuapaka forestry investment project was evaluated using a discounted cashflow analysis, in particular pre and post tax NPVs and IRRs.

The age structure of the Tuapaka plantations is such that a 28 year window of the whole investment period was used to analyse the worth of the project. The clearwood regime gave the most favourable returns on investment for the current 31.3ha of forestry development. This project had a pre and post tax IRR of 9.11% and 7.78% respectively. In contrast, the framing regime returned 7.61% and 6.17%. Although the variation in returns appear small they are however very significant, given the size and period of investment. An important consideration here is the scale of investment required in order to achieve these IRRs. The clearwood regime requires a total pre tax funding of $247,921 over the full 28 year term and has a pre tax value in year 28 of $1,152,897, of which $636,733 is harvested timber. In contrast, the framing regime requires a total funding of $214,806 and has a value in year 28 of $645,455, of which $410,512 is harvested timber.

Taxation has a significant effect on the returns realised from these projects. If the investor can fully utilise the tax benefits in the year in which they occur the IRR received for the clearwood and framing regimes will be 7.78% and 6.17% respectively. If the tax benefits can not be fully utilised at the time of occurrence and deducted at harvest, the IRR received declines to 7.34% and 5.84%, significantly reducing the final net worth of the projects. This corresponds to a decline in net revenue of $17,508 for the clearwood and $10,356 for the framing regime at the estate level over the project term. Under the current economic environment, Tuapaka is not in a position to fully utilise the tax benefits. Should the returns from farming improve the likely post tax IRR realised will range between 7.34%-7.78% for the clearwood regime and 5.84%-6.17% for the framing regime.

The second important factor influencing the success of these projects is the availability of cashflow necessary to finance the silvicultural management, particularly for the clearwood regime. The timing of these cash requirements is related to timely and optimal sivicultural inputs that underly the final harvest volume and revenue. If silviculture is delayed the returns identified in this project will not be fully realised. This would be a result of final harvest volumes or log qualities being jeopardised due to the affects of untimely silvicultural management.

Tuapaka will receive harvest income early in the project term. In year 8 of the project a pre tax revenue of $244,091 will be made available from the harvest of the 12.5ha stand planted in 1973. These funds could be made available for funding the current and future forestry development.

6.5.1 Regime Selection

The project evaluation tends to favour the clearwood regime. There are also other considerations that make the clearwood regime a favourable investment. Pruning will capture greater market flexibility and reduce market risks associated with changes in relative prices amongst log grades. The scale of forestry development on Tuapaka is relatively small compared with the larger corporate sector. Therefore producing a larger proportion of logs in the higher value pruned grades will aid Tuapaka's marketing opportunities.

Increasing the scale of forestry development on Tuapaka to 68.0ha using the clearwood regime improves the returns of the project. The IRR increases to a pre and post tax return of 9.40% and 8.18% respectively. These returns compare favourably with recent forestry investment prospectuses which prescribe post tax returns of between 6% and 9% (Dickie, 1997; Anon. 1997b; Anon. 1995b).

The current forestry development has not affected the total stock carrying capacity of the property. However, increasing the scale of development is likely to see a substitution of stock for trees. As an investment opportunity forestry returns exceed those of current farming returns. Rate of return received from North Island hill country farms range between 0-5% (Anon. 1996d). Other issues that need to be considered before large scale forestry development takes place include the ability to generate income in order to meet both farm and living expenses should stock numbers be depleted. Also, problems can arise in trying to finance a larger forestry project, particularly the associated cashflow demands. However, there are joint venture schemes, partnerships, and sales of cutting rights that can help landowners successfully develop forestry on their properties. These options and questions are not investigated in this project, but they have been identified as areas of concern when investing in forestry diversification.

An important consideration involved with this type of project evaluation is that the underlying assumptions made in the analysis remain true for the length of the project. Under the identified site and investment conditions, forestry development on Tuapaka is very feasible. These results could be considered conservative considering the underlying yield predictions procedures and the prices used for the log grade classes, especially in the P1 and P2 class. The prices used in this analysis are average prices which do not consider the potential quality of the logs produced, particularly in the pruned log class. The production of higher quality logs will achieve price premiums over lower quality logs, however in order to realise the full potential from this site greater emphasis needs to be applied to appropriate and timely silviculture.

The use of growth modelling systems, such as STANDPAK, and discounted cashflow techniques are only a guide in the decision making process, not a substitute for it. However, with accurately generated harvest and financial information reliable predictions can be made, allowing confident investment decisions to be made.

6.6 CONCLUSIONS

- Site index at Tuapaka was estimated to be 23m, with a high basal area increment potential;
- The best STANDPAK configuration combined the EARLY (high +20% basal area increment) and NAPIRAD growth models (switched at MTH 18m). The resultant configuration predicted basal area to within 6% of the field estimate;
- The number of pruning operations required to achieve a 6.0m pruned height in the clearwood regimes varied between 3-10. These were manipulated by varying the timing of thinning, CRL at each pruning lift, and crop stocking;
- The most profitable clearwood regime required 3 pruning lifts. This regime had the highest NPV ($2,681/ha), and was the best compromise between final harvest value and the number of required pruning lifts. Three pruning lifts were achieved by a delayed thinning; reducing the CRL to 2.0m-2.2m for the first and second pruning lifts; and maintaining a high ratio of unpruned trees through to thinning;
- The best framing regime involved a final crop stocking of 400sph thinned at age 12.6 years. This regime produced a NPV of $1,100/ha;
- The clearwood regimes were generally more profitable than the framing regimes due to the improvement in average timber value. Pruning increased the log grade out turn in the higher valued P1/P2 log grade class to 37%. This improvement more than compensated for increased silvicultural cost and reduced log volume;
- At the 31.3ha estate level the clearwood regime produced a pre and post tax IRR of 9.11% and 7.78% respectively over a 28 year period;
- Over the 28 year investment period the clearwood regime is predicted to have a pre tax value of $1,153,000, from required cash inputs of $247,921. In comparison the framing regime is predicted to be worth $645,000, from required cash inputs of $214,806;
- Further analysis found that expanding the scale of forestry on Tuapaka to 68ha, utilising a clearwood regime, improved pre and post tax IRR to 9.40% and 8.18% over the 28 year period. The expansion is expected to increase the farm profitability because the IRRs being generated are likely to exceed those from farming, particularly on steep hill country.

6.6.1 Recommendations

Although pruning can be expensive and slows diameter growth, the advantage is to sacrifice the quantity of timber produced for superior quality. The clearwood regime typifies this, as it has a superior post tax rate of return in comparison to the framing regime for the existing 31.3ha of forestry (7.8% vs 6.2%). These returns are very favourable in comparison with other investment opportunities.

Pruning is recommended as the best option for existing and future forestry development on Tuapaka. Should the silvicultural management schedule identified in this project be followed and market prices remain at present levels in real terms, the above returns are accomplishable.

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Appendices

Contents:

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APPENDIX ONE: PSP, Inventory Data and STANDPAK Configuration.

PSP Data Summary

A summary of the data collected from the four Permanent Sample Plots established on Tuapaka by the New Zealand Forest Research Institute, June 1995. The diameter at breast height was measured in centimetres and tree height in metres.

Tree No.	Plot 1/1		Plot 2/1		Plot 2/2		Plot 2/3	
	DBH	Ht	DBH	Ht	DBH	Ht	DBH	Ht
1	35.8	22.0	44.0	19.0	49.5	22.4	23.2	-
2	40.4	22.4	39.8	19.7	49.5	-	37.0	25.3
3	39.5	-	36.7	-	40.0	23.6	32.6	-
4	45.1	22.2	36.1	18.8	61.0	24.9	35.0	21.4
5	35.5	21.1	34.6	19.3	33.1	22.7	36.8	21.4
6	40.4	22.5	37.0	-	44.2	23.9	46.5	23.1
7	40.5	-	36.2	18.0	48.0	-	52.4	26.2
8	34.5	22.3	31.0	-	38.0	22.3	46.8	-
9	31.4	22.5	40.1	-	43.9	-	52.1	26.1
10	43.8	22.5	37.6	-	52.0	24.7	47.4	-
11	39.5	-	37.8	18.4	49.5	-	42.5	-
12	33.7	21.0	32.2	-	42.8	25.3	40.0	25.7
13	36.3	-	36.7	19.6	39.9	-	36.5	21.7
14	35.3	21.8	36.3	-	49.7	23.5	32.3	24.5
15	35.9	-	40.0	-	42.0	-	35.3	24.5
16	39.0	-	36.8	21.0	37.3	21.8	21.8	-
17	45.0	21.6	46.0	21.5	32.9	-	41.3	25.2
18			38.4	-				
19			42.5	-				
20			48.2	21.0				
21			32.3	-				

<u>Estimated Site Indices:</u> Plot 1/1 - 20.0m; Plot 2/1 - 18.2m; Plot 2/2 - 22.2m; Plot 2/3 - 22.8m.

Estimated Stockings: Plot 1/1 - 340sph; Plot 2/1 - 313sph; Plot 2/2 - 254sph; Plot 2/3 - 254sph.

Field Estimation of STANDPAK Inputs

The results from the PSPs provided the pilot inventory data for an approximation of the variance and mean height and DBH of the population. This provides the necessary information for determining the sample size required for the degree of precision in the final estimate. The pilot inventory supplied the following data:

- 72 DBHs $\bar{x}$ = 39.8cm; and s = 6.7cm;
- 42 heights $\bar{x}$ = 22.4m; and s = 2.1m;
- stocking 254-340sph, average 290sph.

The formula that calculates the number of plots required in the main assessment is outlined below:

$$n = \left(\frac{100\,ts}{d\,\bar{x}} \right)^2$$

where: n = number of plots required;

d = the desired Probable Limit of Error (PLE) (%);

$\bar{x}$ = an estimate of the sample mean value;

s^2 = variance of the estimated sample mean value;

t = the appropriate value of t at n-1 degrees of freedom.

Example of one iteration:

DBH: First iteration used above stand details; (i.e., $\bar{x}$ = 39.8cm; and s = 6.7cm) t = 1.994 at 71 degrees of freedom (i.e., (n-1) = (72-1)) PLE d = 5.0%. New n = 180, this value was then used in another iteration with degrees of freedom now 179 and t = 1.96. These iterations were carried out until there was no change in n.This approach was also used to determine the number of height measurements required.

The results from the Tuapaka inventory were as follows:

- 180 DBHs $\bar{x}$ = 43.0cm (basal area 42.19m^2); and s = 5.9cm; 60 heights $\bar{x}$ = 25.6m; and s = 4.0m.

Results of the STANDPAK Configuration

```
+--------------------------------------------+
|          S T A N D   G R O W T H           |
|    Stand Treatment and Growth Simulation   |
|              Version 6.00                  |
|              New Zealand                   |
|    Forest Research Institute Limited       |
+--------------------------------------------+
Massey University                              Wed Apr 23 13:26:22 1997
TUAPAKA 12.5ha Configuration Results                           #075-67CB
=======================================================================

   Growth Model        : 23 EARLY      DOS fn.          : Standard
   Basal area fn.      : High          Crown fn.        : Beekhuis
   Basal area adj.     : 20.0%         DOS adj.         : 0.0 0.0 0.0 0.0 cm
   Height Model        : 26            Site Index       : 23.0 m
   Stand Volume fn.    : 22            Start Date       : 1978 JUN (5.0)
   Monthly Growth fn.:    6            Mean Top Height  : 4.5 m

   Growth Model        :  9 NAPIRAD
   GF rating           :  7
   Height Model        : 26            Site Index       : 23.0 m
   Stand Volume fn.    : 22            Start Date       : 1978 JUN (5.0)
   Monthly Growth fn.:    6            Mean Top Height  : 4.5 m
```

STANDING YIELD

Age yrs	Stocking stems/ha	MeanHt m	MeanDBH cm	BasalArea m^2/ha	Volume m^3/ha	M.A.I. $m^3/ha/yr$
5.0	1500	3.8	8.9	9.39	22	4.5
6.0	1500	4.8	11.9	16.69	43	7.1
7.0	1500	5.8	14.2	23.82	69	9.8
8.0	1500	6.9	16.2	30.78	100	12.5
9.0	1500	8.0	17.9	37.57	137	15.1
10.0	1500	9.1	19.4	44.19	178	17.8
11.0	1499	10.3	20.7	50.60	224	20.3
12.0	1499	11.4	22.0	56.88	275	22.8
13.0	1498	12.6	23.1	62.94	329	25.2
14.0	1496	13.7	24.2	68.78	387	27.5
15.0	1493	14.9	25.2	74.39	447	29.7
16.0	1489	16.0	26.1	79.76	511	31.8
17.0	1483	17.2	27.0	84.84	576	33.8
>> THINNED stand (below) to waste leaving 290 stems/ha						
17.0	290	18.7	30.7	21.49	144	8.5
>> SWITCHED to later model set from G23 H26 V22 M6						
17.0	290	18.7	30.7	21.49	144	8.5
18.0	289	19.8	32.1	23.40	166	9.2
19.2	288	21.2	34.5	26.97	203	10.5
20.2	288	22.4	36.6	30.25	238	11.8
21.2	287	23.5	38.6	33.52	276	13.0
22.2	286	24.6	40.4	36.68	314	14.1
23.2	285	25.7	42.1	39.72	354	15.2
>> CHANGED element 1 stocking to 290						
23.2	290	25.7	41.8	39.72	354	15.2
>> CHANGED element 1 basal area to 42.19						
23.2	290	25.7	43.0	42.19	375	16.2
24.0	289	26.6	44.3	44.50	408	17.0
25.0	288	27.6	45.7	47.23	448	17.9
26.0	287	28.7	47.0	49.80	489	18.8
27.0	286	29.7	48.2	52.23	529	19.6
28.0	285	30.7	49.3	54.49	568	20.3
29.0	284	31.7	50.4	56.62	608	20.9
30.0	283	32.6	51.4	58.60	646	21.5
31.0	282	33.5	52.3	60.44	684	22.0
32.0	280	34.5	53.1	62.15	720	22.5
33.0	279	35.4	53.9	63.73	756	22.9
34.0	278	36.2	54.6	65.20	790	23.2
35.0	277	37.1	55.3	66.55	824	23.5
>> END Rotation						

```
+--------------------------------------+
|          L O G   G R A D I N G       |
|          Log Grading Model           |
|            Version 6.00              |
|            New Zealand               |
|   Forest Research Institute Limited  |
+--------------------------------------+
```

Massey University Wed Apr 23 13:38:18 1997
TUAPAKA 12.5ha Configuration Results #075-67CB

Log Grade Specifications used : "NZDOM"

Library access : Shared

Description :

Tuapaka NZDOM log-grades.

Do you wish to re-cut heavily swept logs ? No

Length of logs to be re-cut : 10.0

Log Grades	% downgraded to lowest grade	% downgraded to waste
Pruned	2	0
Unpruned	4	2

LOG AGGREGATION YIELD TABLE :

Clearfell Recoverable Volume (all stand elements)

AGE	S1	S2	S3/L3	L1/L2	PULP	Total	Waste	Gross $/ha
25.0	52.9	138.0	116.5	43.6	82.7	433.8	8.9	30,106
26.0	72.0	153.0	105.9	58.6	82.3	471.9	9.6	33,510
27.0	96.1	154.4	104.5	69.8	85.6	510.4	10.4	36,768
28.0	117.1	156.4	105.9	88.3	80.8	548.5	11.2	40,108
29.0	137.5	158.4	96.1	108.3	87.1	587.4	12.0	43,302
30.0	156.9	154.8	96.9	123.9	91.8	624.3	12.7	46,225

APPENDIX TWO: Cost and Price Assumptions

Cost Assumptions

ANNUAL COSTS:	
Insurance and Administration	\$25.00/ha/year
Pest Control	\$5.00/ha/year
FOREST MANAGEMENT:	
Seedling Purchase (GF 19s)	\$0.20/stem
Planting	\$0.25/stem
Spot Spraying	\$0.20/stem
First Pruning Lift	\$1.10/stem
Second Pruning Lift	\$1.35/stem
Proceeding Pruning Lifts	\$1.70/stem
Thinning (Clearwood)	\$130.00/ha
Thinning (Framing)	\$350.00/ha
HARVEST:	
Cable Logging	\$20.00/m^3
Roading	\$400.00/ha
CARTAGE:	
P1 + P2 - Wellington*	(150km x \$0.15/km/m^3) = \$22.50/m^3
Sawn Logs - Manawatu*	(50km x \$0.20/km/m^3) = \$10.00/m^3
Pulp - Winstones*	(150km x \$0.20/km/m^3) = \$30.00/m^3
STANDPAK**	\$25.00/m^3
Commission	5% of net harvest revenue

[*used for 12.5ha harvest in 2001 **used in proceeding STANDPAK and project analysis].

Log Specifications and Price Assumptions

New Zealand Domestic Log Grade Specifications.

Log Grade	Pruned or Unpruned	Small End Diameter (mm)	Lengths (m)	Maximum Branch (mm)	Sweep Class
P1	P	400+	4.0-6.1	NA	1
P2	P	300-399	4.0-6.1	NA	1
S1	U	400+	4.0-6.1	60	1
S2	U	300-399	4.0-6.1	60	1
S3	U	200-299	4.0-6.1	60	1
L1	U	400+	4.0-6.1	140	1
L2	U	300-399	4.0-6.1	140	1
L3	U	200-299	4.0-6.1	140	1
PULP	U	100+	4.0-6.1	NA	2

[Source: Anon, 1996] Farm Budgeting Manual

Indicative Log Prices for New Zealand Domestic Grades.

Log Grade	NZ$/tonne "at mill"	Average Price
P1	148-210	180
P2	111-162	136
S1	90-99	95
S2	70-88	80
L1/L2	56-85	71
S3/L3	58-66	62
PULP	35-55	45

[Source: Edmonds, 1996]

APPENDIX THREE: Clearwood Regimes

Contents:

Stand Growth, Log Grade Yields and Economic Analysis

Fixed Lift: 3 Fixed lift prunes to 6.0m, 1000sph initial - 350sph final.

Regime 1: 10 Prunings 1000sph - 350sph.

Regime 2: 5 Prunings 1000sph - 350sph.

Regime 3: 4 Prunings 1000sph - 350sph.

Regime 4: 3 Prunings 1000sph - 300sph.

Regime 5: 3 Prunings 1200sph - 350sph.

Regime 6: 5 Prunings 800sph - 350sph.

Other Regimes:

4 Prunings 1000sph - 270sph.

4 Prunings 1000sph - 300sph.

4 Prunings 1000sph - 400sph.

3 Prunings 1000sph - 270sph.

3 Prunings 1200sph - 400sph.

6 Prunings 800sph - 350sph.

```
+------------------------------------------------+
|           S T A N D   G R O W T H              |
|   Stand Treatment and Growth Simulation        |
|              Version 6.00                      |
|              New Zealand                       |
|    Forest Research Institute Limited           |
+------------------------------------------------+
Massey University                              Wed Apr 30 14:50:35 1997
Fixed Lift: 3 Prunes to 6.0m                                  #075-67CB
=========================================================================

   Growth Model        : 23 EARLY    DOS fn.         : Standard
   Basal area fn.      : High        Crown fn.       : Beekhuis
   Basal area adj.     : 20.0%       DOS adj.        : 0.0 0.0 0.0 0.0 0.0 cm
   Height Model        : 26          Site Index      : 23.0 m
   Stand Volume fn.    : 22          Start Date      : 1994 JUL (4.1)
   Monthly Growth fn.:  6            Mean Top Height : 3.3 m

   Growth Model        :  9 NAPIRAD
   GF rating           :  7
   Height Model        : 26          Site Index      : 23.0 m
   Stand Volume fn.    : 22          Start Date      : 1994 JUL (4.1)
   Monthly Growth fn.:  6            Mean Top Height : 3.3 m
```

STANDING YIELD

Age yrs	Stocking stems/ha	MeanTopHt m	MeanHt m	BasalArea m^2/ha	MeanDBH cm	Volume m^3/ha	M.A.I. $m^3/ha/yr$
4.1	1000	3.3	2.9	3.10	6.3	7	1.7
5.1	1000	4.4	3.8	10.84	11.7	23	4.5
5.8	1000	5.2	4.5	16.24	14.4	37	6.4
>> PRUNED (Ht) 380 stems/ha to 2.2 m.							
5.8	1000	5.2	4.5	16.24	14.4	37	6.4
7.5	1000	7.4	6.4	29.72	19.5	86	11.4
>> PRUNED (Ht) 350 stems/ha to 4.2 m.							
7.5	1000	7.4	6.4	29.72	19.5	86	11.4
>> THINNED stand (least prnd) to waste leaving 350 stems/ha							
7.5	350	7.4	6.4	10.79	19.8	31	4.1
8.5	350	8.6	8.1	13.19	21.9	43	5.1
9.1	350	9.4	8.8	15.80	24.0	55	6.0
>> PRUNED (Ht) 350 stems/ha to 6.0 m.							
9.1	350	9.4	8.8	15.80	24.0	55	6.0
10.1	350	10.7	10.0	17.37	25.1	68	6.7
11.1	350	11.9	11.1	20.18	27.1	87	7.8
12.1	350	13.2	12.3	24.44	29.8	114	9.4
13.1	350	14.5	13.6	29.92	33.0	151	11.5
14.1	350	15.8	14.8	36.30	36.3	198	14.0
15.1	350	17.0	16.0	43.36	39.7	252	16.7
15.9	350	18.0	16.9	49.51	42.4	304	19.1
>> SWITCHED to later model set from G23 H26 V22 M6							
15.9	350	18.0	17.0	49.51	42.4	304	19.1
22.0	342	25.2	24.1	66.45	49.7	558	25.3
23.0	341	26.3	25.2	68.49	50.6	599	26.0
24.0	340	27.4	26.3	70.34	51.3	639	26.6
25.0	338	28.5	27.3	72.04	52.1	678	27.1
26.0	337	29.5	28.4	73.58	52.7	717	27.5
27.0	335	30.5	29.4	74.98	53.4	754	27.9
28.0	334	31.5	30.4	76.24	53.9	791	28.2
29.0	332	32.5	31.4	77.39	54.5	826	28.5
30.0	331	33.4	32.4	78.43	54.9	860	28.6
31.0	329	34.3	33.3	79.36	55.4	894	28.8
32.0	328	35.2	34.2	80.19	55.8	926	28.9
>> END Rotation							

PRUNING DETAILS

Date	Age (years)	Prune on	Prune to	Stocking (stems/ha)	MTH (m)	MCH (m)	PRH (m)	DBH (cm)	DOS (cm)	Crop DOS (cm)	DOSH (m)	Caliper (cm)	MaxBr (cm)	CRL (m)
1996JAN	5.8	Ht	2.2H	380	5.2	5.0	2.2	15.8	24.6	24.7	0.8	13.6	8.3	2.8
1997OCT	7.5	Ht	4.2H	350	7.4	7.0	4.2	19.8	22.0	22.0	2.4	11.0	6.8	2.8
1999JUL	9.1	Ht	6.0H	350	9.4	8.8	6.0	24.0	20.0	20.0	4.4	10.1	6.3	2.8

Where
Prune codes : C = Crown remaining (m).
% = Percentage of tree height.
H = Prune height (m).
MCH : Mean height of crop (most pruned element).
CRL : Length of average tree crown above pruning.
MTH : Mean top height of stand.
PRH : Prune height.
DOS : Diameter over pruning stubs.
DOSH : Height to largest pruned whorl (DOS).
MaxBr : Diameter of the largest branch stub at DOSH.

LOG AGGREGATION YIELD TABLE :

Clearfell Recoverable Volume (all stand elements)

AGE	P1	P2	S1	S2	S3/L3	L1/L2	PULP	Total	Waste	Gross $/ha
24	99.3	145.8	0.2	2.8	101.8	143.4	125.4	618.7	7.5	60,082
25	162.5	76.4	0.3	3.2	110.5	163.2	141.5	657.5	8.4	64,731
26	189.8	71.9	0.4	4.8	94.0	205.4	129.0	695.3	8.7	70,581
27	201.0	67.9	0.6	4.9	97.1	228.2	132.7	732.5	9.3	74,057
28	211.0	66.2	1.5	4.3	113.7	234.9	137.2	768.8	9.9	77,371
29	220.3	63.0	1.6	5.1	94.0	268.1	151.4	803.7	10.5	80,458
30	228.5	60.3	1.7	5.2	102.1	282.4	156.7	836.9	11.1	83,340

ECONOMIC ANALYSIS

Clearfell Age	Discount Rate (%)	N.P.V. ($)	I.R.R. (%)	Breakeven Price ($/m3)
24.0	8.0	3034.64	13.3	66.01
25.0	8.0	3081.04	13.1	66.34
26.0	8.0	3265.31	13.0	66.78
27.0	8.0	3099.28	12.6	67.31
28.0	8.0	2913.33	12.3	67.95
29.0	8.0	2711.27	11.9	68.69
30.0	8.0	2497.06	11.5	69.56

S T A N D   G R O W T H
Stand Treatment and Growth Simulation
Version 6.00
New Zealand
Forest Research Institute Limited

Massey University — Tue Feb 18 14:38:08 1997

Regime 1: 10 Prunings 1000sph - 350sph — #075-67CB

Growth Model	: 23 EARLY	DOS fn.	: Standard
Basal area fn.	: High	Crown fn.	: Beekhuis
Basal area adj.	: 20.0%	DOS adj.	: 0.0 0.0 0.0 0.0 0.0 cm
Height Model	: 26	Site Index	: 23.0 m
Stand Volume fn.	: 22	Start Date	: 1994 JUL (4.1)
Monthly Growth fn.	: 6	Mean Top Height	: 3.3 m

Growth Model	: 9 NAPIRAD		
GF rating	: 7		
Height Model	: 26	Site Index	: 23.0 m
Stand Volume fn.	: 22	Start Date	: 1994 JUL (4.1)
Monthly Growth fn.	: 6	Mean Top Height	: 3.3 m

STANDING YIELD

Age yrs	Stocking stems/ha	MeanTopHt m	MeanHt m	BasalArea m^2/ha	MeanDBH cm	Volume m^3/ha	M.A.I. m^3/ha/yr
4.1	1000	3.3	2.9	3.10	6.3	7	1.7
4.7	1000	4.0	3.5	6.98	9.4	15	3.1
>> PRUNED (DOS) 380 stems/ha to leave 3.0 m. of crown							
4.7	1000	4.0	3.5	6.98	9.4	15	3.1
4.9	1000	4.2	3.7	9.26	10.9	19	3.9
>> PRUNED (DOS) 350 stems/ha to leave 3.0 m. of crown							
4.9	1000	4.2	3.7	9.26	10.9	19	3.9
5.1	1000	4.4	3.9	10.69	11.7	23	4.4
>> PRUNED (DOS) 350 stems/ha to leave 3.0 m. of crown							
5.1	1000	4.4	3.9	10.69	11.7	23	4.4
5.5	1000	4.9	4.3	13.25	13.0	29	5.3
>> PRUNED (DOS) 350 stems/ha to leave 3.0 m. of crown							
5.5	1000	4.9	4.3	13.25	13.0	29	5.3
6.0	1000	5.5	4.9	18.26	15.2	43	7.1
>> PRUNED (DOS) 350 stems/ha to leave 3.0 m. of crown							
6.0	1000	5.5	4.9	18.26	15.2	43	7.1
>> THINNED stand (least prnd) to waste leaving 350 stems/ha							
6.0	350	5.5	4.9	6.58	15.5	15	2.6
6.6	350	6.3	6.0	8.55	17.6	22	3.3
>> PRUNED (DOS) 350 stems/ha to leave 3.0 m. of crown							
6.6	350	6.3	6.0	8.55	17.6	22	3.3
7.2	350	7.0	6.6	10.91	19.9	30	4.2
>> PRUNED (DOS) 350 stems/ha to leave 3.0 m. of crown							
7.2	350	7.0	6.6	10.91	19.9	30	4.2
7.9	350	8.0	7.4	13.32	22.0	40	5.1
>> PRUNED (DOS) 350 stems/ha to leave 3.0 m. of crown							
7.9	350	8.0	7.4	13.32	22.0	40	5.1
8.9	350	9.2	8.5	15.93	24.1	54	6.1
>> PRUNED (DOS) 350 stems/ha to leave 3.0 m. of crown							
8.9	350	9.2	8.5	15.93	24.1	54	6.1
10.2	350	10.8	9.9	18.71	26.1	74	7.2
>> PRUNED (DOS) 350 stems/ha to 6.0 m.							
10.2	350	10.8	9.9	18.71	26.1	74	7.2
15.2	350	17.2	15.9	44.88	40.4	263	17.3
15.9	350	18.0	16.7	50.25	42.8	308	19.3
>> SWITCHED to later model set from G23 H26 V22 M6							
22.0	342	25.2	24.1	66.99	49.9	562	25.5
23.0	341	26.3	25.2	68.99	50.7	603	26.2
24.0	340	27.4	26.3	70.81	51.5	643	26.8
25.0	338	28.5	27.3	72.48	52.2	682	27.3
26.0	337	29.5	28.4	73.99	52.9	721	27.7
27.0	335	30.5	29.4	75.36	53.5	758	28.0
28.0	334	31.5	30.4	76.61	54.1	795	28.3
29.0	332	32.5	31.4	77.73	54.6	830	28.6
30.0	331	33.4	32.4	78.74	55.1	864	28.8
31.0	329	34.3	33.3	79.65	55.5	897	28.9
32.0	328	35.2	34.2	80.47	55.9	929	29.0
>> END Rotation							

PRUNING DETAILS

Date	Age (years)	Prune on	Prune to	Stocking (stems/ha)	MTH (m)	MCH (m)	PRH (m)	DBH (cm)	DOS (cm)	Crop DOS (cm)	DOSH (m)	Caliper (cm)	MaxBr (cm)	CRL (m)
1994DEC	4.7	DOS	3.0C	380	4.0	3.9	0.9	10.5	18.8	18.8	0.8	13.9	6.0	3.0
1995MAR	4.9	DOS	3.0C	350	4.2	4.1	1.1	11.8	19.0	19.0	1.1	14.3	6.3	3.0
1995JUL	5.1	DOS	3.0C	350	4.4	4.3	1.3	12.5	18.6	18.6	1.3	14.1	6.2	3.0
1995OCT	5.5	DOS	3.0C	350	4.9	4.8	1.8	13.7	19.0	19.0	1.5	13.4	6.2	3.0
1996JUN	6.0	DOS	3.0C	350	5.5	5.4	2.4	15.5	18.9	18.9	2.0	12.9	6.2	3.0
1996NOV	6.6	DOS	3.0C	350	6.3	6.0	3.0	17.6	18.9	18.9	2.6	12.8	6.3	3.0
1997AUG	7.2	DOS	3.0C	350	7.0	6.6	3.6	19.9	18.9	18.9	3.2	12.7	6.4	3.0
1998MAY	7.9	DOS	3.0C	350	8.0	7.4	4.4	22.0	19.1	19.1	3.8	12.1	6.4	3.0
1999APR	8.9	DOS	3.0C	350	9.2	8.5	5.5	24.1	19.0	19.0	4.6	11.2	6.2	3.0
2000AUG	10.2	DOS	6.0H	350	10.8	9.9	6.0	26.1	18.9	18.9	5.7	12.9	6.0	3.9

Where
- Prune codes : C = Crown remaining (m).
  - % = Percentage of tree height.
  - H = Prune height (m).
- MCH : Mean height of crop (most pruned element).
- CRL : Length of average tree crown above pruning.
- MTH : Mean top height of stand.
- PRH : Prune height.
- DOS : Diameter over pruning stubs.
- DOSH : Height to largest pruned whorl (DOS).
- MaxBr : Diameter of the largest branch stub at DOSH.

LOG AGGREGATION YIELD TABLE :

Clearfell Recoverable Volume (all stand elements)

AGE	P1	P2	S1	S2	S3/L3	L1/L2	PULP	Total	Waste	Gross $/ha
24	102.2	144.7	0.2	2.7	100.9	145.0	126.8	622.6	7.6	60,567
25	165.2	75.3	0.3	3.2	109.7	164.6	143.1	661.3	8.5	65,189
26	192.4	70.9	0.4	4.6	93.5	206.7	130.5	699.0	8.8	71,026
27	203.3	67.0	0.6	4.8	96.7	229.5	134.2	736.1	9.4	74,476
28	213.1	65.4	1.4	4.2	113.2	236.0	138.9	772.2	10.0	77,746
29	222.3	62.3	1.6	5.0	93.5	268.9	153.5	807.0	10.5	80,835
30	230.4	59.6	1.7	4.9	101.5	283.2	158.8	840.1	11.1	83,677

ECONOMIC ANALYSIS

Clearfell Age	Discount Rate (%)	N.P.V. ($)	I.R.R. (%)	Breakeven Price ($/m3)
24.0	8.0	984.24	9.3	87.26
25.0	8.0	1024.44	9.2	87.96
26.0	8.0	1202.70	9.4	88.88
27.0	8.0	1031.43	9.1	89.99
28.0	8.0	839.76	8.9	91.30
29.0	8.0	633.37	8.7	92.84
30.0	8.0	416.06	8.4	94.62

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|          S T A N D   G R O W T H              |
|   Stand Treatment and Growth Simulation       |
|              Version 6.00                     |
|              New Zealand                      |
|     Forest Research Institute Limited         |
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Massey University Tue Feb 18 14:21:46 1997
Regime 2: 5 Prunings 1000sph - 350sph #075-67CB

```
Growth Model        : 23 EARLY     DOS fn.          : Standard
Basal area fn.      : High         Crown fn.        : Beekhuis
Basal area adj.     : 20.0%        DOS adj.         : 0.0 0.0 0.0 0.0 0.0 cm
Height Model        : 26           Site Index       : 23.0 m
Stand Volume fn.    : 22           Start Date       : 1994 JUL (4.1)
Monthly Growth fn.:   6            Mean Top Height  : 3.3 m

Growth Model        :  9 NAPIRAD
GF rating           :  7
Height Model        : 26           Site Index       : 23.0 m
Stand Volume fn.    : 22           Start Date       : 1994 JUL (4.1)
Monthly Growth fn.:   6            Mean Top Height  : 3.3 m
```

STANDING YIELD

Age yrs	Stocking stems/ha	MeanTopHt m	MeanHt m	BasalArea m^2/ha	MeanDBH cm	Volume m^3/ha	M.A.I. m^3/ha/yr
4.1	1000	3.3	2.9	3.10	6.3	7	1.7
4.7	1000	4.0	3.5	6.98	9.4	15	3.1
>> PRUNED (DOS) 380 stems/ha to leave 2.0 m. of crown							
4.7	1000	4.0	3.5	6.98	9.4	15	3.1
5.7	1000	5.2	4.5	14.74	13.7	34	5.9
6.4	1000	5.9	5.2	20.50	16.2	51	8.0
>> PRUNED (DOS) 350 stems/ha to leave 2.5 m. of crown							
6.4	1000	5.9	5.2	20.50	16.2	51	8.0
>> THINNED stand (least prnd) to waste leaving 350 stems/ha							
6.4	350	5.9	5.2	6.83	15.8	17	2.7
7.4	350	7.2	6.8	9.61	18.7	27	3.7
7.8	350	7.7	7.2	11.27	20.2	34	4.3
>> PRUNED (DOS) 350 stems/ha to leave 3.0 m. of crown							
7.8	350	7.7	7.2	11.27	20.2	34	4.3
8.9	350	9.1	8.5	14.65	23.1	50	5.6
>> PRUNED (DOS) 350 stems/ha to leave 3.2 m. of crown							
8.9	350	9.1	8.5	14.65	23.1	50	5.6
10.1	350	10.7	9.8	17.52	25.2	68	6.7
>> PRUNED (DOS) 350 stems/ha to 6.0 m.							
10.1	350	10.7	9.8	17.52	25.2	68	6.7
11.1	350	11.9	11.0	20.21	27.1	87	7.8
12.1	350	13.2	12.2	24.34	29.8	114	9.4
13.1	350	14.5	13.4	29.72	32.9	150	11.5
14.1	350	15.8	14.6	36.03	36.2	196	13.9
15.1	350	17.0	15.8	43.04	39.6	251	16.6
15.9	350	18.0	16.8	49.17	42.3	301	18.9
>> SWITCHED to later model set from G23 H26 V22 M6							
22.0	342	25.2	24.1	66.21	49.6	556	25.2
23.0	341	26.3	25.2	68.25	50.5	597	25.9
24.0	340	27.4	26.3	70.12	51.3	637	26.5
25.0	338	28.5	27.3	71.83	52.0	676	27.0
26.0	337	29.5	28.4	73.38	52.7	715	27.5
27.0	335	30.5	29.4	74.79	53.3	752	27.8
28.0	334	31.5	30.4	76.07	53.9	789	28.1
29.0	332	32.5	31.4	77.23	54.4	824	28.4
30.0	331	33.4	32.4	78.28	54.9	859	28.6
31.0	329	34.3	33.3	79.22	55.4	892	28.7
32.0	328	35.2	34.2	80.06	55.8	924	28.8
>> END Rotation							

PRUNING DETAILS

Date	Age (years)	Prune on	Prune to	Stocking (stems/ha)	MTH (m)	MCH (m)	PRH (m)	DBH (cm)	DOS (cm)	Crop DOS (cm)	DOSH (m)	Caliper (cm)	MaxBr (cm)	CRL (m)
1994DEC	4.7	DOS	2.0C	380	4.0	3.9	1.9	10.5	18.8	18.8	0.8	9.7	6.0	2.0
1996SEP	6.4	DOS	2.5C	350	5.9	5.7	3.2	15.8	18.8	18.8	2.1	10.2	5.9	2.5
1998JAN	7.8	DOS	3.0C	350	7.7	7.2	4.2	20.2	18.8	18.8	3.4	11.5	6.1	3.0
1999MAR	8.9	DOS	3.2C	350	9.1	8.5	5.3	23.1	18.9	18.9	4.4	11.4	6.0	3.2
2000JUL	10.1	DOS	6.0H	350	10.7	9.8	6.0	25.2	18.8	18.8	5.5	12.4	5.9	3.8

Where
- Prune codes : C = Crown remaining (m).
  - % = Percentage of tree height.
  - H = Prune height (m).
- MCH : Mean height of crop (most pruned element).
- CRL : Length of average tree crown above pruning.
- MTH : Mean top height of stand.
- PRH : Prune height.
- DOS : Diameter over pruning stubs.
- DOSH : Height to largest pruned whorl (DOS).
- MaxBr : Diameter of the largest branch stub at DOSH.

LOG AGGREGATION YIELD TABLE :

Clearfell Recoverable Volume (all stand elements)

AGE	P1	P2	S1	S2	S3/L3	L1/L2	PULP	Total	Waste	Gross $/ha
24	98.0	146.3	0.2	2.8	102.3	142.6	124.6	616.8	7.5	59,854
25	161.2	76.9	0.3	3.2	110.7	162.6	140.8	655.7	8.4	64,503
26	188.7	72.3	0.4	4.8	94.2	204.8	128.3	693.5	8.7	70,376
27	199.9	68.3	0.6	5.0	97.3	227.5	132.1	730.7	9.3	73,857
28	210.0	66.6	1.5	4.4	114.0	234.2	136.5	767.1	9.9	77,191
29	219.4	63.4	1.6	5.3	94.2	267.7	150.6	802.2	10.5	80,315
30	227.7	60.6	1.8	5.2	102.3	282.4	155.5	835.4	11.0	83,205

ECONOMIC ANALYSIS

Clearfell Age	Discount Rate (%)	N.P.V. ($)	I.R.R. (%)	Breakeven Price ($/m3)
24.0	8.0	2377.39	11.8	72.59
25.0	8.0	2426.43	11.6	73.02
26.0	8.0	2613.69	11.6	73.60
27.0	8.0	2449.60	11.3	74.30
28.0	8.0	2266.17	11.0	75.13
29.0	8.0	2066.71	10.7	76.10
30.0	8.0	1854.89	10.4	77.24

S T A N D   G R O W T H

Stand Treatment and Growth Simulation

Version 6.00

New Zealand

Forest Research Institute Limited

Massey University — Tue Feb 18 13:44:57 1997

Regime 3: 4 Prunings 1000sph - 350sph — #075-67CB

Growth Model	: 23 EARLY	DOS fn.	: Standard
Basal area fn.	: High	Crown fn.	: Beekhuis
Basal area adj.	: 20.0%	DOS adj.	: 0.0 0.0 0.0 0.0 cm
Height Model	: 26	Site Index	: 23.0 m
Stand Volume fn.	: 22	Start Date	: 1994 JUL (4.1)
Monthly Growth fn.	: 6	Mean Top Height	: 3.3 m

Growth Model	: 9 NAPIRAD		
GF rating	: 7		
Height Model	: 26	Site Index	: 23.0 m
Stand Volume fn.	: 22	Start Date	: 1994 JUL (4.1)
Monthly Growth fn.	: 6	Mean Top Height	: 3.3 m

STANDING YIELD

Age yrs	Stocking stems/ha	MeanTopHt m	MeanHt m	BasalArea m^2/ha	MeanDBH cm	Volume m^3/ha	M.A.I. m^3/ha/yr
4.1	1000	3.3	2.9	3.10	6.3	7	1.7
4.7	1000	4.0	3.5	6.98	9.4	15	3.1
>> PRUNED (DOS) 380 stems/ha to leave 2.0 m. of crown							
4.7	1000	4.0	3.5	6.98	9.4	15	3.1
5.7	1000	5.2	4.5	14.74	13.7	34	5.9
6.4	1000	5.9	5.2	20.50	16.2	51	8.0
>> PRUNED (DOS) 350 stems/ha to leave 2.5 m. of crown							
6.4	1000	5.9	5.2	20.50	16.2	51	8.0
7.4	1000	7.2	6.4	28.83	19.2	82	11.1
8.4	1000	8.4	7.6	35.75	21.3	115	13.7
>> PRUNED (DOS) 350 stems/ha to leave 3.0 m. of crown							
8.4	1000	8.4	7.6	35.75	21.3	115	13.7
>> THINNED stand (least prnd) to waste leaving 350 stems/ha							
8.4	350	8.4	7.6	10.50	19.5	34	4.1
9.4	350	9.7	9.2	12.24	21.1	45	4.8
10.2	350	10.8	10.2	15.17	23.5	60	5.9
>> PRUNED (DOS) 350 stems/ha to 6.0 m.							
10.2	350	10.8	10.2	15.17	23.5	60	5.9
11.2	350	12.1	11.4	18.02	25.6	79	7.0
12.2	350	13.4	12.6	22.34	28.5	106	8.7
13.2	350	14.6	13.8	27.84	31.8	142	10.8
14.2	350	15.9	15.0	34.23	35.3	188	13.2
15.2	350	17.2	16.2	41.28	38.8	243	15.9
15.9	350	18.0	17.0	46.61	41.2	286	18.0
>> SWITCHED to later model set from G23 H26 V22 M6							
22.0	343	25.2	24.1	64.34	48.9	540	24.5
23.0	341	26.3	25.2	66.49	49.8	582	25.2
24.0	340	27.4	26.3	68.47	50.7	622	25.9
25.0	338	28.5	27.3	70.27	51.4	662	26.4
26.0	337	29.5	28.4	71.92	52.1	701	26.9
27.0	335	30.5	29.4	73.43	52.8	739	27.3
28.0	334	31.5	30.4	74.79	53.4	776	27.7
29.0	332	32.5	31.4	76.03	54.0	812	28.0
30.0	331	33.4	32.4	77.16	54.5	847	28.2
31.0	329	34.3	33.3	78.17	55.0	880	28.4
32.0	328	35.2	34.2	79.08	55.4	913	28.5
>> END Rotation							

PRUNING DETAILS

Date	Age (years)	Prune on	Prune to	Stocking (stems/ha)	MTH (m)	MCH (m)	PRH (m)	DBH (cm)	DOS (cm)	Crop DOS (cm)	DOSH (m)	Caliper (cm)	MaxBr (cm)	CRL (m)
1994DEC	4.7	DOS	2.0C	380	4.0	3.9	1.9	10.5	18.8	18.8	0.8	9.7	6.0	2.0
1996SEP	6.4	DOS	2.5C	350	5.9	5.7	3.2	15.8	18.7	18.7	2.1	10.2	5.9	2.5
1998SEP	8.4	DOS	3.0C	350	8.4	8.0	5.0	19.5	18.9	18.9	3.4	9.7	5.5	3.0
2000AUG	10.2	DOS	6.0H	350	10.8	10.2	6.0	23.5	18.8	18.8	5.2	12.0	5.5	4.2

Where
Prune codes : C = Crown remaining (m).
% = Percentage of tree height.
H = Prune height (m).
MCH : Mean height of crop (most pruned element).
CRL : Length of average tree crown above pruning.
MTH : Mean top height of stand.
PRH : Prune height.
DOS : Diameter over pruning stubs.
DOSH : Height to largest pruned whorl (DOS).
MaxBr : Diameter of the largest branch stub at DOSH.

LOG AGGREGATION YIELD TABLE :

Clearfell Recoverable Volume (all stand elements)

AGE	P1	P2	S1	S2	S3/L3	L1/L2	PULP	Total	Waste	Gross $/ha
24	88.1	149.8	0.2	3.0	105.1	136.8	120.2	603.2	7.4	58,128
25	151.2	80.7	0.3	3.5	112.9	156.9	136.1	641.6	8.3	62,764
26	179.6	75.7	0.4	5.4	95.9	199.3	122.8	679.3	8.5	68,715
27	191.6	71.4	0.6	5.6	98.9	222.3	127.5	718.0	9.2	72,356
28	202.4	69.5	1.5	4.9	115.9	229.9	130.7	754.9	9.7	75,809
29	212.1	65.9	1.8	5.9	95.9	263.6	144.5	789.7	10.3	78,947
30	221.2	62.9	1.9	5.9	100.1	279.1	152.9	824.0	10.9	81,926

ECONOMIC ANALYSIS

Clearfell Age	Discount Rate (%)	N.P.V. ($)	I.R.R. (%)	Breakeven Price ($/m3)
24.0	8.0	2504.40	12.2	70.03
25.0	8.0	2569.78	12.1	70.40
26.0	8.0	2781.83	12.1	70.90
27.0	8.0	2637.09	11.8	71.45
28.0	8.0	2474.61	11.5	72.15
29.0	8.0	2284.75	11.1	73.02
30.0	8.0	2082.93	10.8	73.99

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|            S T A N D   G R O W T H             |
|     Stand Treatment and Growth Simulation      |
|                 Version 6.00                   |
|                 New Zealand                    |
|        Forest Research Institute Limited       |
+------------------------------------------------+
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Massey University Tue Feb 18 14:15:21 1997

Regime 4: 3 Prunings 1000sph - 300sph #075-67CB

```
Growth Model        : 23 EARLY     DOS fn.          : Standard
Basal area fn.      : High         Crown fn.        : Beekhuis
Basal area adj.     : 20.0%        DOS adj.         : 0.0 0.0 0.0 0.0 cm
Height Model        : 26           Site Index       : 23.0 m
Stand Volume fn.    : 22           Start Date       : 1994 JUL (4.1)
Monthly Growth fn.:  6             Mean Top Height  : 3.3 m

Growth Model        :  9 NAPIRAD
GF rating           :  7
Height Model        : 26           Site Index       : 23.0 m
Stand Volume fn.    : 22           Start Date       : 1994 JUL (4.1)
Monthly Growth fn.:  6             Mean Top Height  : 3.3 m
```

STANDING YIELD

Age yrs	Stocking stems/ha	MeanTopHt m	MeanHt m	BasalArea m²/ha	MeanDBH cm	Volume m³/ha	M.A.I. m³/ha/yr
4.1	1000	3.3	2.9	3.10	6.3	7	1.7
4.7	1000	4.0	3.5	6.98	9.4	15	3.1
>> PRUNED (DOS) 330 stems/ha to leave 2.0 m. of crown							
4.7	1000	4.0	3.5	6.98	9.4	15	3.1
5.7	1000	5.2	4.5	14.82	13.7	34	5.9
6.5	1000	6.1	5.4	21.49	16.5	54	8.3
>> PRUNED (DOS) 300 stems/ha to leave 2.2 m. of crown							
6.5	1000	6.1	5.4	21.49	16.5	54	8.3
7.5	1000	7.4	6.6	29.67	19.4	86	11.4
8.5	1000	8.6	7.8	36.57	21.6	120	14.0
9.2	1000	9.5	8.6	41.88	23.1	149	16.1
>> PRUNED (DOS) 300 stems/ha to 6.0 m.							
9.2	1000	9.5	8.6	41.88	23.1	149	16.1
>> THINNED stand (least prnd) to waste leaving 300 stems/ha							
9.2	300	9.5	8.6	9.95	20.5	36	3.9
10.2	300	10.8	10.3	11.17	21.8	45	4.4
11.2	300	12.1	11.5	13.86	24.3	61	5.4
12.2	300	13.4	12.7	17.89	27.6	85	7.0
13.2	300	14.6	13.9	22.99	31.2	118	8.9
14.2	300	15.9	15.1	28.96	35.1	159	11.2
15.2	300	17.2	16.3	35.63	38.9	209	13.7
15.9	300	18.0	17.1	40.75	41.6	250	15.7
>> SWITCHED to later model set from G23 H26 V22 M6							
15.9	300	18.0	17.2	40.75	41.6	250	15.7
22.0	294	25.2	24.2	58.67	50.4	492	22.3
23.0	293	26.3	25.3	60.89	51.4	532	23.1
24.0	292	27.4	26.4	62.94	52.4	571	23.8
25.0	291	28.5	27.5	64.83	53.3	610	24.4
26.0	290	29.5	28.5	66.56	54.1	648	24.9
27.0	289	30.5	29.6	68.14	54.8	685	25.3
28.0	287	31.5	30.6	69.59	55.5	721	25.7
29.0	286	32.5	31.5	70.91	56.2	756	26.0
30.0	285	33.4	32.5	72.11	56.7	791	26.3
31.0	284	34.3	33.4	73.20	57.3	824	26.5
32.0	283	35.2	34.3	74.19	57.8	856	26.7
33.0	281	36.1	35.2	75.08	58.3	886	26.8
34.0	280	36.9	36.1	75.89	58.7	916	26.9
35.1	279	37.8	37.0	76.66	59.2	947	27.0
>> END Rotation							

PRUNING DETAILS

Date	Prune on Age (years)		Prune to	Stocking (stems/ha)	MTH (m)	MCH (m)	PRH (m)	DBH (cm)	DOS (cm)	Crop DOS (cm)	DOSH (m)	Caliper (cm)	MaxBr (cm)	CRL (m)
1994DEC	4.7	DOS	2.0C	330	4.0	3.9	1.9	10.6	18.9	18.9	0.8	9.6	6.0	2.0
1996OCT	6.5	DOS	2.2C	300	6.1	6.0	3.8	16.1	19.1	19.1	2.1	8.8	5.9	2.2
1999AUG	9.2	DOS	6.0H	300	9.5	9.2	6.0	20.5	18.9	18.9	4.0	9.2	5.3	3.2

Where
- Prune codes : C = Crown remaining (m).
  - % = Percentage of tree height.
  - H = Prune height (m).
- MCH : Mean height of crop (most pruned element).
- CRL : Length of average tree crown above pruning.
- MTH : Mean top height of stand.
- PRH : Prune height.
- DOS : Diameter over pruning stubs.
- DOSH : Height to largest pruned whorl (DOS).
- MaxBr : Diameter of the largest branch stub at DOSH.

LOG AGGREGATION YIELD TABLE :

Clearfell Recoverable Volume (all stand elements)

AGE	P1	P2	S1	S2	S3/L3	L1/L2	PULP	Total	Waste	Gross $/ha
24	98.9	121.4	0.3	3.1	84.1	136.8	106.6	551.3	6.7	54,313
25	158.3	57.7	0.4	3.5	91.9	156.4	121.0	589.2	7.5	58,906
26	184.5	53.1	0.6	5.1	78.2	195.6	109.3	626.3	7.8	64,551
27	195.9	49.2	0.8	5.2	80.9	219.6	111.3	662.9	8.4	68,061
28	206.1	46.9	2.0	4.3	95.0	226.9	117.3	698.4	9.0	71,289
29	215.5	44.0	2.2	5.0	78.3	257.7	130.3	733.1	9.6	74,398
30	223.9	41.6	2.3	5.0	84.3	272.3	136.6	766.0	10.1	77,285

ECONOMIC ANALYSIS

Clearfell Age	Discount Rate (%)	N.P.V. ($)	I.R.R. (%)	Breakeven Price ($/m3)
24.0	8.0	2710.87	13.0	67.36
25.0	8.0	2787.01	12.9	67.58
26.0	8.0	2974.18	12.8	67.92
27.0	8.0	2845.99	12.5	68.38
28.0	8.0	2680.56	12.1	68.95
29.0	8.0	2507.33	11.8	69.63
30.0	8.0	2317.60	11.4	70.44

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|            S T A N D   G R O W T H            |
|     Stand Treatment and Growth Simulation     |
|                 Version 6.00                  |
|                  New Zealand                  |
|       Forest Research Institute Limited       |
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Massey University — Tue Feb 18 14:17:26 1997

Regime 5: 3 Prunings 1200sph - 350sph — #075-67CB

Growth Model	: 23 EARLY	DOS fn.	: Standard
Basal area fn.	: High	Crown fn.	: Beekhuis
Basal area adj.	: 20.0%	DOS adj.	: 0.0 0.0 0.0 0.0 cm
Height Model	: 26	Site Index	: 23.0 m
Stand Volume fn.	: 22	Start Date	: 1994 JUL (4.1)
Monthly Growth fn.	: 6	Mean Top Height	: 3.3 m

Growth Model	: 9 NAPIRAD		
GF rating	: 7		
Height Model	: 26	Site Index	: 23.0 m
Stand Volume fn.	: 22	Start Date	: 1994 JUL (4.1)
Monthly Growth fn.	: 6	Mean Top Height	: 3.3 m

STANDING YIELD

Age yrs	Stocking stems/ha	MeanTopHt m	MeanHt m	BasalArea m^2/ha	MeanDBH cm	Volume m^3/ha	M.A.I. $m^3/ha/yr$
4.1	1200	3.3	2.9	3.72	6.3	9	2.1
4.7	1200	4.0	3.5	7.86	9.1	17	3.5
>> PRUNED (DOS) 400 stems/ha to leave 2.0 m. of crown							
4.7	1200	4.0	3.5	7.86	9.1	17	3.5
5.7	1200	5.2	4.6	16.16	13.1	37	6.5
6.7	1200	6.4	5.7	23.76	15.9	63	9.3
6.9	1200	6.5	5.8	25.28	16.4	68	9.9
>> PRUNED (DOS) 350 stems/ha to leave 2.5 m. of crown							
6.9	1200	6.5	5.8	25.28	16.4	68	9.9
7.9	1200	7.8	7.0	32.29	18.5	99	12.6
8.9	1200	9.1	8.2	39.14	20.4	135	15.2
9.9	1200	10.5	9.5	46.56	22.2	181	18.1
>> PRUNED (DOS) 350 stems/ha to 6.0 m.							
9.9	1200	10.5	9.5	46.56	22.2	181	18.1
>> THINNED stand (least prnd) to waste leaving 350 stems/ha							
9.9	350	10.5	9.5	11.11	20.1	44	4.4
10.9	350	11.8	11.2	13.42	22.1	58	5.3
11.9	350	13.1	12.4	17.26	25.1	81	6.8
12.9	350	14.3	13.6	22.37	28.5	113	8.7
13.9	350	15.6	14.8	28.44	32.2	154	11.0
14.9	350	16.9	16.0	35.22	35.8	204	13.6
15.9	350	18.0	17.1	42.23	39.2	260	16.3
>> SWITCHED to later model set from G23 H26 V22 M6							
15.9	350	18.0	17.0	42.23	39.2	260	16.3
22.0	343	25.2	24.1	61.05	47.6	513	23.3
23.0	341	26.3	25.2	63.39	48.6	555	24.1
24.0	340	27.4	26.3	65.54	49.6	596	24.8
25.0	338	28.5	27.3	67.52	50.4	636	25.4
26.0	337	29.5	28.4	69.34	51.2	676	26.0
27.0	336	30.5	29.4	71.00	51.9	715	26.4
28.0	334	31.5	30.4	72.51	52.6	753	26.8
29.0	333	32.5	31.4	73.90	53.2	789	27.2
30.0	331	33.4	32.4	75.15	53.8	825	27.5
31.0	330	34.3	33.3	76.29	54.3	859	27.7
32.0	328	35.2	34.2	77.33	54.8	893	27.9
>> END Rotation							

PRUNING DETAILS

Date	Prune on		Stocking (stems/ha)	MCH (m)		DBH (cm)	Crop DOS (cm)		Caliper (cm)		CRL (m)
	Age (years)	Prune to		MTH (m)	PRH (m)		DOS (cm)	DOSH (m)		MaxBr (cm)	
1994DEC	4.7 DOS	2.0C	400	4.0	3.9	1.9	10.4	18.6	18.7	0.8	9.6	5.9	2.0
1997FEB	6.9 DOS	2.5C	350	6.5	6.3	3.8	16.0	19.0	19.0	2.1	9.1	5.6	2.5
2000MAY	9.9 DOS	6.0H	350	10.5	10.0	6.0	20.1	19.0	19.0	4.0	10.0	5.0	4.0

Where
Prune codes : C = Crown remaining (m).
% = Percentage of tree height.
H = Prune height (m).
MCH : Mean height of crop (most pruned element).
CRL : Length of average tree crown above pruning.
MTH : Mean top height of stand.
PRH : Prune height.
DOS : Diameter over pruning stubs.
DOSH : Height to largest pruned whorl (DOS).
MaxBr : Diameter of the largest branch stub at DOSH.

LOG AGGREGATION YIELD TABLE :

Clearfell Recoverable Volume (all stand elements)

Age	P1	P2	S1	S2	S3/L3	L1/L2	PULP	Total	Waste	Gross $/ha
24	71.4	154.9	0.3	5.5	110.9	127.0	109.0	579.1	7.1	55,185
25	134.1	87.4	0.5	7.3	107.8	163.3	118.0	618.3	8.0	60,244
26	163.3	81.9	0.6	8.0	116.9	180.8	104.7	656.1	8.3	66,026
27	176.7	77.0	1.0	10.5	102.9	214.6	112.5	695.0	8.9	69,892
28	188.7	74.8	2.8	9.3	120.6	222.7	113.9	732.8	9.5	73,563
29	199.5	70.7	3.2	11.1	100.2	258.0	125.8	768.4	10.1	76,909
30	209.5	67.1	3.5	11.0	104.8	274.9	132.4	803.4	10.6	80,022

ECONOMIC ANALYSIS

Clearfell Age	Discount Rate (%)	N.P.V. ($)	I.R.R. (%)	Breakeven Price ($/m3)
24.0	8.0	2397.97	12.2	69.05
25.0	8.0	2537.09	12.2	69.31
26.0	8.0	2739.22	12.2	69.73
27.0	8.0	2639.20	11.9	70.20
28.0	8.0	2512.09	11.6	70.80
29.0	8.0	2352.02	11.3	71.56
30.0	8.0	2171.40	11.0	72.43

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|              S T A N D   G R O W T H          |
|     Stand Treatment and Growth Simulation     |
|                 Version 6.00                  |
|                 New Zealand                   |
|       Forest Research Institute Limited       |
+-----------------------------------------------+
Massey University                          Tue Feb 18 14:26:03 1997
Regime 6: 5 Prunings 800sph - 350sph                       #075-67CB
=====================================================================

   Growth Model        : 23 EARLY    DOS fn.          : Standard
   Basal area fn.      : High        Crown fn.        : Beekhuis
   Basal area adj.     : 20.0%       DOS adj.         : 0.0 0.0 0.0 0.0 0.0 cm
   Height Model        : 26          Site Index       : 23.0 m
   Stand Volume fn.    : 22          Start Date       : 1994 JUL (4.1)
   Monthly Growth fn.:  6            Mean Top Height : 3.3 m

   Growth Model        :  9 NAPIRAD
   GF rating           :  7
   Height Model        : 26          Site Index       : 23.0 m
   Stand Volume fn.    : 22          Start Date       : 1994 JUL (4.1)
   Monthly Growth fn.:  6            Mean Top Height : 3.3 m

                         STANDING YIELD
                         --------------

Age  Stocking  MeanTopHt MeanHt BasalArea MeanDBH  Volume    M.A.I.
yrs  stems/ha      m        m     m²/ha      cm      m³/ha    m³/ha/yr
 4.1    800       3.3      2.9     2.48      6.3        6        1.4
 4.6    800       3.9      3.4     5.17      9.1       11        2.3
>>  PRUNED (DOS ) 380 stems/ha to leave  2.0 m. of crown
 4.6    800       3.9      3.4     5.17      9.1       11        2.3
 5.6    800       5.1      4.4    11.82     13.7       26        4.7
 5.9    800       5.5      4.8    15.14     15.5       35        5.9
>>  PRUNED (DOS ) 350 stems/ha to leave  2.5 m. of crown
 5.9    800       5.5      4.8    15.14     15.5       35        5.9
 7.2    800       7.0      6.2    25.08     20.0       69        9.5
>>  PRUNED (DOS ) 350 stems/ha to leave  3.0 m. of crown
 7.2    800       7.0      6.2    25.08     20.0       69        9.5
 8.1    800       8.1      7.2    32.61     22.8      100       12.4
>>  PRUNED (DOS ) 350 stems/ha to leave  3.0 m. of crown
 8.1    800       8.1      7.2    32.61     22.8      100       12.4
>>  THINNED stand (least prnd) to waste leaving 350 stems/ha
 8.1    350       8.1      7.2    11.83     20.7       37        4.5
 9.5    350       9.9      9.2    15.34     23.6       56        5.9
>>  PRUNED (DOS ) 350 stems/ha to  6.0 m.
 9.5    350       9.9      9.2    15.34     23.6       56        5.9
10.5    350      11.2     10.3    17.13     25.0       70        6.6
11.5    350      12.5     11.5    20.19     27.1       90        7.8
12.5    350      13.7     12.7    24.72     30.0      120        9.6
13.5    350      15.0     13.9    30.39     33.2      159       11.7
14.5    350      16.3     15.1    36.91     36.6      207       14.2
15.5    350      17.5     16.3    44.07     40.0      264       17.0
15.9    350      18.0     16.8    47.85     41.7      294       18.4
>>  SWITCHED to later model set from G23 H26 V22 M6
22.0    342      25.2     24.1    65.25     49.3      548       24.9
23.0    341      26.3     25.2    67.35     50.1      589       25.6
24.0    340      27.4     26.3    69.28     51.0      629       26.2
25.0    338      28.5     27.3    71.03     51.7      669       26.7
26.0    337      29.5     28.4    72.64     52.4      708       27.2
27.0    335      30.5     29.4    74.10     53.0      746       27.6
28.0    334      31.5     30.4    75.42     53.6      782       27.9
29.0    332      32.5     31.4    76.62     54.2      818       28.2
30.0    331      33.4     32.4    77.70     54.7      853       28.4
31.0    329      34.3     33.3    78.68     55.2      886       28.5
32.0    328      35.2     34.2    79.56     55.6      918       28.7
>>  END Rotation
```

PRUNING DETAILS

Date	Age (years)	Prune on	Prune to	Stocking (stems/ha)	MTH (m)	MCH (m)	PRH (m)	DBH (cm)	DOS (cm)	Crop DOS (cm)	DOSH (m)	Caliper (cm)	MaxBr (cm)	CRL (m)
1994NOV	4.6	DOS	2.0C	380	3.9	3.7	1.7	9.8	18.1	18.1	0.8	9.9	5.8	2.0
1996MAY	5.9	DOS	2.5C	350	5.5	5.2	2.7	15.2	18.9	18.9	1.9	11.3	6.3	2.5
1997AUG	7.2	DOS	3.0C	350	7.0	6.6	3.6	18.7	19.0	19.0	2.9	11.9	6.1	3.0
1998JUL	8.1	DOS	3.0C	350	8.1	7.6	4.6	20.7	18.4	18.4	3.8	11.1	5.9	3.0
1999OCT	9.5	DOS	6.0H	350	9.9	9.2	6.0	23.6	18.9	18.9	4.8	10.5	5.9	3.2

Where
Prune codes : C = Crown remaining (m).
% = Percentage of tree height.
H = Prune height (m).
MCH : Mean height of crop (most pruned element).
CRL : Length of average tree crown above pruning.
MTH : Mean top height of stand.
PRH : Prune height.
DOS : Diameter over pruning stubs.
DOSH : Height to largest pruned whorl (DOS).
MaxBr : Diameter of the largest branch stub at DOSH.

LOG AGGREGATION YIELD TABLE :

Clearfell Recoverable Volume (all stand elements)

AGE	P1	P2	S1	S2	S3/L3	L1/L2	PULP	Total	Waste	Gross $/ha
24	92.9	148.2	0.2	2.9	103.7	139.6	122.4	609.9	7.4	58,977
25	156.2	78.8	0.3	3.4	111.9	159.8	138.3	648.7	8.3	63,640
26	184.1	74.1	0.4	5.1	95.1	202.1	125.8	686.7	8.6	69,568
27	195.7	69.9	0.6	5.3	98.2	225.0	129.6	724.2	9.2	73,109
28	206.1	68.0	1.5	4.7	115.0	232.1	133.4	760.9	9.8	76,477
29	215.8	64.7	1.7	5.6	95.1	265.8	147.5	796.1	10.4	79,658
30	224.4	61.7	1.8	5.5	103.3	280.8	151.9	829.6	11.0	82,571

ECONOMIC ANALYSIS

Clearfell Age	Discount Rate (%)	N.P.V. ($)	I.R.R. (%)	Breakeven Price ($/m3)
24.0	8.0	2395.45	11.9	71.78
25.0	8.0	2455.25	11.8	72.18
26.0	8.0	2653.39	11.8	72.72
27.0	8.0	2499.36	11.5	73.37
28.0	8.0	2326.58	11.2	74.15
29.0	8.0	2133.27	10.8	75.08
30.0	8.0	1928.55	10.5	76.16

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+------------------------------------------------+
|              S T A N D   G R O W T H           |
|     Stand Treatment and Growth Simulation      |
|                  Version 6.00                  |
|                  New Zealand                   |
|        Forest Research Institute Limited       |
+------------------------------------------------+
Massey University                              Tue Feb 18 13:23:59 1997
4 Prunings 1000sph - 270sph                                   #075-67CB
=======================================================================

   Growth Model         : 23 EARLY    DOS fn.          : Standard
   Basal area fn.       : High        Crown fn.        : Beekhuis
   Basal area adj.      : 20.0%       DOS adj.         : 0.0 0.0 0.0 0.0 cm
   Height Model         : 26          Site Index       : 23.0 m
   Stand Volume fn.     : 22          Start Date       : 1994 JUL (4.1)
   Monthly Growth fn.:   6            Mean Top Height  : 3.3 m

   Growth Model         :  9 NAPIRAD
   GF rating            :  7
   Height Model         : 26          Site Index       : 23.0 m
   Stand Volume fn.     : 22          Start Date       : 1994 JUL (4.1)
   Monthly Growth fn.:   6            Mean Top Height  : 3.3 m


                              STANDING YIELD
                              --------------

Age  Stocking  MeanTopHt MeanHt BasalArea MeanDBH  Volume   M.A.I.
yrs  stems/ha     m        m      m²/ha      cm     m³/ha    m³/ha/yr
 4.1   1000      3.3      2.9     3.10      6.3       7       1.7
 4.7   1000      4.0      3.5     6.98      9.4      15       3.1
>>  PRUNED (DOS ) 330 stems/ha to leave  2.0 m. of crown
 4.7   1000      4.0      3.5     6.98      9.4      15       3.1
 5.7   1000      5.2      4.5    14.82     13.7      34       5.9
 6.4   1000      5.9      5.3    20.60     16.2      51       8.0
>>  PRUNED (DOS ) 270 stems/ha to leave  2.5 m. of crown
 6.4   1000      5.9      5.3    20.60     16.2      51       8.0
 7.4   1000      7.2      6.4    28.67     19.1      81      11.0
 8.6   1000      8.8      7.9    36.99     21.7     123      14.2
>>  PRUNED (DOS ) 270 stems/ha to leave  3.0 m. of crown
 8.6   1000      8.8      7.9    36.99     21.7     123      14.2
>>  THINNED stand (least prnd) to waste leaving 270 stems/ha
 8.6    270      8.8      7.9     8.29     19.8      28       3.2
 9.6    270     10.0      9.7     9.30     20.9      35       3.6
10.7    270     11.4     10.9    12.16     23.9      51       4.7
>>  PRUNED (DOS ) 270 stems/ha to  6.0 m.
10.7    270     11.4     10.9    12.16     23.9      51       4.7
11.7    270     12.7     12.1    15.40     26.9      70       6.0
12.7    270     14.0     13.3    19.73     30.5      97       7.6
13.7    270     15.3     14.4    24.98     34.3     132       9.6
14.7    270     16.5     15.7    31.01     38.2     176      12.0
15.7    270     17.8     16.9    37.68     42.2     228      14.5
15.9    270     18.0     17.1    39.74     43.3     243      15.3
>>  SWITCHED to later model set from G23 H26 V22 M6
15.9    270     18.0     17.3    39.74     43.3     243      15.3
22.0    265     25.2     24.4    57.02     52.3     478      21.7
23.0    264     26.3     25.5    59.17     53.4     517      22.4
24.0    263     27.4     26.5    61.14     54.4     555      23.1
25.0    262     28.5     27.6    62.96     55.3     592      23.6
26.0    261     29.5     28.6    64.63     56.1     629      24.1
27.0    260     30.5     29.7    66.16     56.9     665      24.6
28.0    259     31.5     30.6    67.55     57.6     700      25.0
29.0    258     32.5     31.6    68.83     58.2     734      25.3
30.0    257     33.4     32.6    69.99     58.8     767      25.5
31.0    256     34.3     33.5    71.04     59.4     799      25.7
32.0    255     35.2     34.4    71.99     59.9     830      25.9
>>  END Rotation
```

PRUNING DETAILS

Date	Age (years)	Prune on	Prune to	Stocking (stems/ha)	MTH (m)	MCH (m)	PRH (m)	DBH (cm)	DOS (cm)	Crop DOS (cm)	DOSH (m)	Caliper (cm)	MaxBr (cm)	CRL (m)
1994DEC	4.7	DOS	2.0C	330	4.0	3.9	1.9	10.6	18.9	19.0	0.8	9.6	6.0	2.0
1996SEP	6.4	DOS	2.5C	270	5.9	5.9	3.4	15.8	18.6	18.6	2.1	9.9	5.8	2.5
1998NOV	8.6	DOS	3.0C	270	8.8	8.5	5.5	19.8	18.9	18.9	3.6	9.1	5.4	3.0
2000DEC	10.7	DOS	6.0H	270	11.4	10.9	6.0	23.9	18.6	18.6	5.7	13.1	5.4	4.9

Where
Prune codes : C = Crown remaining (m).
% = Percentage of tree height.
H = Prune height (m).
MCH : Mean height of crop (most pruned element).
CRL : Length of average tree crown above pruning.
MTH : Mean top height of stand.
PRH : Prune height.
DOS : Diameter over pruning stubs.
DOSH : Height to largest pruned whorl (DOS).
MaxBr : Diameter of the largest branch stub at DOSH.

LOG AGGREGATION YIELD TABLE :

Clearfell Recoverable Volume (all stand elements)

AGE	P1	P2	S1	S2	S3/L3	L1/L2	PULP	Total	Waste	Gross $/ha
24	118.5	96.2	0.3	1.9	66.2	135.7	114.0	532.6	6.4	53,463
25	171.6	39.8	0.4	2.1	73.8	152.7	128.6	568.9	7.2	57,711
26	194.5	36.2	0.4	2.8	63.8	187.7	119.4	604.8	7.5	62,851
27	204.6	33.8	0.7	2.9	66.1	209.5	123.0	640.5	8.1	66,231
28	213.7	31.3	1.4	2.7	61.5	228.9	135.3	674.9	8.7	69,225
29	221.8	29.4	1.5	2.7	63.5	242.0	147.0	707.9	9.2	72,015
30	229.2	27.7	1.6	2.6	67.2	254.4	157.4	740.1	9.8	74,695

ECONOMIC ANALYSIS

Clearfell Age	Discount Rate (%)	N.P.V. ($)	I.R.R. (%)	Breakeven Price ($/m3)
24.0	8.0	2512.33	12.5	70.43
25.0	8.0	2552.43	12.4	70.69
26.0	8.0	2684.80	12.3	71.09
27.0	8.0	2550.44	12.0	71.59
28.0	8.0	2374.14	11.6	72.24
29.0	8.0	2180.58	11.3	73.03
30.0	8.0	1984.03	10.9	73.95

S T A N D   G R O W T H
Stand Treatment and Growth Simulation
Version 6.00
New Zealand
Forest Research Institute Limited

Massey University — Thu Feb 13 13:39:36 1997
4 Prunings 1000sph - 300sph — #075-67CB

Growth Model	: 23 EARLY	DOS fn.	: Standard
Basal area fn.	: High	Crown fn.	: Beekhuis
Basal area adj.	: 20.0%	DOS adj.	: 0.0 0.0 0.0 0.0 cm
Height Model	: 26	Site Index	: 23.0 m
Stand Volume fn.	: 22	Start Date	: 1994 JUL (4.1)
Monthly Growth fn.	: 6	Mean Top Height	: 3.3 m

Growth Model	: 9 NAPIRAD		
GF rating	: 7		
Height Model	: 26	Site Index	: 23.0 m
Stand Volume fn.	: 22	Start Date	: 1994 JUL (4.1)
Monthly Growth fn.	: 6	Mean Top Height	: 3.3 m

STANDING YIELD:

Age yrs	Stocking stems/ha	MeanTopHt m	MeanHt m	BasalArea m^2/ha	MeanDBH cm	Volume m^3/ha	M.A.I. m^3/ha/yr
4.1	1000	3.3	2.9	3.10	6.3	7	1.7
4.7	1000	4.0	3.5	6.98	9.4	15	3.1
>> PRUNED (DOS) 330 stems/ha to leave 2.0 m. of crown							
4.7	1000	4.0	3.5	6.98	9.4	15	3.1
5.7	1000	5.2	4.5	14.82	13.7	34	5.9
6.5	1000	6.1	5.4	21.49	16.5	54	8.3
>> PRUNED (DOS) 300 stems/ha to leave 2.5 m. of crown							
6.5	1000	6.1	5.4	21.49	16.5	54	8.3
7.5	1000	7.4	6.6	29.52	19.4	85	11.3
8.6	1000	8.8	7.9	37.13	21.7	123	14.3
>> PRUNED (DOS) 300 stems/ha to leave 3.0 m. of crown							
8.6	1000	8.8	7.9	37.13	21.7	123	14.3
>> THINNED stand (least prnd) to waste leaving 300 stems/ha							
8.6	300	8.8	7.9	9.16	19.7	31	3.6
9.6	300	10.0	9.6	10.32	20.9	39	4.0
10.6	300	11.3	10.7	13.02	23.5	54	5.1
>> PRUNED (DOS) 300 stems/ha to 6.0 m.							
10.6	300	11.3	10.7	13.02	23.5	54	5.1
11.6	300	12.6	11.9	16.22	26.2	73	6.3
12.6	300	13.9	13.1	20.65	29.6	101	8.0
13.6	300	15.2	14.3	26.09	33.3	138	10.1
14.6	300	16.4	15.5	32.34	37.0	183	12.5
15.6	300	17.7	16.7	39.23	40.8	236	15.1
15.9	300	17.9	17.0	41.57	42.0	254	16.0
>> SWITCHED to later model set from G23 H26 V22 M6							
22.0	294	25.2	24.2	59.47	50.7	499	22.6
23.0	293	26.3	25.3	61.65	51.8	539	23.4
24.0	292	27.4	26.4	63.66	52.7	578	24.0
25.0	291	28.5	27.5	65.50	53.5	616	24.6
26.0	290	29.5	28.5	67.19	54.3	654	25.1
27.0	289	30.5	29.6	68.74	55.1	691	25.6
28.0	287	31.5	30.6	70.15	55.7	727	25.9
29.0	286	32.5	31.5	71.43	56.4	762	26.2
30.0	285	33.4	32.5	72.60	56.9	796	26.5
31.0	284	34.3	33.4	73.66	57.5	829	26.7
32.0	283	35.2	34.3	74.62	58.0	861	26.9
>> END Rotation							

PRUNING DETAILS

Date	Age (years)	Prune on	Prune to	Stocking (stems/ha)	MTH (m)	MCH (m)	PRH (m)	DBH (cm)	DOS (cm)	Crop DOS (cm)	DOSH (m)	Caliper (cm)	MaxBr (cm)	CRL (m)
1994DEC	4.7	DOS	2.0C	330	4.0	3.9	1.9	10.6	18.9	18.9	0.8	9.6	6.0	2.0
1996OCT	6.5	DOS	2.5C	300	6.1	6.0	3.5	16.1	18.9	18.9	2.1	9.8	5.8	2.5
1998NOV	8.6	DOS	3.0C	300	8.8	8.5	5.5	19.7	18.6	18.6	3.7	9.2	5.3	3.0
2000NOV	10.6	DOS	6.0H	300	11.3	10.7	6.0	23.5	18.3	18.3	5.7	12.7	5.3	4.7

Pruning codes : C = Crown remaining (m).
% = Percentage of tree height.
H = Prune height (m).

MCH : Mean height of crop (most pruned element).
CRL : Length of average tree crown above pruning.
MTH : Mean top height of stand.
PRH : Prune height.
DOS : Diameter over pruning stubs.
DOSH : Height to largest pruned whorl (DOS).
MaxBr : Diameter of the largest branch stub at DOSH.

LOG AGGREGATION YIELD TABLE :

Clearfell Recoverable Volume (all stand elements)

AGE	P1	P2	S1	S2	S3/L3	L1/L2	PULP	Total	Waste	Gross $/ha
24	103.7	119.3	0.2	2.4	81.8	136.4	113.4	557.2	6.7	54,961
25	162.6	55.9	0.3	2.8	89.5	155.2	128.6	595.0	7.6	59,478
26	188.3	51.5	0.4	3.9	76.4	193.6	117.8	631.9	7.9	65,031
27	199.4	47.8	0.6	4.0	79.0	216.9	120.6	668.4	8.5	68,495
28	209.5	45.6	1.5	3.4	92.5	224.0	127.7	704.2	9.1	71,712
29	218.5	42.9	1.7	3.9	76.2	253.4	141.6	738.2	9.6	74,726
30	226.6	40.6	1.8	3.9	81.9	267.1	149.1	771.0	10.2	77,544

ECONOMIC ANALYSIS

Clearfell Age	Discount Rate (%)	N.P.V. ($)	I.R.R. (%)	Breakeven Price ($/m3)
24.0	8.0	2500.52	12.4	70.18
25.0	8.0	2564.71	12.3	70.45
26.0	8.0	2739.00	12.3	70.86
27.0	8.0	2601.94	11.9	71.40
28.0	8.0	2431.71	11.6	72.04
29.0	8.0	2248.19	11.3	72.85
30.0	8.0	2052.81	10.9	73.78

STAND GROWTH
Stand Treatment and Growth Simulation
Version 6.00
New Zealand
Forest Research Institute Limited

Massey University — Fri Feb 14 08:42:14 1997
4 Prunings 1000sph - 400sph — #075-67CB

Growth Model	: 23 EARLY	DOS fn.	: Standard
Basal area fn.	: High	Crown fn.	: Beekhuis
Basal area adj.	: 20.0%	DOS adj.	: 0.0 0.0 0.0 cm
Height Model	: 26	Site Index	: 23.0 m
Stand Volume fn.	: 22	Start Date	: 1994 JUL (4.1)
Monthly Growth fn.	: 6	Mean Top Height	: 3.3 m

Growth Model	: 9 NAPIRAD		
GF rating	: 7		
Height Model	: 26	Site Index	: 23.0 m
Stand Volume fn.	: 22	Start Date	: 1994 JUL (4.1)
Monthly Growth fn.	: 6	Mean Top Height	: 3.3 m

STANDING YIELD:

Age yrs	Stocking stems/ha	MeanTopHt m	MeanHt m	BasalArea m^2/ha	MeanDBH cm	Volume m^3/ha	M.A.I. m^3/ha/yr
4.1	1000	3.3	2.9	3.10	6.3	7	1.7
4.7	1000	4.0	3.5	6.98	9.4	15	3.1
>> PRUNED (DOS) 430 stems/ha to leave 2.0 m. of crown							
4.7	1000	4.0	3.5	6.98	9.4	15	3.1
5.7	1000	5.2	4.5	14.66	13.7	33	5.8
6.2	1000	5.8	5.1	19.49	15.8	47	7.6
>> PRUNED (DOS) 400 stems/ha to leave 2.5 m. of crown							
6.2	1000	5.8	5.1	19.49	15.8	47	7.6
7.2	1000	7.0	6.2	27.95	18.9	78	10.7
8.0	1000	8.0	7.1	33.73	20.7	104	12.9
>> PRUNED (DOS) 400 stems/ha to leave 3.0 m. of crown							
8.0	1000	8.0	7.1	33.73	20.7	104	12.9
>> THINNED stand (least prnd) to waste leaving 400 stems/ha							
8.0	400	8.0	7.1	11.57	19.2	36	4.5
9.0	400	9.3	8.7	13.95	21.1	49	5.4
9.8	400	10.3	9.6	16.76	23.1	64	6.5
>> PRUNED (DOS) 400 stems/ha to 6.0 m.							
9.8	400	10.3	9.6	16.76	23.1	64	6.5
10.8	400	11.5	10.7	19.28	24.8	81	7.5
11.8	400	12.8	11.9	23.07	27.1	106	8.9
12.8	400	14.1	13.1	28.21	30.0	140	10.9
13.8	400	15.4	14.3	34.40	33.1	184	13.3
14.8	400	16.6	15.5	41.33	36.3	236	16.0
15.9	400	18.0	16.9	50.07	39.9	308	19.3
>> SWITCHED to later model set from G23 H26 V22 M6							
22.0	391	25.2	23.9	67.98	47.1	572	25.9
23.0	389	26.3	25.0	70.13	47.9	614	26.7
24.0	387	27.4	26.1	72.10	48.7	656	27.3
25.0	386	28.5	27.2	73.90	49.4	697	27.8
26.0	384	29.5	28.2	75.54	50.1	737	28.3
27.0	382	30.5	29.3	77.03	50.7	776	28.7
28.0	380	31.5	30.3	78.38	51.2	814	29.0
29.0	378	32.5	31.3	79.60	51.8	851	29.3
30.0	376	33.4	32.2	80.70	52.2	886	29.5
31.0	374	34.3	33.2	81.69	52.7	921	29.7
32.0	373	35.2	34.1	82.58	53.1	954	29.8
>> END Rotation							

PRUNING DETAILS

Date	Age (years)	Prune on	Prune to	Stocking (stems/ha)	MTH (m)	MCH (m)	PRH (m)	DBH (cm)	DOS (cm)	Crop DOS (cm)	DOSH (m)	Caliper (cm)	MaxBr (cm)	CRL (m)
1994DEC	4.7	DOS	2.0C	430	4.0	3.8	1.8	10.4	18.7	18.8	0.8	9.8	6.0	2.0
1996AUG	6.2	DOS	2.5C	400	5.8	5.5	3.0	15.4	18.6	18.6	2.0	10.6	6.0	2.5
1998JUN	8.0	DOS	3.0C	400	8.0	7.6	4.6	19.2	19.0	19.0	3.2	10.3	5.7	3.0
2000JAN	9.8	DOS	6.0H	400	10.3	9.6	6.0	23.1	19.1	19.1	4.8	10.9	5.7	3.6

Pruning codes : C = Crown remaining (m).
% = Percentage of tree height.
H = Prune height (m).

MCH : Mean height of crop (most pruned element).
CRL : Length of average tree crown above pruning.
MTH : Mean top height of stand.
PRH : Prune height.
DOS : Diameter over pruning stubs.
DOSH : Height to largest pruned whorl (DOS).
MaxBr : Diameter of the largest branch stub at DOSH.

LOG AGGREGATION YIELD TABLE :

Clearfell Recoverable Volume (all stand elements)

AGE	P1	P2	S1	S2	S3/L3	L1/L2	PULP	Total	Waste	Gross $/ha
24	71.3	175.3	0.2	3.6	128.8	131.1	128.7	638.9	7.9	60,067
25	135.2	105.3	0.3	4.9	126.5	167.4	139.3	678.9	8.8	65,074
26	164.5	100.2	0.3	7.0	115.8	197.1	130.8	715.8	9.1	70,885
27	177.4	95.6	0.5	7.4	119.1	219.9	136.3	756.2	9.7	74,704
28	189.0	94.5	1.6	6.7	138.0	227.8	137.0	794.5	10.3	78,455
29	199.5	90.4	1.8	8.1	114.7	264.4	150.4	830.3	10.9	81,675
30	209.0	86.7	1.9	8.3	121.3	280.5	157.1	864.8	11.5	84,761

ECONOMIC ANALYSIS

Clearfell Age	Discount Rate (%)	N.P.V. ($)	I.R.R. (%)	Breakeven Price ($/m3)
24.0	8.0	2361.91	11.8	70.55
25.0	8.0	2468.84	11.8	70.95
26.0	8.0	2659.41	11.8	71.57
27.0	8.0	2521.42	11.5	72.15
28.0	8.0	2379.64	11.2	72.90
29.0	8.0	2194.32	10.9	73.82
30.0	8.0	1989.09	10.6	74.87

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+-------------------------------------------+
|          S T A N D   G R O W T H          |
|   Stand Treatment and Growth Simulation   |
|              Version 6.00                 |
|              New Zealand                  |
|      Forest Research Institute Limited    |
+-------------------------------------------+
Massey University                         Tue Feb 18 14:08:21 1997
3 Prunings 1000sph - 270sph                                #075-67CB
======================================================================

   Growth Model        : 23 EARLY     DOS fn.          : Standard
   Basal area fn.      : High         Crown fn.        : Beekhuis
   Basal area adj.     : 20.0%        DOS adj.         : 0.0 0.0 0.0 0.0 0.0 cm
   Height Model        : 26           Site Index       : 23.0 m
   Stand Volume fn.    : 22           Start Date       : 1994 JUL (4.1)
   Monthly Growth fn.:  6             Mean Top Height  : 3.3 m

   Growth Model        :  9 NAPIRAD
   GF rating           :  7
   Height Model        : 26           Site Index       : 23.0 m
   Stand Volume fn.    : 22           Start Date       : 1994 JUL (4.1)
   Monthly Growth fn.:  6             Mean Top Height  : 3.3 m
```

STANDING YIELD

Age yrs	Stocking stems/ha	MeanTopHt m	MeanHt m	BasalArea m^2/ha	MeanDBH cm	Volume m^3/ha	M.A.I. m^3/ha/yr
4.1	1000	3.3	2.9	3.10	6.3	7	1.7
4.7	1000	4.0	3.5	6.98	9.4	15	3.1
>> PRUNED (DOS) 330 stems/ha to leave 2.0 m. of crown							
4.7	1000	4.0	3.5	6.98	9.4	15	3.1
5.7	1000	5.2	4.5	14.82	13.7	34	5.9
6.4	1000	5.9	5.3	20.60	16.2	51	8.0
>> PRUNED (DOS) 270 stems/ha to leave 2.2 m. of crown							
6.4	1000	5.9	5.3	20.60	16.2	51	8.0
7.4	1000	7.2	6.4	28.79	19.1	81	11.0
8.4	1000	8.4	7.6	35.70	21.3	115	13.7
9.1	1000	9.4	8.5	41.02	22.9	144	15.8
>> PRUNED (DOS) 270 stems/ha to 6.0 m.							
9.1	1000	9.4	8.5	41.02	22.9	144	15.8
>> THINNED stand (least prnd) to waste leaving 270 stems/ha							
9.1	270	9.4	8.5	8.86	20.4	31	3.5
10.1	270	10.7	10.2	9.89	21.6	39	3.9
11.1	270	11.9	11.4	12.38	24.2	54	4.8
12.1	270	13.2	12.6	16.10	27.6	76	6.2
13.1	270	14.5	13.8	20.83	31.3	106	8.1
14.1	270	15.8	15.0	26.42	35.3	144	10.2
15.1	270	17.0	16.2	32.73	39.3	191	12.6
15.9	270	18.0	17.1	38.35	42.5	235	14.8
>> SWITCHED to later model set from G23 H26 V22 M6							
15.9	270	18.0	17.3	38.35	42.5	235	14.8
22.0	265	25.2	24.4	55.96	51.8	469	21.3
23.0	264	26.3	25.5	58.16	52.9	508	22.0
24.0	263	27.4	26.5	60.19	54.0	546	22.7
25.0	262	28.5	27.6	62.06	54.9	584	23.3
26.0	261	29.5	28.6	63.78	55.7	621	23.8
27.0	260	30.5	29.7	65.36	56.5	657	24.3
28.0	259	31.5	30.6	66.81	57.3	692	24.7
29.0	258	32.5	31.6	68.13	57.9	726	25.0
30.0	257	33.4	32.6	69.33	58.6	760	25.3
31.0	256	34.3	33.5	70.42	59.1	792	25.5
32.0	255	35.2	34.4	71.42	59.7	823	25.7
>> END Rotation							

PRUNING DETAILS

Date	Age (years)	Prune on	Prune to	Stocking (stems/ha)	MTH (m)	MCH (m)	PRH (m)	DBH (cm)	DOS (cm)	Crop DOS (cm)	DOSH (m)	Caliper (cm)	MaxBr (cm)	CRL (m)
1994DEC	4.7	DOS	2.0C	330	4.0	3.9	1.9	10.6	18.9	19.0	0.8	9.6	6.0	2.0
1996SEP	6.4	DOS	2.2C	270	5.9	5.9	3.7	15.8	18.6	18.6	2.1	8.9	5.8	2.2
1999JUL	9.1	DOS	6.0H	270	9.4	9.1	6.0	20.4	19.1	19.1	3.9	9.1	5.3	3.1

Where
Prune codes: C = Crown remaining (m).
% = Percentage of tree height.
H = Prune height (m).
MCH : Mean height of crop (most pruned element).
CRL : Length of average tree crown above pruning.
MTH : Mean top height of stand.
PRH : Prune height.
DOS : Diameter over pruning stubs.
DOSH : Height to largest pruned whorl (DOS).
MaxBr : Diameter of the largest branch stub at DOSH.

LOG AGGREGATION YIELD TABLE :

Clearfell Recoverable Volume (all stand elements)

AGE	P1	P2	S1	S2	S3/L3	L1/L2	PULP	Total	Waste	Gross $/ha
24	111.8	99.5	0.3	2.4	69.1	136.2	105.6	524.9	6.3	52,583
25	166.0	42.0	0.5	2.7	76.6	154.0	119.6	561.4	7.1	56,921
26	189.6	38.1	0.6	3.6	65.9	190.2	109.4	597.5	7.5	62,168
27	200.1	34.9	0.8	3.7	68.3	213.2	111.9	633.0	8.0	65,544
28	209.7	32.8	1.7	3.4	63.8	233.1	123.3	667.9	8.6	68,695
29	218.1	30.6	1.9	3.4	66.0	247.2	133.9	701.1	9.1	71,541
30	225.8	28.8	2.1	3.3	70.0	260.6	143.0	733.5	9.7	74,302

ECONOMIC ANALYSIS

Clearfell Age	Discount Rate (%)	N.P.V. ($)	I.R.R. (%)	Breakeven Price ($/m3)
24.0	8.0	2674.06	13.0	67.87
25.0	8.0	2730.97	12.9	68.07
26.0	8.0	2881.24	12.8	68.40
27.0	8.0	2750.94	12.5	68.84
28.0	8.0	2591.41	12.1	69.39
29.0	8.0	2406.01	11.7	70.08
30.0	8.0	2216.99	11.4	70.87

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+------------------------------------------+
|          S T A N D   G R O W T H         |
|   Stand Treatment and Growth Simulation  |
|              Version 6.00                |
|              New Zealand                 |
|    Forest Research Institute Limited     |
+------------------------------------------+
Massey University                             Tue Feb 18 14:20:02 1997
3 Prunings 1200sph - 400sph                                   #075-67CB
=======================================================================

  Growth Model       : 23 EARLY    DOS fn.          : Standard
  Basal area fn.     : High        Crown fn.        : Beekhuis
  Basal area adj.    : 20.0%       DOS adj.         : 0.0 0.0 0.0 0.0 cm
  Height Model       : 26          Site Index       : 23.0 m
  Stand Volume fn.   : 22          Start Date       : 1994 JUL (4.1)
  Monthly Growth fn.:   6          Mean Top Height : 3.3 m

  Growth Model       :  9 NAPIRAD
  GF rating          :  7
  Height Model       : 26          Site Index       : 23.0 m
  Stand Volume fn.   : 22          Start Date       : 1994 JUL (4.1)
  Monthly Growth fn.:   6          Mean Top Height : 3.3 m
```

STANDING YIELD

Age yrs	Stocking stems/ha	MeanTopHt m	MeanHt m	BasalArea m^2/ha	MeanDBH cm	Volume m^3/ha	M.A.I. m^3/ha/yr
4.1	1200	3.3	2.9	3.72	6.3	9	2.1
4.7	1200	4.0	3.5	7.86	9.1	17	3.5
>> PRUNED (DOS) 450 stems/ha to leave 2.0 m. of crown							
4.7	1200	4.0	3.5	7.86	9.1	17	3.5
5.7	1200	5.2	4.5	16.12	13.1	37	6.5
6.7	1200	6.4	5.6	23.82	15.9	63	9.3
>> PRUNED (DOS) 400 stems/ha to leave 2.5 m. of crown							
6.7	1200	6.4	5.6	23.82	15.9	63	9.3
7.7	1200	7.6	6.8	30.87	18.1	93	12.0
8.7	1200	8.9	8.0	37.74	20.0	128	14.7
9.7	1200	10.2	9.1	44.44	21.7	168	17.3
>> PRUNED (DOS) 400 stems/ha to 6.0 m.							
9.7	1200	10.2	9.1	44.44	21.7	168	17.3
>> THINNED stand (least prnd) to waste leaving 400 stems/ha							
9.7	400	10.2	9.1	12.26	19.8	47	4.8
10.7	400	11.4	10.8	14.39	21.4	61	5.7
11.7	400	12.7	12.0	17.82	23.8	82	7.0
12.7	400	14.0	13.2	22.65	26.8	113	8.8
13.7	400	15.3	14.4	28.59	30.2	153	11.1
14.7	400	16.5	15.5	35.30	33.5	202	13.7
15.7	400	17.8	16.7	42.51	36.8	259	16.5
15.9	400	18.0	17.0	44.66	37.7	275	17.3
>> SWITCHED to later model set from G23 H26 V22 M6							
15.9	400	18.0	16.8	44.66	37.7	275	17.3
22.0	391	25.2	23.9	63.96	45.6	538	24.4
23.0	389	26.3	25.0	66.34	46.6	581	25.2
24.0	388	27.4	26.1	68.53	47.5	624	26.0
25.0	386	28.5	27.2	70.54	48.3	666	26.6
26.0	384	29.5	28.2	72.38	49.0	707	27.1
27.0	382	30.5	29.3	74.07	49.7	746	27.6
28.0	380	31.5	30.3	75.60	50.3	785	28.0
29.0	379	32.5	31.3	77.00	50.9	823	28.4
30.0	377	33.4	32.2	78.27	51.4	860	28.6
31.0	375	34.3	33.2	79.41	51.9	896	28.9
32.0	373	35.2	34.1	80.45	52.4	930	29.0
>> END Rotation							

PRUNING DETAILS

Date	Age (years)	Prune on	Prune to	Stocking (stems/ha)	MTH (m)	MCH (m)	PRH (m)	DBH (cm)	DOS (cm)	Crop DOS (cm)	DOSH (m)	Caliper (cm)	MaxBr (cm)	CRL (m)
1994DEC	4.7	DOS	2.0C	450	4.0	3.8	1.8	10.3	18.5	18.6	0.8	9.7	5.9	2.0
1996DEC	6.7	DOS	2.5C	400	6.4	6.1	3.6	15.6	18.8	18.8	2.0	9.3	5.6	2.5
1999DEC	9.7	DOS	6.0H	400	10.2	9.6	6.0	19.8	19.0	19.0	3.8	9.4	5.0	3.6

Where
Prune codes : C = Crown remaining (m).
% = Percentage of tree height.
H = Prune height (m).
MCH : Mean height of crop (most pruned element).
CRL : Length of average tree crown above pruning.
MTH : Mean top height of stand.
PRH : Prune height.
DOS : Diameter over pruning stubs.
DOSH : Height to largest pruned whorl (DOS).
MaxBr : Diameter of the largest branch stub at DOSH.

LOG AGGREGATION YIELD TABLE :

Clearfell Recoverable Volume (all stand elements)

Age	P1	P2	S1	S2	S3/L3	L1/L2	PULP	Total	Waste	Gross $/ha
24	54.2	177.2	0.2	6.0	130.4	116.3	124.1	608.4	7.6	56,281
25	115.4	112.0	0.3	8.3	131.9	151.0	130.7	649.6	8.5	61,477
26	145.2	106.6	0.5	9.1	143.0	168.6	115.7	688.8	8.8	67,452
27	159.0	101.6	0.7	13.0	122.5	203.8	126.9	727.6	9.4	71,319
28	172.1	96.8	2.6	12.2	128.7	212.5	142.0	766.9	10.1	74,823
29	183.8	95.9	3.0	14.5	119.3	249.6	137.7	803.8	10.6	78,886
30	194.6	91.7	3.4	14.9	121.8	266.8	146.2	839.4	11.2	82,088

ECONOMIC ANALYSIS

Clearfell Age	Discount Rate (%)	N.P.V. ($)	I.R.R. (%)	Breakeven Price ($/m3)
24.0	8.0	2236.20	11.9	69.20
25.0	8.0	2387.42	11.8	69.46
26.0	8.0	2611.08	11.9	69.90
27.0	8.0	2513.12	11.6	70.45
28.0	8.0	2355.67	11.3	71.06
29.0	8.0	2269.26	11.1	71.84
30.0	8.0	2088.64	10.8	72.75

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+------------------------------------------------+
|              S T A N D   G R O W T H            |
|       Stand Treatment and Growth Simulation     |
|                   Version 6.00                  |
|                   New Zealand                   |
|          Forest Research Institute Limited      |
+------------------------------------------------+
Massey University                                 Tue Feb 18 14:30:20 1997
6 Prunings 800sph - 350sph                                        #075-67CB
===========================================================================

   Growth Model        : 23 EARLY    DOS fn.          : Standard
   Basal area fn.      : High        Crown fn.        : Beekhuis
   Basal area adj.     : 20.0%       DOS adj.         : 0.0 0.0 0.0 0.0 0.0 cm
   Height Model        : 26          Site Index       : 23.0 m
   Stand Volume fn.    : 22          Start Date       : 1994 JUL (4.1)
   Monthly Growth fn.:  6            Mean Top Height  : 3.3 m

   Growth Model        :  9 NAPIRAD
   GF rating           :  7
   Height Model        : 26          Site Index       : 23.0 m
   Stand Volume fn.    : 22          Start Date       : 1994 JUL (4.1)
   Monthly Growth fn.:  6            Mean Top Height  : 3.3 m
```

STANDING YIELD

Age yrs	Stocking stems/ha	MeanTopHt m	MeanHt m	BasalArea m^2/ha	MeanDBH cm	Volume m^3/ha	M.A.I. m^3/ha/yr
4.1	800	3.3	2.9	2.48	6.3	6	1.4
4.6	800	3.9	3.4	5.17	9.1	11	2.3
>> PRUNED (DOS) 380 stems/ha to leave 2.0 m. of crown							
4.6	800	3.9	3.4	5.17	9.1	11	2.3
5.6	800	5.1	4.4	11.82	13.7	26	4.7
5.9	800	5.5	4.8	15.14	15.5	35	5.9
>> PRUNED (DOS) 350 stems/ha to leave 2.5 m. of crown							
5.9	800	5.5	4.8	15.14	15.5	35	5.9
>> THINNED stand (least prnd) to waste leaving 350 stems/ha							
5.9	350	5.5	4.8	6.31	15.2	15	2.5
7.0	350	6.8	6.2	9.81	18.9	26	3.8
>> PRUNED (DOS) 350 stems/ha to leave 3.0 m. of crown							
7.0	350	6.8	6.2	9.81	18.9	26	3.8
7.6	350	7.5	6.9	11.45	20.4	33	4.4
>> PRUNED (DOS) 350 stems/ha to leave 3.0 m. of crown							
7.6	350	7.5	6.9	11.45	20.4	33	4.4
8.5	350	8.6	7.8	14.07	22.6	46	5.4
>> PRUNED (DOS) 350 stems/ha to leave 3.0 m. of crown							
8.5	350	8.6	7.8	14.07	22.6	46	5.4
9.6	350	10.0	9.1	16.66	24.6	62	6.4
>> PRUNED (DOS) 350 stems/ha to 6.0 m.							
9.6	350	10.0	9.1	16.66	24.6	62	6.4
10.6	350	11.3	10.2	18.46	25.9	76	7.1
11.6	350	12.6	11.4	21.51	28.0	97	8.3
12.6	350	13.9	12.6	26.00	30.8	127	10.0
13.6	350	15.2	13.8	31.66	33.9	167	12.2
14.6	350	16.4	15.0	38.18	37.3	216	14.7
15.6	350	17.7	16.2	45.35	40.6	273	17.5
15.9	350	18.0	16.6	48.35	41.9	297	18.6
>> SWITCHED to later model set from G23 H26 V22 M6							
22.0	342	25.2	24.1	65.61	49.4	551	25.0
23.0	341	26.3	25.2	67.69	50.3	592	25.7
24.0	340	27.4	26.3	69.60	51.1	632	26.3
25.0	338	28.5	27.3	71.34	51.8	672	26.8
26.0	337	29.5	28.4	72.92	52.5	710	27.3
27.0	335	30.5	29.4	74.36	53.1	748	27.7
28.0	334	31.5	30.4	75.67	53.7	785	28.0
29.0	332	32.5	31.4	76.85	54.3	820	28.3
30.0	331	33.4	32.4	77.92	54.8	855	28.5
31.0	329	34.3	33.3	78.89	55.2	888	28.6
32.0	328	35.2	34.2	79.75	55.7	921	28.7
>> END Rotation							

PRUNING DETAILS

Date	Age (years)	Prune on	Prune to	Stocking (stems/ha)	MTH (m)	MCH (m)	PRH (m)	DBH (cm)	DOS (cm)	Crop DOS (cm)	DOSH (m)	Caliper (cm)	MaxBr (cm)	CRL (m)
1994NOV	4.6	DOS	2.0C	380	3.9	3.7	1.7	9.8	18.1	18.1	0.8	9.9	5.8	2.0
1996MAY	5.9	DOS	2.5C	350	5.5	5.2	2.7	15.2	18.8	18.8	1.9	11.3	6.3	2.5
1997JUN	7.0	DOS	3.0C	350	6.8	6.2	3.2	18.9	18.8	18.8	2.9	12.9	6.4	3.0
1997NOV	7.6	DOS	3.0C	350	7.5	6.9	3.9	20.4	18.6	18.6	3.4	12.4	6.3	3.0
1998OCT	8.5	DOS	3.0C	350	8.6	7.8	4.8	22.6	18.8	18.8	4.1	11.6	6.3	3.0
1999NOV	9.6	DOS	6.0H	350	10.0	9.1	6.0	24.6	18.9	18.9	5.0	10.8	6.1	3.1

Where
Prune codes : C = Crown remaining (m).
% = Percentage of tree height.
H = Prune height (m).
MCH : Mean height of crop (most pruned element).
CRL : Length of average tree crown above pruning.
MTH : Mean top height of stand.
PRH : Prune height.
DOS : Diameter over pruning stubs.
DOSH : Height to largest pruned whorl (DOS).
MaxBr : Diameter of the largest branch stub at DOSH.

LOG AGGREGATION YIELD TABLE :

Clearfell Recoverable Volume (all stand elements)

AGE	P1	P2	S1	S2	S3/L3	L1/L2	PULP	Total	Waste	Gross $/ha
24	94.8	147.5	0.2	2.9	103.2	140.7	123.2	612.5	7.5	59,307
25	158.1	78.1	0.3	3.3	111.5	160.9	139.1	651.3	8.4	63,969
26	185.8	73.4	0.4	5.0	94.8	203.1	126.8	689.2	8.7	69,868
27	197.3	69.3	0.6	5.2	97.8	226.2	130.4	726.7	9.3	73,404
28	207.6	67.5	1.5	4.5	114.6	233.0	134.5	763.3	9.8	76,751
29	217.1	64.2	1.7	5.4	94.8	266.6	148.6	798.4	10.4	79,896
30	225.7	61.3	1.8	5.4	102.9	281.3	153.4	831.8	11.0	82,821

ECONOMIC ANALYSIS

Clearfell Age	Discount Rate (%)	N.P.V. ($)	I.R.R. (%)	Breakeven Price ($/m3)
24.0	8.0	2111.77	11.3	74.96
25.0	8.0	2167.73	11.2	75.41
26.0	8.0	2360.95	11.2	76.03
27.0	8.0	2204.01	10.9	76.77
28.0	8.0	2026.96	10.6	77.65
29.0	8.0	1831.35	10.3	78.70
30.0	8.0	1623.08	10.0	79.92

APPENDIX FOUR: Framing Regimes

Contents:

Stand Growth, Log Grade Yields and Economic Analysis

Regime 1: Initial 1000sph, thinned to 400sph at MCH 12m.

Regime 2: 1000sph - 400sph at MCH 9m.

Regime 3: 800sph - 400sph at age 8 years MCH 7m.

Regime 4: 800sph - 400sph at MCH 12m.

Regime 5: 800sph - 400sph at MCH 9m.

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+------------------------------------------------+
|              S T A N D   G R O W T H           |
|     Stand Treatment and Growth Simulation      |
|                  Version 6.00                  |
|                  New Zealand                   |
|        Forest Research Institute Limited       |
+------------------------------------------------+
Massey University                       Mon Feb 10 15:51:05 1997
Regime 1: Initial 1000sph, thinned to 400sph @ MCH 12m     #075-67CB
=====================================================================

   Growth Model        : 23 EARLY    DOS fn.           : Standard
   Basal area fn.      : High        Crown fn.         : Beekhuis
   Basal area adj.     : 20.0%       DOS adj.          : 0.0 0.0 0.0 cm
   Height Model        : 26          Site Index        : 23.0 m
   Stand Volume fn.    : 22          Start Date        : 1996 JUN (4.0)
   Monthly Growth fn.:  6            Mean Top Height   : 3.3 m

   Growth Model        :  9 NAPIRAD
   GF rating           :  7
   Height Model        : 26          Site Index        : 23.0 m
   Stand Volume fn.    : 22          Start Date        : 1996 JUN (4.0)
   Monthly Growth fn.:  6            Mean Top Height   : 3.3 m
```

STANDING YIELD:

Age yrs	Stocking stems/ha	MeanHt m	MeanDBH cm	BasalArea m^2/ha	Volume m^3/ha	M.A.I. m^3/ha/yr
12.6	1000	12.1	28.3	62.78	310	24.5
>> THINNED stand (least prnd) to waste leaving 400 stems/ha						
12.6	400	13.1	30.1	28.51	140	11.1
15.9	400	17.0	40.5	51.52	316	20.0
>> SWITCHED to later model set from G23 H26 V22 M6						
15.9	400	16.8	40.5	51.52	316	20.0
22.0	391	24.0	47.5	69.18	583	26.5
23.0	389	25.1	48.3	71.26	625	27.1
24.0	387	26.2	49.1	73.16	667	27.7
25.0	385	27.2	49.7	74.89	708	28.3
26.0	384	28.3	50.4	76.46	747	28.7
27.0	382	29.3	51.0	77.89	786	29.1
28.0	380	30.3	51.5	79.18	824	29.4
29.0	378	31.3	52.0	80.35	860	29.6
30.0	376	32.3	52.5	81.40	896	29.8
31.0	374	33.3	52.9	82.34	930	30.0
32.0	372	34.2	53.3	83.19	963	30.0
>> END Rotation						

LOG AGGREGATION YIELD TABLE :

Clearfell Recoverable Volume (all stand elements)

AGE	P1	P2	S1	S2	S3/L3	L1/L2	PULP	Total	Waste	Gross $/ha
24	0.0	0.0	43.6	70.1	143.1	294.6	84.2	635.6	13.0	43,328
25	0.0	0.0	49.0	72.6	137.9	324.6	89.7	673.8	13.8	46,096
26	0.0	0.0	54.3	76.4	134.9	356.5	91.1	713.1	14.6	49,045
27	0.0	0.0	61.1	75.4	133.9	387.3	92.5	750.2	15.3	51,799
28	0.0	0.0	65.6	75.5	135.6	421.9	88.6	787.2	16.1	54,621
29	0.0	0.0	69.5	76.0	126.7	456.1	94.0	822.3	16.8	57,151
30	0.0	0.0	72.5	74.8	130.7	479.3	99.1	856.4	17.5	59,465

ECONOMIC ANALYSIS :

Clearfell Age	Discount Rate (%)	N.P.V. ($)	I.R.R. (%)	Breakeven Price ($/m3)
24.0	8.0	1191.91	12.0	56.28
25.0	8.0	1174.47	11.8	56.48
26.0	8.0	1163.96	11.6	56.70
27.0	8.0	1131.76	11.4	57.00
28.0	8.0	1099.82	11.2	57.33
29.0	8.0	1037.81	10.9	57.74
30.0	8.0	956.22	10.7	58.20

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Regime 2: Initial 1000sph, thinned to 400sph @ MCH 9m   #075-67CB

```
Growth Model       : 23 EARLY     DOS fn.          : Standard
Basal area fn.     : High         Crown fn.        : Beekhuis
Basal area adj.    : 20.0%        DOS adj.         : 0.0 0.0 0.0 0.0 cm
Height Model       : 26           Site Index       : 23.0 m
Stand Volume fn.   : 22           Start Date       : 1996 JUN (4.0)
Monthly Growth fn.:  6            Mean Top Height  : 3.3 m

Growth Model       :  9 NAPIRAD
GF rating          :  7
Height Model       : 26           Site Index       : 23.0 m
Stand Volume fn.   : 22           Start Date       : 1996 JUN (4.0)
Monthly Growth fn.:  6            Mean Top Height  : 3.3 m
```

STANDING YIELD:

Age yrs	Stocking stems/ha	MeanHt m	MeanDBH cm	BasalArea m^2/ha	Volume m^3/ha	M.A.I. m^3/ha/yr
10.0	1000	9.1	24.5	46.98	183	18.2
>> THINNED stand (least prnd) to waste leaving 400 stems/ha						
10.0	400	10.0	26.2	21.56	83	8.3
15.9	400	17.0	44.7	62.67	384	24.2
>> SWITCHED to later model set from G23 H26 V22 M6						
15.9	400	16.8	44.7	62.67	384	24.2
22.0	390	24.0	50.1	76.87	647	29.4
23.0	389	25.1	50.7	78.47	688	29.9
24.0	387	26.2	51.3	79.91	728	30.3
25.0	385	27.2	51.8	81.20	767	30.6
26.0	383	28.3	52.3	82.36	804	30.9
27.0	381	29.3	52.8	83.40	841	31.1
28.0	379	30.3	53.2	84.33	877	31.3
29.0	378	31.3	53.6	85.16	911	31.4
30.0	376	32.3	54.0	85.89	944	31.4
31.0	374	33.3	54.3	86.53	976	31.5
32.0	372	34.2	54.6	87.09	1007	31.4
>> END Rotation						

LOG AGGREGATION YIELD TABLE :

Clearfell Recoverable Volume (all stand elements)

AGE	P1	P2	S1	S2	S3/L3	L1/L2	PULP	Total	Waste	Gross $/ha
24	0.0	0.0	34.4	38.7	130.0	389.9	98.1	691.1	14.1	46,521
25	0.0	0.0	36.7	41.4	126.0	420.7	103.1	728.0	14.9	49,120
26	0.0	0.0	39.0	41.7	126.5	453.2	106.0	766.3	15.6	51,831
27	0.0	0.0	41.9	41.0	124.5	484.3	109.6	801.4	16.4	54,297
28	0.0	0.0	44.0	41.1	126.9	517.3	108.0	837.3	17.1	56,924
29	0.0	0.0	44.9	41.5	119.2	549.2	115.5	870.3	17.8	59,167
30	0.0	0.0	45.4	41.3	127.6	569.7	117.7	901.8	18.4	61,273

ECONOMIC ANALYSIS

Clearfell Age	Discount Rate (%)	N.P.V. ($)	I.R.R. (%)	Breakeven Price ($/m3)
24.0	8.0	1278.56	12.1	55.59
25.0	8.0	1237.34	11.9	55.84
26.0	8.0	1193.45	11.6	56.11
27.0	8.0	1133.79	11.3	56.46
28.0	8.0	1082.21	11.1	56.84
29.0	8.0	999.17	10.8	57.29
30.0	8.0	910.45	10.5	57.80

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Regime 3: Initial 800sph, thinned to 400sph @ age 8 years #075-67CB

Growth Model	: 23 EARLY	DOS fn.	: Standard
Basal area fn.	: High	Crown fn.	: Beekhuis
Basal area adj.	: 20.0%	DOS adj.	: 0.0 0.0 0.0 0.0 0.0 cm
Height Model	: 26	Site Index	: 23.0 m
Stand Volume fn.	: 22	Start Date	: 1996 JUN (4.0)
Monthly Growth fn.	: 6	Mean Top Height	: 3.2 m

Growth Model	: 9 NAPIRAD		
GF rating	: 7		
Height Model	: 26	Site Index	: 23.0 m
Stand Volume fn.	: 22	Start Date	: 1996 JUN (4.0)
Monthly Growth fn.	: 6	Mean Top Height	: 3.2 m

STANDING YIELD:

Age yrs	Stocking stems/ha	MeanHt m	MeanDBH cm	BasalArea m^2/ha	Volume m^3/ha	M.A.I. m^3/ha/yr
8.0	800	7.0	23.1	33.45	102	12.6
>> THINNED stand (least prnd) to waste leaving 400 stems/ha						
8.0	400	7.5	24.3	18.56	56	7.0
15.9	400	16.8	49.5	77.12	470	29.5
>> SWITCHED to later model set from G23 H26 V22 M6						
15.9	400	16.8	49.5	77.12	470	29.5
22.0	390	23.9	53.0	86.11	721	32.7
23.0	388	25.0	53.4	87.07	760	33.0
24.0	387	26.1	53.8	87.91	797	33.2
25.0	385	27.2	54.2	88.64	834	33.3
26.0	383	28.2	54.5	89.29	869	33.4
27.0	381	29.3	54.8	89.84	903	33.4
28.0	379	30.3	55.1	90.32	936	33.4
29.0	377	31.3	55.3	90.73	968	33.3
30.0	375	32.2	55.6	91.07	999	33.2
31.0	373	33.2	55.8	91.36	1028	33.1
32.0	371	34.1	56.0	91.59	1057	33.0
>> END Rotation						

LOG AGGREGATION YIELD TABLE :

Clearfell Recoverable Volume (all stand elements)

AGE	P1	P2	S1	S2	S3/L3	L1/L2	PULP	Total	Waste	Gross $/ha
24	0	0	16.2	12.6	102.9	471.4	133.7	737.0	15.0	48,413
25	0	0	16.9	12.6	111.1	489.0	142.7	772.4	15.8	50,642
26	0	0	17.3	12.8	109.0	518.2	150.5	807.8	16.5	52,990
27	0	0	18.1	13.2	99.3	553.7	158.1	842.5	17.2	55,359
28	0	0	18.4	13.5	105.6	569.9	167.5	874.8	17.9	57,376
29	0	0	18.9	14.0	106.0	598.0	169.0	905.9	18.5	59,551
30	0	0	18.8	14.5	100.2	623.9	179.8	937.2	19.1	61,546

ECONOMIC ANALYSIS

Clearfell Age	Discount Rate (%)	N.P.V. ($)	I.R.R. (%)	Breakeven Price ($/m3)
24.0	8.0	1353.19	12.7	54.07
25.0	8.0	1267.80	12.2	54.33
26.0	8.0	1198.67	11.9	54.62
27.0	8.0	1135.31	11.6	54.95
28.0	8.0	1038.13	11.2	55.34
29.0	8.0	968.78	11.0	55.77
30.0	8.0	878.62	10.7	56.24

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Regime 4: Initial stand 800sph, thinned to 400sph @ MCH 12m #075-67CB

Growth Model	: 23 EARLY	DOS fn.	: Standard
Basal area fn.	: High	Crown fn.	: Beekhuis
Basal area adj.	: 20.0%	DOS adj.	: 0.0 0.0 0.0 0.0 cm
Height Model	: 26	Site Index	: 23.0 m
Stand Volume fn.	: 22	Start Date	: 1996 JUN (4.0)
Monthly Growth fn.	: 6	Mean Top Height	: 3.2 m

Growth Model	: 9 NAPIRAD		
GF rating	: 7		
Height Model	: 26	Site Index	: 23.0 m
Stand Volume fn.	: 22	Start Date	: 1996 JUN (4.0)
Monthly Growth fn.	: 6	Mean Top Height	: 3.2 m

STANDING YIELD:

Age yrs	Stocking stems/ha	MeanHt m	MeanDBH cm	BasalArea m^2/ha	Volume m^3/ha	M.A.I. $m^3/ha/yr$
12.5	800	12.1	31.4	62.02	299	23.9
>> THINNED stand (least prnd) to waste leaving 400 stems/ha						
12.5	400	12.8	32.8	33.72	162	13.0
15.9	400	16.9	42.9	57.79	354	22.2
>> SWITCHED to later model set from G23 H26 V22 M6						
15.9	400	16.8	42.9	57.79	354	22.2
22.0	391	23.9	48.9	73.46	617	28.0
23.0	389	25.0	49.7	75.28	658	28.6
24.0	387	26.1	50.3	76.93	699	29.1
25.0	385	27.2	50.9	78.43	739	29.5
26.0	383	28.2	51.5	79.78	777	29.9
27.0	382	29.2	52.0	80.99	815	30.1
28.0	380	30.3	52.5	82.09	852	30.4
29.0	378	31.3	52.9	83.07	887	30.5
30.0	376	32.2	53.3	83.94	921	30.7
31.0	374	33.2	53.7	84.72	954	30.7
32.0	372	34.1	54.1	85.41	986	30.8

>> END Rotation

LOG AGGREGATION YIELD TABLE :

Clearfell Recoverable Volume (all stand elements)

AGE	P1	P2	S1	S2	S3/L3	L1/L2	PULP	Total	Waste	Gross $/ha
24.0	0.0	0.0	27.3	43.2	135.5	371.1	87.5	664.5	13.6	44,736
25.0	0.0	0.0	29.9	45.1	132.8	402.2	92.4	702.3	14.3	47,396
26.0	0.0	0.0	32.7	47.9	129.0	436.5	94.7	740.7	15.1	50,190
27.0	0.0	0.0	36.3	47.6	128.9	469.0	95.6	777.3	15.9	52,849
28.0	0.0	0.0	38.6	48.4	131.3	502.8	91.6	812.8	16.6	55,500
29.0	0.0	0.0	40.5	49.0	123.6	537.0	97.5	847.8	17.3	57,945
30.0	0.0	0.0	42.2	48.6	127.1	559.3	103.3	880.4	18.0	60,136

ECONOMIC ANALYSIS

Clearfell Age	Discount Rate (%)	N.P.V. ($)	I.R.R. (%)	Breakeven Price ($/m3)
24.0	8.0	1334.83	12.8	54.58
25.0	8.0	1303.30	12.5	54.77
26.0	8.0	1277.80	12.3	54.99
27.0	8.0	1236.79	12.0	55.27
28.0	8.0	1195.80	11.8	55.60
29.0	8.0	1128.10	11.5	55.96
30.0	8.0	1041.82	11.1	56.39

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Regime 5: Initial 800sph, thinned to 400sph @ MCH 9m #075-67CB

Growth Model	: 23 EARLY	DOS fn.	: Standard
Basal area fn.	: High	Crown fn.	: Beekhuis
Basal area adj.	: 20.0%	DOS adj.	: 0.0 0.0 0.0 0.0 0.0 cm
Height Model	: 26	Site Index	: 23.0 m
Stand Volume fn.	: 22	Start Date	: 1996 JUN (4.0)
Monthly Growth fn.	: 6	Mean Top Height	: 3.2 m

Growth Model	: 9 NAPIRAD		
GF rating	: 7		
Height Model	: 26	Site Index	: 23.0 m
Stand Volume fn.	: 22	Start Date	: 1996 JUN (4.0)
Monthly Growth fn.	: 6	Mean Top Height	: 3.2 m

STANDING YIELD:

Age yrs	Stocking stems/ha	MeanHt m	MeanDBH cm	BasalArea m^2/ha	Volume m^3/ha	M.A.I. m^3/ha/yr
9.0	800	8.1	25.3	40.24	138	15.3
9.9	800	9.1	27.1	46.23	175	17.6
>> THINNED stand (least prnd) to waste leaving 400 stems/ha						
9.9	400	9.7	28.4	25.36	96	9.6
10.0	400	9.9	28.9	26.16	100	9.9
15.0	400	15.8	44.8	63.04	363	24.2
15.9	400	16.9	46.6	68.10	416	26.1
>> SWITCHED to later model set from G23 H26 V22 M6						
15.9	400	16.8	46.6	68.10	416	26.1
22.0	390	23.9	51.2	80.36	674	30.6
23.0	389	25.0	51.8	81.73	714	31.0
24.0	387	26.1	52.3	82.95	753	31.3
25.0	385	27.2	52.7	84.04	791	31.6
26.0	383	28.2	53.2	85.01	828	31.8
27.0	381	29.3	53.6	85.87	863	31.9
28.0	379	30.3	53.9	86.63	898	32.0
29.0	377	31.3	54.3	87.30	932	32.1
30.0	376	32.2	54.6	87.88	964	32.1
31.0	374	33.2	54.9	88.39	995	32.1
32.0	372	34.1	55.2	88.83	1025	32.0
>> END Rotation						

LOG AGGREGATION YIELD TABLE :

Clearfell Recoverable Volume (all stand elements)

AGE	P1	P2	S1	S2	S3/L3	L1/L2	PULP	Total	Waste	Gross $/ha
24	0.0	0.0	19.9	22.7	123.7	441.5	106.6	713.8	14.6	47,519
25	0.0	0.0	21.1	24.7	121.3	471.0	111.7	749.9	15.3	49,969
26	0.0	0.0	22.3	24.9	120.2	503.4	116.6	787.4	16.1	52,551
27	0.0	0.0	23.7	24.8	119.9	534.4	119.6	822.4	16.8	54,994
28	0.0	0.0	24.7	25.3	122.5	565.6	118.9	857.0	17.5	57,474
29	0.0	0.0	25.2	25.7	115.1	595.4	127.6	889.1	18.1	59,602
30	0.0	0.0	25.5	25.7	123.5	614.5	131.2	920.5	18.8	61,669

ECONOMIC ANALYSIS

Clearfell Age	Discount Rate (%)	N.P.V. ($)	I.R.R. (%)	Breakeven Price ($/m3)
24.0	8.0	1384.20	12.8	54.24
25.0	8.0	1331.83	12.5	54.48
26.0	8.0	1277.49	12.1	54.74
27.0	8.0	1215.99	11.8	55.06
28.0	8.0	1157.08	11.5	55.42
29.0	8.0	1070.00	11.2	55.83
30.0	8.0	980.14	10.9	56.29

APPENDIX FIVE: Financial Analysis

Contents:

Tuapaka Cash Budget (1996/97).

Land and Tree Valuation.

Forestry Cashflow Analysis.

TUAPAKA FARM
Farm Working Account for the year ending 30th June 1996
Budget 1996/97

	1996/97	324 $/HA	$/HA Monitor Farm (373ha)	
INCOME				
Cattle account	66,894	206	48	
Sheep account	43,234	133	163	
Wool account	27,119	84	125	
Sundry income	5,200	16	6	
Total Sales	142,447	440	342	
Cost of Sales				
Cattle purchases	32,610	101	9	
Sheep purchases	1,700	5	5	
Total Sales	34,310	106	14	
NET FARM INCOME	108,137	334	328	
EXPENDITURE				
SALARIES AND WAGES				
ACC Levies	750	2		
Salaries	28,500	88	91	(personal drawings+tax)
Wages	6,000	19	15	
Total	35,250	109	106	
WORKING EXPENSES				
Animal Health	7,814	24	20	
Electricity	1,680	5	5	
Fertiliser	24,640	76	28	
Shearing	6,200	19	32	
Vehicle Fuel & Oil	1,500	5	9	
Weed and Pest control	3,750	12	2	
Other			10	
Total	45,584	141	106	
REPAIRS AND MAINTENANCE				
R & M Buildings	4,088	13		
R & M Equipment	3,375	10		
R & M Improvements	5,400	17		
R & M Vehicles	2,625	8		
Total	15,488	48	29	
ADMINISTRATION EXPENSES				
Administration Fees	1,500	5		
Supervision	4,050	13		
Sundry	375	1		
Telephones	750	2		
Insurance	1,875	6		
Rates	3,750	12		
Total	12,300	38	33	
TOTAL FARM EXPENSES	108,622	335	274	
EFFECTIVE FARM SURPLUS	(485)	(1)	54	
ASSET CHARGES				
Depreciation	13,500	42		
NET TAXABLE INCOME	(13,985)	(43)		

Land and Tree Valuations

Land:

Current valuation for the Tuapaka hill country unit is around $1,650/ha based on $150 per stock unit (su) (pers. comm. Grant, 1997).

Estimated stocking for the scarpment considering landuse capability class VI-VII is 6 and 8su/ha.

Estimated land valuation for scarpment is around $1,000/ha. The land purchase and sale price is not a taxable item.

Trees:

The cashflows associated with 1 hectare of trees (land value excluded) were discounted at an 8% discount rate to an age associated with the project termination (i.e., 28 years). This value was then multiplied by the number of hectares associated with the stand. All the immature (or standing timber) trees were then totaled and entered in the "Standing Timber" section under "Revenues" in the discounted cashflow sheet.

For example:

6.1ha planted in 1994 is one year from harvest at the term of the project in 2021 i.e., 27 years of age.

The cashflows associated with 1ha were discounted at 8% to year 27 and then multiplied by 6.1ha to give a standing value of the trees for that stand within the project, refer to valuation sheet over.

Each stand was then valued in the similar manner, and the total value of the standing timber entered into the cashflow analysis.

A similar approach was used to to value the 1973 plantings. The beginning of the project term is 8 years before the stand is due to be harvested. The stand has a corressponding value in year zero of the project that is equal to the final harvest value discounted by 8% per year. This is then entered as the purchase price of the trees in year zero.

HARVEST REVENUES

FRAMING REGIME

Harvest Revenue (pre-tax) $/ha

LOG GRADE	Volume m3	$/m3	Net Revenue
P1	0.00	180.00	0.00
P2	0.00	136.00	0.00
S1	65.60	95.00	6232.00
S2	75.50	80.00	6040.00
S3/L3	135.60	71.00	9627.60
L1/L2	421.90	62.00	26157.80
PULP	88.60	45.00	3987.00
TOTAL	787.20		52044.40

Roading $/ha		400.00
Harvest $20.00/m3		15744.00
Cartage $25.00/m3		19680.00
		16220.40
Commission	5%	811.02
Pre-tax Harvest Value $/ha		$ 15,409.38
Average $/m3		$ 19.57

PRUNING REGIME

Harvest Revenue (pre-tax) $/ha

LOG GRADE	Volume m3	$/m3	Net Revenue
P1	206.10	180.00	37098.00
P2	46.90	136.00	6378.40
S1	2.00	95.00	190.00
S2	4.30	80.00	344.00
S3/L3	95.00	71.00	6745.00
L1/L2	226.90	62.00	14067.80
PULP	117.30	45.00	5278.50
TOTAL	698.50		70101.70

Roading $/ha		400.00
Harvest $20.00/m3		13970.00
Cartage $25.00/m3		17462.50
		38269.20
Commission	5%	1913.46
Pre-tax Harvest Value $/ha		$ 36,355.74
Average $/m3		$ 52.05

NPV of an unharvested Clearwood block at the 1ha level.

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Costs																													
Forest Management	(650)				(363)		(405)			(640)																			
Annual	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)
Total Costs	(680)	(30)	(30)	(30)	(393)	(30)	(435)	(30)	(30)	(670)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	'30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)
Revenues																													36,356
Pre-Tax Cashflow	(680)	(30)	(30)	(30)	(393)	(30)	(435)	(30)	(30)	(670)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	36,326
Age of Stand	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Pre-Tax NPV	$2,186	$3,040	$3,314	$3,609	$3,927	$4,635	$5,035	$5,873	$6,373	$6,913	$8,136	$8,817	$9,552	$10,346	$11,204	$12,130	$13,131	$14,211	$15,378	$16,638	$18,000	$19,469	$21,057	$22,772	$24,623	$26,623	$28,783	$33,635	

DR Pre-Tax 8.00%

NPV of an unharvested Framing block at the 1ha level.

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Costs																													
Forest Management	(650)												(350)																
Annual	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)
Total Costs	(680)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(380)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)
Revenues																													15,409
Pre-Tax Cashflow	(680)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(380)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	(30)	15,379
Age of Stand	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Pre-Tax NPV	$589	$1,316	$1,451	$1,597	$1,755	$1,925	$2,109	$2,308	$2,522	$2,754	$3,005	$3,275	$3,567	$4,232	$4,601	$4,999	$5,429	$5,893	$6,395	$6,936	$7,521	$8,153	$8,835	$9,572	$10,368	$11,227	$12,155	$14,240	

DR Pre-Tax 8.00%

Tuapaka Planting 12.5ha

Years from clearfell	10	9	8'	7	6	5	4	3	2	1	Harvest (28yrs)	Harvest Value
Valuation Pre-Tax	$ 8,482	$ 9,220	$10,022	$10,893	######	$12,870	$13,989	$15,206	$16,528	$17,965	$19,527	$20,555

Entry value in year zero $125,272
(8 years from harvest)

Less Commission (5%) $19,527

Tree Valuations (Standing Timber)

	Area	Planted	Age	Value
Framing (31.3ha)	6.1	1994	27	86865
	1.9	1995	26	23095
	12.5	2001	20	94014
Total				203971

	Area	Planted	Age	Value
Pruning (31.3ha)	6.1	1994	27	205173
	1.9	1995	26	54688
	12.5	2001	20	224994
Total				484864

	Area	Planted	Age	Value
Pruning (68ha)	6.1	1994	27	205173
	1.9	1995	26	54688
	6.7	1998	23	152570
	5.3	1999	22	111602
	5	2000	21	97347
	12.5	2001	20	224994
	7	2002	19	116469
	10.1	2003	18	155320
	2.6	2004	17	36949
Total				1155116

FORESTRY CASHFLOW ANALYSIS: **Framing Regime 31.3ha**

Project Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Calendar Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
New Plantings (ha)	10.8	6.1	1.9												
Total Area (ha)	23.3	29.4	31.3	31.3	31.3	31.3	31.3	31.3	31.3	31.3	31.3	31.3	31.3	31.3	31.3
Capital Expenditure	Land Value $/ha		1000												
Land	23300	6100	1900	0	0	0	0	0	0	0	0	0	0	0	0
Existing Trees	125272														
Forestry Inputs															
Seedling Purchases	2160	1220	380						2500						
Planting	2700	1525	475						3125						
Releasing	2160	1220	380						2500						
Prune 1															
Prune 2															
Prune 3															
Thinning													3780	2135	665
Annual Costs															
Insurance/Administration	583	735	783	783	783	783	783	783	783	783	783	783	783	783	783
Pest Control	117	147	157	157	157	157	157	157	157	157	157	157	157	157	157
Management Costs	7719	4847	2174	939	939	939	939	939	9064	939	939	939	4719	3074	1604
Total Investment Costs	156291	10947	4074	939	939	939	939	939	9064	939	939	939	4719	3074	1604
Revenues															
Harvested Timber									244091						
Standing Timber															
Land															
TOTAL REVENUES	0	0	0	0	0	0	0	0	244091	0	0	0	0	0	0
Pre-Tax Cashflow	(156,291)	(10,947)	(4,074)	(939)	(939)	(939)	(939)	(939)	235,027	(939)	(939)	(939)	(4,719)	(3,074)	(1,604)
Tax Refund @ 33%	2,547	1,600	717	310	310	310	310	310	(36,218)	310	310	310	1,557	1,014	529
Post-Tax Cashflow	(153,744)	(9,347)	(3,357)	(629)	(629)	(629)	(629)	(629)	198,809	(629)	(629)	(629)	(3,162)	(2,060)	(1,075)
Cost of Bush									6,414						
Without Tax Credits	(156,291)	(10,947)	(4,074)	(939)	(939)	(939)	(939)	(939)	200,924	(939)	(939)	(939)	(4,719)	(3,074)	(1,604)

Project Year	15	16	17	18	19	20	21	22	23	24	25	26	27	28	
Calendar Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	
New Plantings (ha)															
Total Area (ha)	31.3	31.3	31.3	31.3	31.3	31.3	31.3	31.3	31.3	31.3	31.3	31.3	31.3	31.3	
Capital Expenditure															
Land	0	0	0	0	0	0	0	0	0	0	0	0	0	0	31,300
Existing Trees															
Forestry Inputs															
Seedling Purchases															6,260
Planting															7,825
Releasing															6,260
Prune 1															
Prune 2															
Prune 3															
Thinning						4375									10,955
Annual Costs															
Insurance/Administration	783	783	783	783	783	783	783	783	783	783	783	783	783	783	22,445
Pest Control	157	157	157	157	157	157	157	157	157	157	157	157	157	157	4,489
Management Costs	939	939	939	939	939	5314	939	939	939	939	939	939	939	939	58,234
Total Investment Costs	939	939	939	939	939	5314	939	939	939	939	939	939	939	939	214,806
Revenues															
Harvested Timber														166421	410,512
Standing Timber														203971	203,971
Land														31300	31,300
TOTAL REVENUES	0	0	0	0	0	0	0	0	0	0	0	0	0	401692	645,783
Pre-Tax Cashflow	(939)	(939)	(939)	(939)	(939)	(5,314)	(939)	(939)	(939)	(939)	(939)	(939)	(939)	400,753	430,977
Tax Refund @ 33%	310	310	310	310	310	1,754	310	310	310	310	310	310	310	(122,228)	(142,530)
Post-Tax Cashflow	(629)	(629)	(629)	(629)	(629)	(3,560)	(629)	(629)	(629)	(629)	(629)	(629)	(629)	278,525	288,447
Cost of Bush														9,503	
Without Tax Credits	(939)	(939)	(939)	(939)	(939)	(5,314)	(939)	(939)	(939)	(939)	(939)	(939)	(939)	281,970	278,091

IRR before inflation pre-tax	7.61%	After tax	6.18%	Without Tax Credits	5.84%
NPV before inflation pre-tax	($7,432)	After tax	$18,248		$10,892
Discount Rate Pre-Tax	8.00%	Tax rate	33%		
Discount Rate Post-Tax	5.36%				

FORESTRY CASHFLOW ANALYSIS: **Pruning Regime 31.3ha**

Project Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Calendar Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
New Plantings (ha)	10.8	6.1	1.9												
Total Area (ha)	23.3	29.4	31.3	31.3	31.3	31.3	31.3	31.3	31.3	31.3	31.3	31.3	31.3	31.3	31.3
Capital Expenditure	Land Value $/ha		1000												
Land	23300	6100	1900	0	0	0	0	0	0	0	0	0	0	0	0
Existing Trees	125272														
Forestry Inputs															
Seedling Purchases	2160	1220	380						2500						
Planting	2700	1525	475						3125						
Releasing	2160	1220	380						2500						
Prune 1					3920	2214	690						4538		
Prune 2							4374	2471	770						5063
Prune 3										5508	3111	969			
Thinning										1404	793	247			
Annual Costs															
Insurance/Administration	583	735	783	783	783	783	783	783	783	783	783	783	783	783	783
Pest Control	117	147	157	157	157	157	157	157	157	157	157	157	157	157	157
Management Costs	7719	4847	2174	939	4859	3153	6003	3410	9834	7851	4843	2155	5477	939	6002
Total Investment Costs	156291	10947	4074	939	4859	3153	6003	3410	9834	7851	4843	2155	5477	939	6002
Revenues															
Harvested Timber									244091						
Standing Timber															
Land															
TOTAL REVENUES	0	0	0	0	0	0	0	0	244091	0	0	0	0	0	0
Pre-Tax Cashflow	(156,291)	(10,947)	(4,074)	(939)	(4,859)	(3,153)	(6,003)	(3,410)	234,257	(7,851)	(4,843)	(2,155)	(5,477)	(939)	(6,002)
Tax Refund @ 33%	2,547	1,600	717	310	1,604	1,041	1,981	1,125	(35,964)	2,591	1,598	711	1,807	310	1,980
Post-Tax Cashflow	(153,744)	(9,347)	(3,357)	(629)	(3,256)	(2,113)	(4,022)	(2,284)	198,293	(5,260)	(3,245)	(1,444)	(3,669)	(629)	(4,021)
Cost of Bush									10,924						
Without Tax Credits	(156,291)	(10,947)	(4,074)	(939)	(4,859)	(3,153)	(6,003)	(3,410)	201,897	(7,851)	(4,843)	(2,155)	(5,477)	(939)	(6,002)

Project Year	15	16	17	18	19	20	21	22	23	24	25	26	27	28	
Calendar Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	
New Plantings (ha)															
Total Area (ha)	31.3	31.3	31.3	31.3	31.3	31.3	31.3	31.3	31.3	31.3	31.3	31.3	31.3	31.3	
Capital Expenditure															
Land	0	0	0	0	0	0	0	0	0	0	0	0	0	0	31,300
Existing Trees															125,272
Forestry Inputs															
Seedling Purchases															6,260
Planting															7,825
Releasing															6,260
Prune 1															11,362
Prune 2															12,677
Prune 3			6375												15,963
Thinning			1625												4,069
Annual Costs															
Insurance/Administration	783	783	783	783	783	783	783	783	783	783	783	783	783	783	22,445
Pest Control	157	157	157	157	157	157	157	157	157	157	157	157	157	157	4,489
Management Costs	939	939	8939	939	939	939	939	939	939	939	939	939	939	939	91,349
Total Investment Costs	939	939	8939	939	939	939	939	939	939	939	939	939	939	939	247,921
Revenues															
Harvested Timber														392642	636,733
Standing Timber														484864	484,864
Land														31300	31,300
TOTAL REVENUES	0	0	0	0	0	0	0	0	0	0	0	0	0	908806	1,152,897
Pre-Tax Cashflow	(939)	(939)	(8,939)	(939)	(939)	(939)	(939)	(939)	(939)	(939)	(939)	(939)	(939)	907,867	904,975
Tax Refund @ 33%	310	310	2,950	310	310	310	310	310	310	310	310	310	310	(289,576)	(298,950)
Post-Tax Cashflow	(629)	(629)	(5,989)	(629)	(629)	(629)	(629)	(629)	(629)	(629)	(629)	(629)	(629)	618,291	606,026
Cost of Bush														15,666	
Without Tax Credits	(939)	(939)	(8,939)	(939)	(939)	(939)	(939)	(939)	(939)	(939)	(939)	(939)	(939)	623,770	588,518

IRR before Inflation pre-tax	9.11%	After tax	7.78%	Without Tax Credits	7.34%
NPV before Inflation pre-tax	$ 30,827	After tax	$79,434		$66,936
Discount Rate Pre-Tax	8.00%	Tax rate	33%		
Discount Rate Post-Tax	5.36%				

FORESTRY CASHFLOW ANALYSIS: **Pruning Regime 68ha**

Project Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Calendar Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
New Plantings (ha)	10.8	6.1	1.9			6.7	5.3	5		7	10.1	2.6			
Total Area (ha)	23.3	29.4	31.3	31.3	31.3	38	43.3	48.3	48.3	55.3	65.4	68	68	68	68
Capital Expenditure	Land Value $/ha		1000												
Land	23300	6100	1900	0	0	6700	5300	5000	0	7000	10100	2600	0	0	0
Existing Trees	125272														
Forestry Inputs															
Seedling Purchases	2160	1220	380			1340	1060	1000	2500	1400	2020	520			
Planting	2700	1525	475			1675	1325	1250	3125	1750	2525	650			
Releasing	2160	1220	380			1340	1060	1000	2500	1400	2020	520			
Prune 1					3920	2214	690			2432	1924	1815	4538	2541	3666
Prune 2							4374	2471	770			2714	2147	2025	5063
Prune 3										5508	3111	969			3417
Thinning										1404	793	247			871
Annual Costs															
Insurance/Administration	583	735	783	783	783	950	1083	1208	1208	1383	1635	1700	1700	1700	1700
Pest Control	117	147	157	157	157	190	217	242	242	277	327	340	340	340	340
Management Costs	7719	4847	2174	939	4859	7709	9808	7170	10344	15553	14355	9475	8724	6606	15057
Total Investment Costs	156291	10947	4074	939	4859	14409	15108	12170	10344	22553	24455	12075	8724	6606	15057
Revenues															
Harvested Timber									244091						
Standing Timber															
Land															
TOTAL REVENUES	0	0	0	0	0	0	0	0	244091	0	0	0	0	0	0
Pre-Tax Cashflow	(156,291)	(10,947)	(4,074)	(939)	(4,859)	(14,409)	(15,108)	(12,170)	233,747	(22,553)	(24,455)	(12,075)	(8,724)	(6,606)	(15,057)
Tax Refund @ 33%	2,547	1,600	717	310	1,604	2,544	3,237	2,366	(35,796)	5,133	4,737	3,127	2,879	2,160	4,969
Post-Tax Cashflow	(153,744)	(9,347)	(3,357)	(629)	(3,256)	(11,865)	(11,871)	(9,804)	197,951	(17,421)	(19,718)	(8,948)	(5,845)	(4,426)	(10,088)
Cost of Bush									14,924						
Without Tax Credits	(156,291)	(10,947)	(4,074)	(939)	(4,859)	(14,409)	(15,108)	(12,170)	202,875	(22,553)	(24,455)	(12,075)	(8,724)	(6,606)	(15,057)
IRR before inflation pre-tax		9.40%			After tax		8.18%		Without Tax Credits			7.56%			
NPV before inflation pre-tax		$ 54,227			After tax		$131,632					$106,750			
Discount Rate Pre-Tax		8.00%			Tax rate		33%								
Discount Rate Post-Tax		5.36%													

Project Year	15	16	17	18	19	20	21	22	23	24	25	26	27	28	Total
Calendar Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	
New Plantings (ha)															
Total Area (ha)	68	68	68	68	68	68	68	68	68	68	68	68	68	68	
Capital Expenditure															
Land	0	0	0	0	0	0	0	0	0	0	0	0	0	0	68,000
Existing Trees															125,272
Forestry Inputs															
Seedling Purchases															13,600
Planting															17,000
Releasing															13,600
Prune 1	944														24,684
Prune 2	2835	4091	1053												27,540
Prune 3	2703	2550	6375	3570	5151	1326									34,680
Thinning	689	650	1625	910	1313	338									8,840
Annual Costs															
Insurance/Administration	1700	1700	1700	1700	1700	1700	1700	1700	1700	1700	1700	1700	1700	1700	41,730
Pest Control	340	340	340	340	340	340	340	340	340	340	340	340	340	340	8,346
Management Costs	9211	9331	11093	6520	8504	3704	2040	2040	2040	2040	2040	2040	2040	2040	190,020
Total Investment Costs	9211	9331	11093	6520	8504	3704	2040	2040	2040	2040	2040	2040	2040	2040	383,292
Revenues															
Harvested Timber														392642	636,733
Standing Timber														1155116	1,155,116
Land														68000	68,000
TOTAL REVENUES	0	0	0	0	0	0	0	0	0	0	0	0	0	1615758	1,859,849
Pre-Tax Cashflow	(9,211)	(9,331)	(11,093)	(6,520)	(8,504)	(3,704)	(2,040)	(2,040)	(2,040)	(2,040)	(2,040)	(2,040)	(2,040)	1,613,718	1,476,557
Tax Refund @ 33%	3,040	3,079	3,661	2,152	2,806	1,222	673	673	673	673	673	673	673	(510,759)	(487,935)
Post-Tax Cashflow	(6,171)	(6,251)	(7,432)	(4,368)	(5,698)	(2,482)	(1,367)	(1,367)	(1,367)	(1,367)	(1,367)	(1,367)	(1,367)	1,102,959	988,622
Cost of Bush														43,696	
Without Tax Credits	(9,211)	(9,331)	(11,093)	(6,520)	(8,504)	(3,704)	(2,040)	(2,040)	(2,040)	(2,040)	(2,040)	(2,040)	(2,040)	1,118,051	950,018