SCION
forests · products · innovation

An Update on Forestry Economics and Market Outlook to Support Land-Owner Decision Making on Lower Nutrient Leaching Land Use Systems

John Moore, Graham West, Leslie Dowling

www.scionresearch.com

SCION forests·products·innovation

REPORT INFORMATION SHEET

REPORT TITLE	AN UPDATE ON FORESTRY ECONOMICS AND MARKET OUTLOOK TO SUPPORT LAND-OWNER DECISION MAKING ON LOWER NUTRIENT LEACHING LAND USE SYSTEMS
AUTHORS	JOHN MOORE, GRAHAM WEST, LESLIE DOWLING
CLIENT	LAKE TAUPO PROTECTION TRUST
CLIENT CONTRACT NO:	QT-4174
FRST CONTRACT NO:	N/A
SIDNEY OUTPUT NUMBER	56753
SIGNED OFF BY	PETER CLINTON
DATE	NOVEMBER 2015
CONFIDENTIALITY REQUIREMENT	CONFIDENTIAL (FOR CLIENT USE ONLY)
INTELLECTUAL PROPERTY	© NEW ZEALAND FOREST RESEARCH INSTITUTE LIMITED ALL RIGHTS RESERVED. UNLESS PERMITTED BY CONTRACT OR LAW, NO PART OF THIS WORK MAY BE REPRODUCED, STORED OR COPIED IN ANY FORM OR BY ANY MEANS WITHOUT THE EXPRESS PERMISSION OF THE NEW ZEALAND FOREST RESEARCH INSTITUTE LIMITED (TRADING AS SCION).

An Update on Forestry Economics and Market Outlook to Support Land-Owner Decision Making on Lower Nutrient Leaching Land Use Systems

John Moore, Graham West, Leslie Dowling
Scion, Private Bag 3020, Rotorua, 3046

November 2015

Table of Contents

EXECUTIVE SUMMARY

Background

Intensified use of pastoral land over the past 40 years has contributed to increasing concerns about the amount of nitrate entering the ground water of fresh water catchments. Regulatory schemes to mitigate these effects have been established in Lake Taupo catchment and are now planned for Lake Rotorua catchment. Conversion to production forestry is one mitigation option that can help to reduce nitrate leaching but neither the costs nor the financial returns associated with forestry are well understood.

Methods

We updated earlier analyses that had investigated the economics of forestry as a land use in the Taupo basin. This included a review of factors that affect the profitability of forestry and an analysis of data from recent woodlot sales. We then undertook case studies at three properties in the Central North Island: one in the Lake Taupo catchment; one in the Lake Rotorua catchment and one south of Rotorua that spans the boarder of the Waikato and Rotorua catchments. At each case study site we determined areas potentially suitable for forestry in consultation with the landowner and/or manager. We then undertook an economic analysis of different forestry options, including: radiata pine (pruned and un-pruned regimes), coast redwood, *Cupressus lusitanica* and *Eucalyptus fastigata*. We used spatial models to estimate the site productivity for each of these species on the three sites and then modelled their growth and log grade outturn at maturity using the Forecaster system. Cost and price information was obtained from a variety of sources, including forestry consultants, Ministry for Primary Industries and AgriHQ. The profitability of each forestry option was assessed in terms of net stumpage (revenue from log sales less the cost of harvesting and transport) and net present value (the sum of all future discounted costs and revenues). The latter was then converted into an annuity to enable comparisons with other land uses that provide an annual income.

Results

The results of the three case studies showed that forestry can provide a positive financial return to landowners for the class of land chosen. At each site, radiata pine provided the best return in terms of net present value (NPV). Based on average prices from the Ministry for Primary Industries for the past 12 months (adjusted for the cost of transport to the appropriate mill or port) net stumpages of $15,000 to $41,000 per hectare could be achieved at harvest on a 28-year rotation. The cost (non-discounted) of establishing and tending a stand of radiata pine ranged from $3,700 up to $5,400 per hectare depending on the regime employed. Approximately half these costs are incurred within the first 5-8 years of establishing the stand, while the remainder are incurred as a result of ongoing administrative costs (assumed to be $65/ha/yr). Other species such as *Cupressus lusitanica* and coast redwood had higher growing costs, primarily due to the higher cost of seedlings. In contrast, growing *Eucalyptus fastigata* on a short rotation pulp regime was not profitable on any of the sites. All of the economic analyses are sensitive to assumptions about growth rates, costs and revenues. Robust information on these factors are often more difficult to obtain for species other than radiata pine. The net present value is highly sensitive to forestry regimes that have high upfront costs. Therefore, early income from carbon credits or the sale of nitrogen units (where this is an option) will have a large positive effect on NPV. At an 8 per cent discount rate, radiata pine was able to provide an annuity of between $-59/ha/yr and $145/ha/yr at the different case study sites assuming current average log prices and no payments for carbon. This increases to between $114/ha/yr and $326/ha/yr if a constant carbon price of $6/t CO_2 is assumed during the entire rotation.

Conclusions

The profitability of forestry is strongly influenced by location. This factor affects the growth rate of different species and hence the volume of logs that will be produced, the cost of harvesting, the cost of building on farm roads to get the logs to the highway and the cost of transport to the mill or port. Therefore, making good initial decisions about where to locate a forest will have a large bearing on future profitability. The case studies undertaken here have demonstrated that forestry can make good returns under the assumptions used around the class of land, growth rates, costs and prices. Better quality land with higher productivity, lower costs, and acceptance of lower discount rates are likely to return much better profits. All of the factors affecting forestry profitability can and do change and it is possibly tenuous to try to predict future prices for logs when the markets for these logs and the products they will be made into is likely to be different to the current situation. However, the forecast of future of wood availability for the Central North Island shows that there will be declining availability at the time when wood from forests planted now becomes ready for harvest. This, coupled with a large predicted increase global demand for wood products means that market conditions are likely to be favourable when trees from forests planted today are harvested. Tree crops also provide a diversification of income and reduce exposure to the fortunes of a single sector or value chain. Timber crops have the flexibility to be harvested over a 10 year window and can be used as a hedge against price and climate variability to provide resilient cash flows for a landowner.

1. Introduction

Intensified use of pastoral land in the Taupo basin over the past 40 years has contributed to increasing concerns about the amount of nitrogen entering Lake Taupo. Similar concerns exist in other catchments such as the Rotorua Lakes and the Waikato River, however the Taupo basin is currently the only catchment where a cap and trade scheme for nitrogen exists. The Lake Taupo Protection Trust administers public funds which are being used to reduce the amount of nitrogen by at least 20% between 2007 and 2020. This is being achieved through a number of options including purchasing land and converting it to lower nitrogen leaching uses or providing existing landowners with financial incentives to change land use. In the future, it is possible that similar schemes will be introduced in other catchments in New Zealand.

Production forestry is a land use that has the potential to reduce nitrate leaching, while also providing economic returns to landowners. Previous studies in the Taupo basin (Knowles & Hansen, 2004a, 2004b; Knowles, Hansen, et al., 2004) showed that forestry was more profitable than pastoral farming at the one-hectare scale, but integrating forestry within an existing farming operation was limited by the availability of capital. Since this work was published there have been significant changes in global markets; investment in regional processing; new tree genetics and improved silviculture regimes; and mechanization of forest operations. Furthermore, the earlier studies did not take into account the impact of N limits on farm management and income. New tools such as MyLand (West & Turner, 2013) have also been developed which provides a framework for evaluating integrated land-use, such as forestry and farming.

The overall aim of the project is to update the earlier analysis of forestry options in the Lake Taupo catchment using updated modelling tools and information. We undertook this project in two stages. The first stage consisted of a summary of the current and predicted future log supply and demand in this region in order to provide some context for those looking to establish forests. Information on wood availability in the Central North Island wood supply region was obtained from the National Exotic Forest Description and the regional Wood Availability Forecasts, both of which are compiled by the Ministry for Primary Industries. These provide projections of how much wood is likely to be available for harvest in the future. Wood availability in the Central North Island is projected to increase to 13 M m^3 per annum by 2020, but will decrease again after 2035. Past deforestation within the CNI, notably in the area north of Taupo, will have an impact on log supply in the long term, mostly after 2040. Most of the increase in available wood after

2020 will be in the form of unpruned logs, with the volume of pruned logs predicted to decrease over time. This declining availability of pruned logs in the future coupled with a recent upward trend in the price difference between pruned and unpruned logs suggest that pruning may be a worthwhile investment. However, it is the price differential at time of harvest that is important, which is more difficult to predict.

While the Central North Island has a large and relatively diverse wood processing sector, current saw log supply and harvest exceeds local processing demand, with the exception of chip logs. As a result, log exports make up a significant proportion of the Central North Island harvest volume, with the Port of Tauranga handling 5.844M m^3 in 2014 (down from 6.423M m^3 in 2013). This volume is approximately half the total harvest for the CNI so prices in this market are also an important benchmark for domestic log prices. There are a number of future processing developments that could increase the proportion of logs processed on shore. These include the expansion of the Red Stag and Sequal sawmills and the construction of the new Lumbercube mill in Rotorua, as well as other proposed developments, some of which are much less certain. In order for more domestic processing investment to occur there needs to be stability in the log supply to ensure that the processors have locally available supply. If there is not an expansion of the planted estate to alleviate the drop in long term log supply the investment in processing may not occur.

The second stage of the project was to investigate the economic potential of different forestry options at case study sites in the region. These case studies covered a range of forestry options, not simply radiata pine. By basing these case studies on actual properties, the importance of location on the economics of forest growing could be demonstrated. This report presents an overview of different forestry options for landowners and then presents the results from a techno-economic evaluation of a selection of these options at the three case study properties.

2. Current and Future Profitability of Forestry

For many landowners, the decision on whether to establish new forests or replant existing forests will depend on current levels of profitability and their perceptions of future trends. There was a large wave of afforestation in the early 1990s that was prompted by very high export prices for logs, mainly into the Korean and Japanese markets, and the relatively low prices for other agricultural products. Log prices in these two markets fell dramatically in the mid- to late 1990s with the onset of the Asian Financial Crisis and there was a corresponding sharp decline in the rates of new land planting. Many small woodlot owners, particularly those who owned post-1989 forests, saw carbon as a potential additional source of income and one that provided early cashflow. However, the carbon price in New Zealand fell dramatically but has started to climb again. In recent years there has been a rapid expansion of log exports into China and a lift in log prices. This has coincided with many small woodlots reaching maturity and this has focussed attention on the economics of small scale forestry. In this section, we summarise the key factors that affect the economics of small scale forestry. Many of the factors that affect the costs of harvesting and transport are affected by location and, therefore, the initial decision of where to establish a farm woodlot will have a large impact on future profitability.

2.1. Return to forest growers from recent woodlot sales

Woodlots that were planted in the late 1980s and early 1990s are now beginning to be harvested. There has been considerable interest in the economics of small scale forestry. A recent investigation of the profitability of small scale forestry in the Wanganui District showed that harvesting and transport costs are the main drivers of profitability for small-scale forest owners (Park, 2011). In her research Park (2011) sampled 58 small scale forests in this district and predicted that 10% of these would not be economically profitable at 2011 log prices and costs. Based on these findings, it has been suggested that small forest owners may need to work more collaboratively to achieve economies of scale across the value chain (Levack, 2015; Moore, 2015). However, there have also been examples of small-scale forest owners achieving good returns, including an owner west of Taupo who achieved a net return of $38,044 per hectare from harvesting a 6.5 ha woodlot (Robinson, 2015). To obtain a more comprehensive picture of returns from small-scale forestry Scion has assembled a dataset on the net returns from 135 recent woodlot harvests. Net stumpage per hectare (i.e. the return to the owner after deducting harvesting and transport costs) ranged from $1,485 up to $72,500 (Figure 1). The average return to growers in this sample was approximately $19,000 per ha. There was no clear trend in the level of return with woodlot size, although it is worth noting that one of the lowest returns was achieved from harvesting the largest woodlot in the sample. These data could be interpreted as showing that scale is less important in determining the profitability of forestry than location. In reality, there is an interaction between these two factors as a small woodlot that is difficult to access will have high costs of harvesting and roading that can only distributed over a relatively small volume of wood.

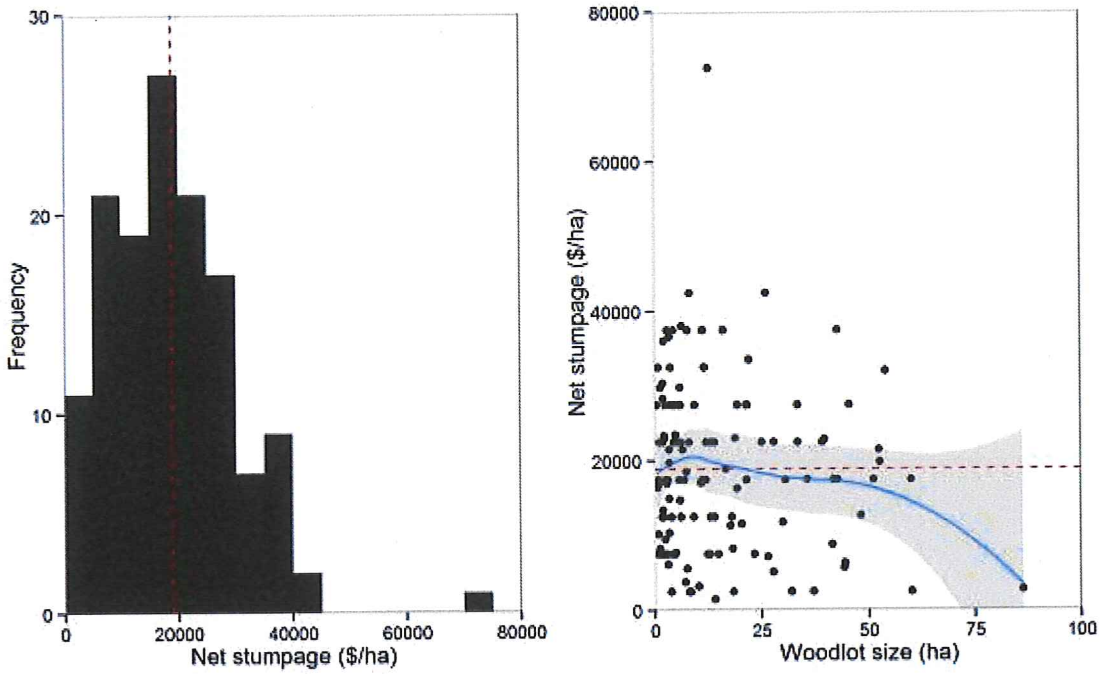

Figure 1. Distribution of net returns from recent woodlot harvests. The right panel shows that there is no clear trend in returns as a function of woodlot size (blue line with 95% confidence interval shown by the grey shading). The dashed red line in both panels indicates the mean return.

2.2. Trends in log prices

While costs are a major determinant of profitability, so are log prices. In the early 1990s there was a "spike" in export log prices driven mainly by the Japanese and Korean markets. Since this time, there has been a decline in log prices although there has been an increase in log prices since 2010 which has largely been driven by the Chinese market (Figure 2). There has also been a substantial reduction in the premium paid for pruned logs over un-pruned sawlog grades in both the domestic and export markets. In many cases this has resulted in forest owners receiving relatively low returns as their silvicultural regimes deliberately understocked the site in order to grow large diameter pruned logs that would attract a significant premium. The lower yields produced under these regimes has affected the profitability of forest growing.

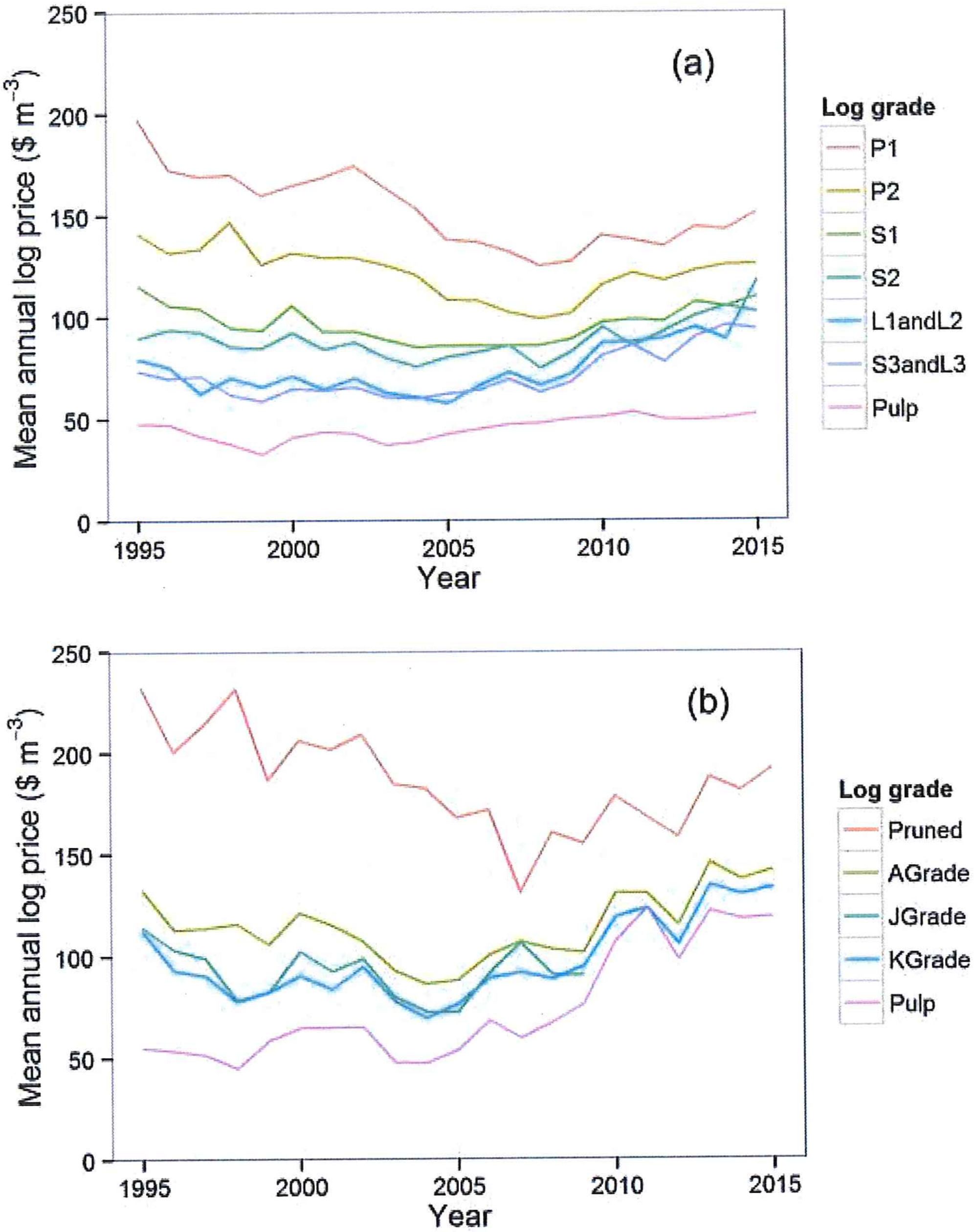

Figure 2. Historical trend in the prices for different log grades in the (a) domestic and (b) export markets. Data are from the Ministry for Primary Industries and have not been adjusted for inflation.

2.3. Trends in carbon prices

Another source of potential revenue for forest managers is carbon. Post-1989 forest land owners, or holders of a registered forestry right or lease, may voluntarily apply to register as an Emissions Trade Scheme (ETS) participant at any time. They are entitled to receive

NZUs for increases in carbon stocks and must pay units for decreases. Forestry joined the ETS in 2008 and at this time the price of a New Zealand Unit (NZU) was over $20. The value of NZUs dropped dramatically in July 2011, reaching a low of $1.60 in February 2013 (Figure 3). With New Zealand's withdrawal from the second commitment period of the Kyoto Protocol and legislation to limit the use of international credits, the price of NZU's has increased. As of November 2015, the price of an NZU was approximately $7.00.

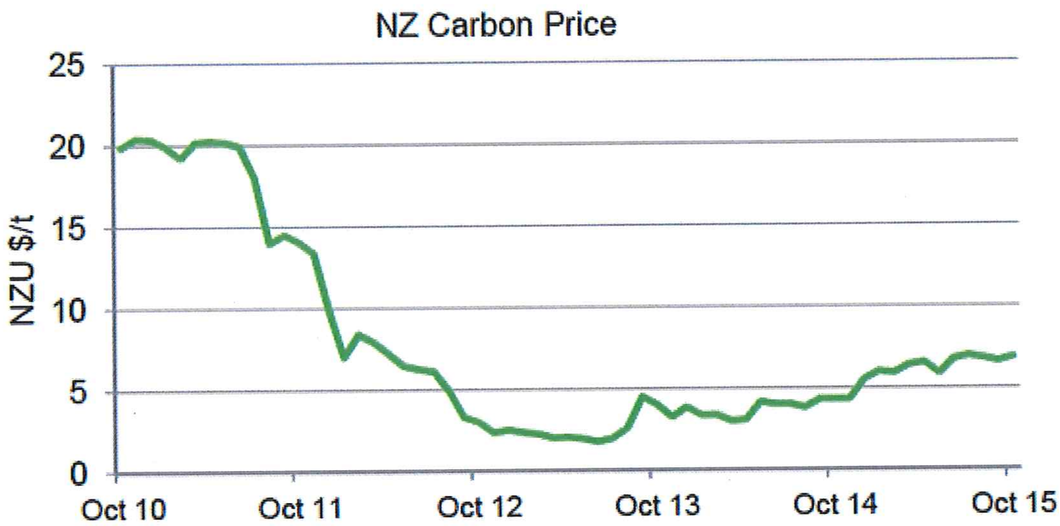

Figure 3. Historical variation in the price of NZUs. Data from NZXAgri.

2.4. Improved returns from genetic gain

There has been a tree breeding programme for radiata pine in New Zealand since the 1950s, with smaller programmes in other commercial species. The major focus of these programmes has been to improve the returns from forestry by improving stem form and growth rates. Improving these two traits results in a higher volume of more valuable log grades. More recently there has also been a focus on ensuring that gains in stem volume do not come at the expense of wood quality. The genetic worth of radiata pine tree stocks is expressed via its GF Plus rating, and these ratings are managed by the Radiata Pine Breeding Company (www.rpbc.co.nz). There are GF Plus ratings for growth, stem form, branch cluster frequency and wood density. A recent study showed that there is a strong relationship between the GF Plus growth rating and the amount of additional volume and value that can be realised at the end of the rotation (Kimberley, et al., 2015). On average, an increase of one unit of GF Plus for growth results in a 1.5% increase in stem volume at age 30 years. Moving from moderately improved tree stocks, which are typical of stands being harvested at present, to highly improved tree stocks is estimated to result in an additional 15.3% stumpage revenue at the end of a 30 year rotation. These gains are predicted to be greater on more productive sites. We have factored these gains into our analyses on the assumption that landowners would plant the most highly improved genetic stock that was available to them.

There are tree improvement programmes in other species such as Douglas-fir and a number of the Eucalyptus species, but the large block trials necessary to quantify realised genetic gain either do not exist or have yet to reach an age where they can provide meaningful data. However, it is expected that selection and breeding for improved stem form and tree health will result in considerable yield gains over unimproved seedlots.

3. Potential Forestry Options

There are a wide range of forestry options that landowners can choose from. In addition to more traditional options such as radiata pine, *Eucalyptus* and Douglas-fir, other options such as indigenous tree species (particularly totara and kauri) and manuka are of interest to many landowners. In this report, we only model the economics of radiata pine, *Cupressus lusitanica*, *Eucalyptus fastigata* and coast redwood (*Sequoia sempervirens*) for three case study sites. We provide some more general information on other forestry options in the following sections. Additional information on many of these species is available through a series of information notes that can be downloaded from the Scion website (http://www.scionresearch.com/general/publications/science-publications/science-info-sheets). Information is also available from the New Zealand Farm Forestry Association (http://www.nzffa.org.nz/).

3.1. Radiata pine

Radiata pine is the most widespread exotic tree species planted in New Zealand and it comprises approximately 90% of the area of the planted forest estate (Ministry for Primary Industries, 2014). It is able to grow on a wide range of sites, but productivity is generally greater on warmer wetter sites than on cooler drier sites (Watt, et al., 2010). The average level of productivity for existing forests is approximately 24 $m^3 ha^{-1} yr^{-1}$, which equates to a total standing yield at the end of a 30 year rotation of approximately 720 $m^3 ha^{-1}$. However, with improved genetics and changes to silvicultural regimes this figure will increase. Radiata pine wood can be used for a wide range of end uses, such as appearance grade joinery timber, structural timber, outdoor timber, pulp and paper, and different panel products. It has low natural durability but is very easy to preservative treat to improve durability.

Silvicultural regimes for radiata pine were historically characterised by intensive thinning and pruning, with the objective of producing large pruned logs. However, many large forest owners have reduced the area that they prune or have stopped pruning altogether as a result of the reduced premiums for pruned logs grades relative to unpruned logs. This has also been accompanied by an increase in stand stocking in order to fully occupy the site with trees. In this study we simulated two silvicultural regimes for radiata pine: (1) a pruned regime and (2) an unpruned regime.

3.2. *Eucalyptus fastigata*

At present most *Eucalyptus* species are grown in New Zealand to provide a source of short fibre pulp. However, there is a strong desire to produce solid wood from *Eucalyptus* species in order to improve the economics of forest growing. Timber from *Eucalyptus fastigata* is the easiest to mill and dry of any of the ash *Eucalyptus* group. This species is suited to deep volcanic soils, but not sticky clays or coastal sites. It displays fast vigorous growth on good soils. Although *Eucalyptus fastigata* does best in more sheltered sites, it does not require complete shelter. It is also one of the healthiest *Eucalyptus* species growing in New Zealand. Given the uncertainties around future timber markets for this species, we have assumed that it is grown on a pulp wood regime in this study, but consideration should be given to solid wood production through appropriate tending of the stand (i.e. thinning and possibly pruning). This may provide higher returns subject to developing timber markets not considered here.

3.3. Coast Redwood

There are approximately 6,300 ha of coast redwood growing in New Zealand. The species was widely planted by the former New Zealand Forest Service, but a number of these plantings were unsuccessful due to poor siting. Recent work has shown that the productivity of redwood is positively related to temperature (Palmer, et al., 2012). The productivity maps developed as part of this study should enable better siting of redwood stands. There are now significant areas of new plantings occurring in the Taumarunui area. The key market for coast redwood timber is North America where it is used mainly in building and landscaping (e.g. decks, fences, outdoor furniture, weatherboards, window sashes, doors, blinds and interior trim). In these applications natural durability and dimensional stability are important. Good silvicultural management of redwood stands (i.e. timely thinning and epicormic shoot removal) is required in order to achieve high yields of the most valuable timber grades (Cown, et al., 2013). To achieve the highest value grades we have assumed a regime with intensive silviculture, which incurs higher early costs. Commercial redwood forestry companies, most notable NZ Forestry Ltd and The New Zealand Redwood Company are planting a lower initial stocking to reduce these costs, and are carefully managing weed competition.

3.4. *Cupressus lusitanica*

Several different cypress species have been grown in New Zealand to provide an attractive timber which had a moderate to good level of natural durability. High quality timber (i.e. clear heartwood) is highly valued, particularly in Asian markets. *Cupressus macrocarpa* was planted in many regions of New Zealand but suffers from a stem canker in warmer more humid areas. In these regions, *Cupressus lusitanica* is more suitable as it has better canker resistance. Like many species, cypresses grow better in warm areas with fertile soils which support deep rooting. A spatial map showing the variation in the productivity of *Cupressus lusitanica* across New Zealand has been developed (Watt, et al., 2009), which can be used to aid decisions on where to grow this species. There is no universal agreement on silvicultural regimes for cypress species, but they are generally able to support higher stockings due to their shade tolerance. Pruning or precisely timed thinning is recommended to remove or control branches and to avoid the formation of bark encased knots which reduce the value of sawn timber.

3.5. Douglas-fir

Douglas-fir is the second most widely planted commercial species in New Zealand. The total area of Douglas-fir forests is approximately 107,000 ha. It is a highly regarded timber and is preferred for its superior strength, toughness, durability and decay resistance (Barrett, et al., 1991). As well as being popular for light timber framing, the larger dimensions (beams) are sought after for exposed interior posts and beams because of its good stability and low incidence of twist. Most of the recent plantings in this species have occurred in the South Island due to its lower susceptibility to snow damage compared with radiata pine. There are significant areas of Douglas-fir in the central North Island, but many of these are being replanted in radiata pine after they have been felled. One of the reasons for this is the increased incidence of Swiss Needle Cast in the central North Island (Stone, et al., 2007). This foliage disease causes needles to be shed and there can be considerable resulting growth losses. While this species was included in the earlier modelling study in the Lake Taupo catchment (Knowles & Hansen, 2004a, 2004b;

Knowles, Hansen, et al., 2004), we have not included it here due to forest health concerns and the reduction in the size of the Douglas-fir resource in the central North Island.

3.5. Indigenous timber species

There has been considerable interest by a number of landowners in planting indigenous trees for potential timber production and biodiversity enhancement. The two most promising species and kauri and totara. On relatively productive sites both species can achieve growth rates that are significantly better than those observed in natural stands. It is, therefore, possible to grow these species on 60-80 year rotations. At this age logs will mostly contain sapwood which is non-durable, but is able to be used in interior uses where there is no requirement for natural durability. One of the key challenges to indigenous forestry is the high cost of establishment. This is due to the high cost of tree stocks, which can be 5-10 times greater than for species such as radiata pine. Good weed control is also required to ensure that the trees are not overtopped by competing vegetation. To offset the high costs of establishment and to provide an intermediate source of income, it may be worth considering a nurse crop of manuka. This will also help to improve stem form and control branch size in the main species of interest. Landowners who are considering these species should engage the services of an expert in indigenous forestry.

3.6. Manuka

There is also considerable interest from landowners, including many Maori trusts in growing manuka for honey and essential oil production. Manuka generally flowers within five years of planting and is able to provide income to the landowner from honey production. Annual income of approximately $500 per hive can be obtained in good seasons and there is a premium paid for honey that has a higher Unique Manuka Factor (UMF). In natural stands of manuka, one hectare is able to support one hive, but this figure is expected to be greater in planted stands of improved varieties. To ensure that the honey is monofloral (i.e. is made from the nectar of only one plant species), landowners need to plant at least 20 ha of land in manuka. Manuka could be ideally suited to steeper inaccessible land where the costs associated with harvesting and roading make commercial forestry financially unattractive. However, site access is still a factor if landowners wish to combine oil and honey production. A number of the major honey producers are forming joint venture partnerships with landowners, which involve a revenue sharing arrangement. For this reason we have not explicitly modelled the economics of manuka in this report, but it is a potential option on some sites.

3.6. Ginseng

Ginseng is the common name given to two species of the *Panax* family: *Panax ginseng* (Asian ginseng) and *Panax quinquefolius* (American ginseng). Both are sold throughout Asia as a medicine and a tonic. This has placed huge pressure on wild ginseng (it nearly became extinct), but there is a large market for wild simulated (seeds and rootlets that are planted and grown in a suitable habitat in its natural range) ginseng. Ginseng requires a high level of ambient shade to grow, which means that it could potentially be grown as an understory crop underneath planted forests. A number of large landowners, most notably Maraeroa C, have been examining the potential to grow ginseng as an understory crop beneath radiata pine. Ginseng has certain site requirements (climate, soils and slope) for growth and management, which are met at many sites in the central North Island (Grace, et al., 2013). These are:

- A winter chilling period where the monthly maximum temperature is less than 12 degrees in June and July (61 days). Winter chilling is needed to stimulate germination in the following spring.
- Soil drainage and potential rooting depth Ginseng requires a moist but free draining soil and sufficient soil depth (> 30 cm) for root development.
- Slopes <15°. Slope provides for air movement, drainage, and machinery access, with the majority of ginseng planted between 2° and 6°. However it is also grown on slopes up to 15°.

It takes approximately ten years to grow a crop of ginseng. This includes two years to prepare the site and collect seeds, and eight years to actually grow the crop. Typically, this would be done after the stand has received its final thinning, i.e. around age 10-14 years. It is expected that ginseng would only be grown in a small area within a stand of trees, i.e. an area of a few hectares. For those areas where ginseng is grown as an understory crop a profitability analysis has shown that it could more than double profitability compared to forestry alone (Grace, et al., 2013).

4. Forestry Case Studies

To provide real world examples of the economics of forest growing, we undertook case studies at three properties in the Rotorua Lakes and Lake Taupo areas. For each case study property the extent and location of the area to be planted was discussed with the landowner or manager. At two of the case study properties this involved afforestation of pasture sites, while the third involved replanting of a harvested site. For each option the economic potential was evaluated using the approach shown in Figure 4. The productivity of the different species at each of these sites was estimated from the relevant productivity maps that are contained within the MyLand system (West & Turner, 2013). The growth and yield of each species was modelled using the Forecaster growth and yield prediction system (West, Moore, et al., 2013). The same silvicultural regimes were used at each of the three sites (Table 1). These regimes are considered to be typical current practice for each of these species.

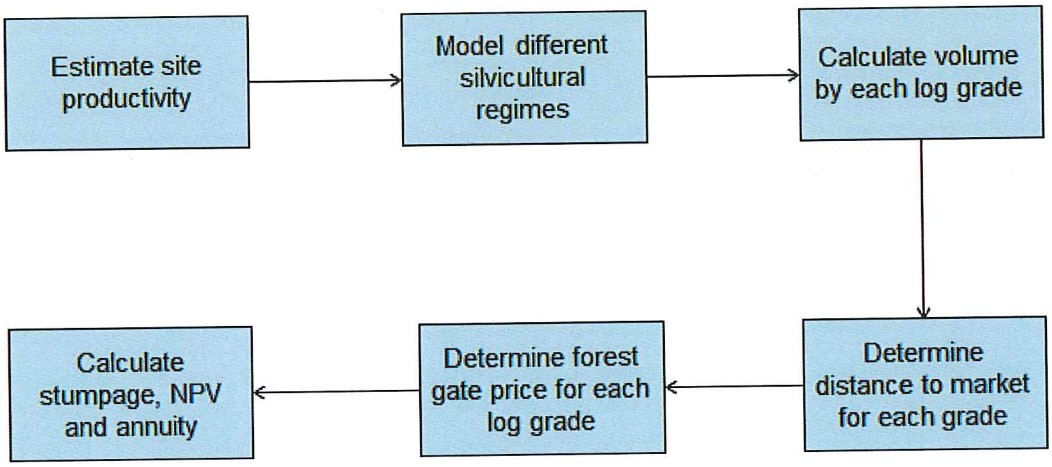

Figure 4. Schematic diagram showing the approach taken to evaluate the economic potential of different forestry options.

We conducted an economic analysis that calculated: (1) the net stumpage after harvest (i.e. the revenue from log sales minus the cost of harvesting and transportation); and (2) the net present value (i.e. the sum of future discounted revenues minus the sum of future discounted costs) of the different forestry options. We then converted this net present value into an annuity, which is a series of equal annual payments that sum to the net present value. Information on costs and prices came from a variety of sources, including AgriHQ and the Ministry for Primary Industries (Table 2 and Appendix 1). Free on board prices obtained from the Ministry for Primary Industries were adjusted to a wharf gate price assuming port storage and handling costs of $18/m^3$. For radiata pine, log prices were based on data from the past four quarters for each grade. We used the average, minimum and maximum prices from this period. Prices for other species were obtained from discussions with relevant parties who are operating in the marketplace. The cost of transport was deducted from the log price to provide a forest gate price (as opposed to a mill door or wharf gate price). We assumed that the cost of log transport was $0.20-0.36 m^{-3} km^{-1} (depending on log length and market) and calculated the closest distance to a mill or port that was capable of handling each particular log grade. In all cases we assumed that the various operations such as planting, weed control, thinning, pruning and harvesting would be undertaken by forestry contractors at rates that were typical for small woodlots. The cost of new road construction was estimated for each site using MyLand. In each case a virtual road was constructed that extended from the nearest farm road capable of carrying a logging truck to the proposed forestry block. The length of this road was measured and it was assumed that it would cost $35,000 per km to build this type of road. This cost was then divided by the woodlot area to determine a cost per hectare. A land rental cost was not included in the economic analysis which is consistent with the economic evaluation of different land uses on freehold land. We did include an annual management cost of $65/ha which covers the cost of rates, administration and activities such as repairs to boundary fences. We assumed three different carbon prices ($0, $6 and $15 per NZU) and three different discount rates (6, 8 and 10%).

Table 1. Characteristics of the silvicultural regimes applied to each of the species.

Attribute	Species and silvicultural regime				
	Radiata pine (clearwood)	Radiata pine (structural)	Coast Redwood	Cupressus lusitanica	Eucalyptus fastigata
Initial planting density (stems/ha)	833	1000	883	1175	1300
Age of first thinning (years)	8-8.5	6.9-7.3	6.9-7.7	4.8	-
Age of second thinning (years)	-	-	12.7-14.6	10.7	-
Residual density after thinning (stems/ha)	350	450	300	350	-
Number of pruning lifts	2	-	3	3	-
Pruned height (m)	6.0	-	6.2	6.0	-
Rotation age (years)	26,28,30	26,28,30	30,40,50	30,35,40	10,15,20

Table 2. Costs and revenues used to calculate financial returns for different forestry options.

Attribute	Species and silvicultural regime				
	Radiata pine (clearwood)	Radiata pine (structural)	Coast Redwood	Cupressus lusitanica	Eucalyptus fastigata
Planting cost ($/ha)	729	870	2296	2233	2120
Releasing cost ($/ha)	249 (x2)	300 (x2)	265 (x2)	353 (x2)	390 (x2)
Pruning cost ($/ha)	990 (lift 1) 798 (lift 2)	-	936 (lift 1) 776 (lift 2) 315 (lift 3)	1044 (lift 1) 886 (lift 2) 369 (lift 3)	-
Thinning cost ($/ha)	545	545	545	545	-
Administration cost ($/ha/yr)	65	65	65	65	65
Inventory cost ($/ha)	150	150	150	150	150
Carbon ($/NZU)	0,6,15	0,6,15	0,6,15	0,6,15	0,6,15

4.1. Truebridge Farm – Karangahape Road, Lake Taupo

The Truebridge Farm is located on the western side of Lake Taupo approximately 20 km north of Kuratua. The property is 261 ha in size and the topography is mostly flat to rolling (Figure 5). There is an existing radiata pine woodlot on the property which is less than 2 ha in size and there are extensive shelterbelts between paddocks. The farm has an excellent network of internal roads, many of which are sealed. The intention of the landowners is to reduce the overall amount of nitrate leaching from their property through a combination of forestry, cut-and-carry fodder systems and reducing the intensity of their existing dry stock farming operations. In discussion with the landowner 44.3 ha of land that could be readily afforested were identified. These included a 37.7 ha area in the north-eastern corner of the property and 6.5 ha in the southern end of the property (Figure 6). To harvest these blocks in the future 870 m and 1590 m of new roads would need to be constructed at an estimated cost of $49,500. The growth and yield for each species was modelled using the Forecaster system initialised with the site productivity values given in Table 3.

Figure 5. Location of the Truebridge Farm on the western shores of Lake Taupo

Figure 6. Location of the proposed areas for afforestation on the property and the existing forest block (blue area on the western side of the property).

Table 3. Site productivity information used to initialise the growth and yield models for different species at the Truebridge Farm.

Species	Site Index (m)*	Volume productivity index**
Radiata pine	31.2	36.7
Eucalyptus fastigata	32.9	-
Cupressus lusitanica	26.5	-
Coast redwood	30.4	13.0

*Site index is defined at the mean height of the largest 100 trees per hectare at a reference age. These reference ages are 15 years for *Eucalyptus fastigata*, 20 years for radiata pine, 30 years from *Cupressus lusitanica* and 40 years for coast redwood
**The radiata pine growth model uses a volume productivity index called the 300 Index which is defined as the volume mean annual increment of a 30 year old stand with a stand density of 300 stems ha^{-1}. The coast redwood model uses a 400 Index which is defined as the volume at age 40 years of a stand growing at a density of 400 stems ha^{-1}.

There were considerable differences in the growing costs among the different regimes (Table 4). Both the coast redwood and *Cupressus lusitanica* options had growing costs that were approximately $8000 per hectare. This was due to the higher cost of tree stocks, coupled with intensive silviculture (i.e. multiple pruning lifts and thinning) aimed at producing high quality appearance grade timber. The radiata pine structural (unpruned) regime and the *Eucalyptus fastigata* pulp regime had similar growing costs, while the growing costs for pruned radiata pine regime were approximately $1600 ha^{-1} higher than for the un-pruned regime. The total cost of establishing and tending 44.3 ha of forest ranged between $165,370 and $355,463 depending on the option chosen. If the landowner has received payments for nitrogen reductions then these would offset some or all of the planting and tending costs, which are two of the main upfront costs in forestry. It may also be prudent to establish the total forest area over a period of four to five years rather than trying to establish the entire area in a single year. In this case, the total cost of planting and release spraying for 10 ha of forest per year over a four year period would be between $12,200 p.a. and $30,170 p.a. depending on the option selected. We have also assumed that contract labour is used for all operations. Substantial savings could be made if pruning was undertaken by the landowner and their own labour was treated as a sunk cost. Similarly, savings could potentially be made on the cost of weed control as the forests are being established on pasture where spot weed control is likely to be very effective as there are no woody weeds present.

Table 4. Costs associated with establishing and tending 44.3 ha of forest under different combinations of species and silvicultural regime at the Truebridge Farm.

Cost ($)	Species and silvicultural regime				
	Radiata pine (clearwood)	Radiata pine (structural)	Coast Redwood	*Cupressus lusitanica*	*Eucalyptus fastigata*
Planting	32,250	38,541	103,485	98,922	92,144
Releasing	22,061	22,060	23,213	34,731	34,554
Pruning	43,636 (lift 1)	-	39,427 (lift 1)	44,300 (lift 1)	-
	34,643 (lift 2)		33,325 (lift 2)	38,231 (lift 2)	
			11,961 (lift 3)	14,353 (lift 3)	
Thinning	24,144	24,143	24,143	24,143	-
Administration*	80,626	80,626	115,180	100,782	43,192
Total cost	237,359	165,370	350,734	355,463	169,890
Cost per ha	5358	3732	7917	8024	3834

*Assuming midpoint rotation length

Gross revenues at harvest of over $60,000 per ha were obtained from the two radiata pine regimes, while the *Cupressus lusitanica* regime had gross revenues in excess of $80,000 per ha (Table 5). The *Cupressus lusitanica* regime had the highest mean log price and also had lower total harvesting costs (due to a lower volume) than the other regimes, which meant that it had the highest net stumpage. This figure was highly influenced by the price for pruned logs and unpruned sawlogs greater than 30 cm in diameter. As the market for cypress logs is small and there is a lack of consistent supply, it is difficult to get robust price information. The gross revenue for the pruned radiata pine regime was slightly higher than for the unpruned regime due to the shorter transport distance to the sawmill for pruned logs resulting in a higher net price paid to the grower.

While the *Eucalyptus fastigata* regime produced very high volumes in a short period of time it yielded the lowest gross revenue due to the fact that the logs produced were only sold as pulp or firewood. The costs of harvesting and transport exceeded the gross revenue resulting in a negative stumpage. Coast redwood was the slowest growing species at the site and only yielded a total volume approximately 420 m^3 ha^{-1} by age 40 years (Figure 7). Given the small piece size of the trees at this age, only a small proportion of the logs were in the larger, more valuable grades. According to the productivity maps developed for coast redwood (Palmer, et al., 2012), this site had below average productivity. On a more productive site a better economic return might have achieved from this species.

Table 5. Costs and revenues associated with harvesting and selling logs from different combinations of species and silvicultural regime at the Truebridge Farm. Values shown are for the midpoint harvest age in each scenario. Radiata pine revenues were based on the mean MPI price.

Attribute	Species and silvicultural regime				
	Radiata pine (clearwood)	Radiata pine (structural)	Coast Redwood	*Cupressus lusitanica*	*Eucalyptus fastigata*
Total standing volume (m^3)*	1043	1147	418	683	1097
Mean return ($/$m^3$)**	65	55	38	125	24
Revenue ($/ha)	67,906	63,252	15,963	82,578	26,406
Harvesting costs ($/$m^3$)	41	41	41	41	41
Harvesting costs ($/ha)***	43,501	47,021	17,155	27,982	44,977
Roading cost ($/ha)	1,119	1119	1119	1119	1119
Total cost ($/ha)	44,620	48,140	18,274	29,101	46,096
Net stumpage ($/ha)	23,286	15,112	-2,311	53,477	-19,690
Total net stumpage ($)	1,031,570	669,461	-102,366	2,369,031	-872,267

*Assuming midpoint rotation length. Includes non-merchantable volume
**Total revenue received divided by total standing volume. Includes the cost of cartage.
***Includes cost of pre-harvest inventory

Harvesting systems and associated costs were assumed to be the same across all species, which may not happen in practice as some are more difficult to make into logs than others and *Eucalyptus* species generally need to be debarked while fresh. Discounted cashflow analysis showed that the highest net present values (NPV) were achieved for the two radiata pine regimes (Figure 8). Along with *Cupressus lusitanica*, these were the only two regimes that achieve positive net present values at a 6 per cent discount rate. While the *Cupressus lusitanica* regime yielded the highest net stumpage it had a negative NPV at 8 per cent discount rate due to the high establishment and silvicultural costs which were compounded over a 35 year rotation. Despite the short rotation for *Eucalyptus fastigata*, this species did not achieve a positive NPV (in fact it didn't achieve a positive stumpage) due to the low revenue relative to harvesting and transport costs. Coast redwood also did not achieve a positive NPV at any of the three discount rates used due to the high establishment and tending costs. This species had the longest rotation of all species considered in this analysis – 40 years.

Including payments for carbon increased the NPV for all options. These calculations accounted for the carbon liability at the end of the rotation, which is approximately half the total growing stock at the end of the rotation. A large amount of carbon is left behind when a stand is harvested in the form of coarse woody debris and stumps. This will decay over time, but this loss will be offset by the carbon sequestered in the next rotation. However, if the stand is harvested and not replanted then the landowner will be liable for all the carbon that was sequestered by the stand. We did not include nitrogen payments in the NPV calculations, but clearly they would have a large positive effect as they provide early cashflow which offsets the establishment costs that are compounded over the length of the rotation. This would particularly benefit regime options where there are high up-front costs due to relatively expensive planting stock.

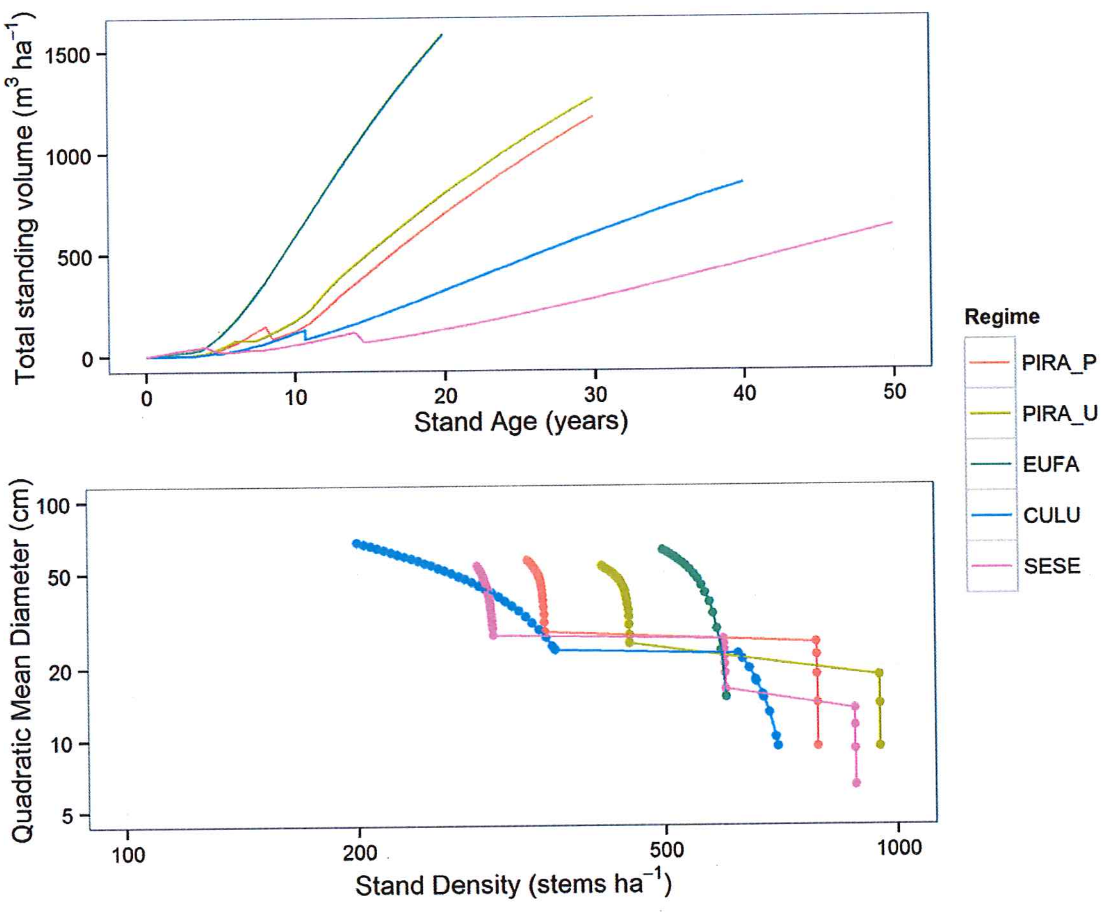

Figure 7. Comparison of yields from the different species and silvicultural regimes at the Truebridge Farm (top) and a stand density management diagram showing stand development for each regime (bottom). The following abbreviations are used for the different regimes: radiata pine pruned (PIRA_P); radiata pine unpruned (PIRA_U); *Eucalyptus fastigata* (EUFA); *Cupressus lusitanica* (CULU); coast redwood (SESE).

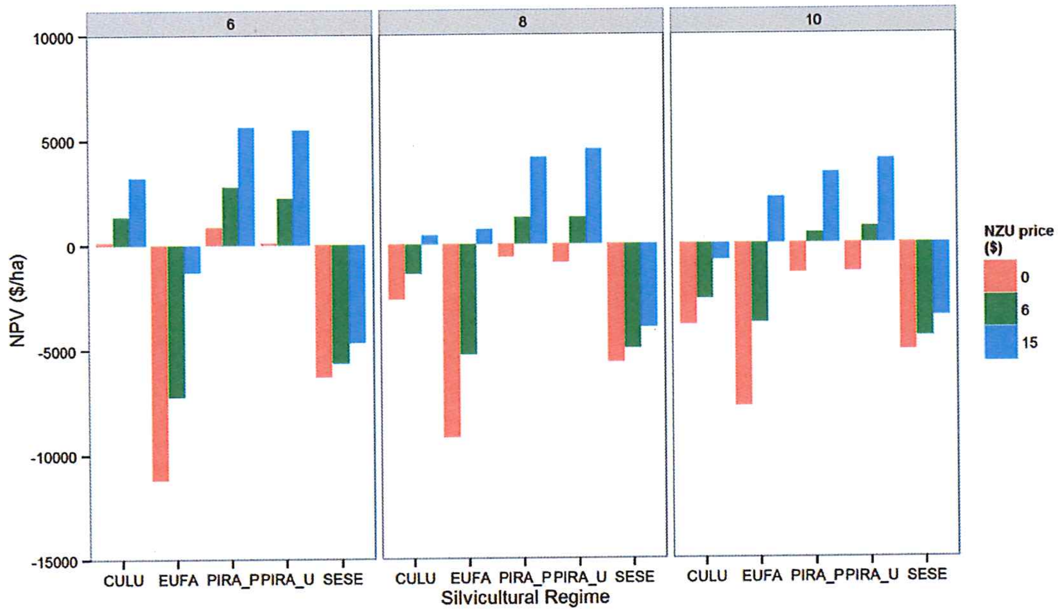

Figure 8. Comparison of net present values between the five different silvicultural regimes with three carbon prices. The following abbreviations are used for the different regimes: radiata pine pruned (PIRA_P); radiata pine unpruned (PIRA_U); *Eucalyptus fastigata* (EUFA); *Cupressus lusitanica* (CULU); coast redwood (SESE). Radiata pine results are based on the mean MPI log price.

The net present value was also highly sensitive to assumptions about log prices. In our analyses for the radiata pine regimes we used minimum, mean and maximum prices from MPI over the last 12 months along with price data from AgriHQ. At the minimum MPI prices, the NPV for the both the pruned regime and unpruned regimes was negative at all discount rates (assuming a zero carbon price). Under an assumption of zero carbon price and maximum prices that have been observed in the past 12 months, both regimes had a positive NPV at both 6% and 8% discount rate (Figure 9). There was a clear impact of carbon price on the NPV, particularly at higher discount rates.

At an 8% discount rate the equivalent annuity (a series of equal annual payments that sum to the NPV) for the radiata pine regimes ranged from -$163/ha/yr up to $27/ha/yr (excluding carbon) (Figure 10). Including a carbon price of $6/t CO_2 increased the annuity from $31/ha/yr to $215/ha/yr, while including a higher carbon price of $15/t CO_2 increased it further to between $291/ha/yr and $501/ha/yr. The range of annuities for the pruned radiata pine regime was slightly higher than for the unpruned regime when a carbon price of $0/t CO2 was assumed by was higher for unpruned regimes when a carbon price of $15/t CO2 was assumed (Appendix 2).

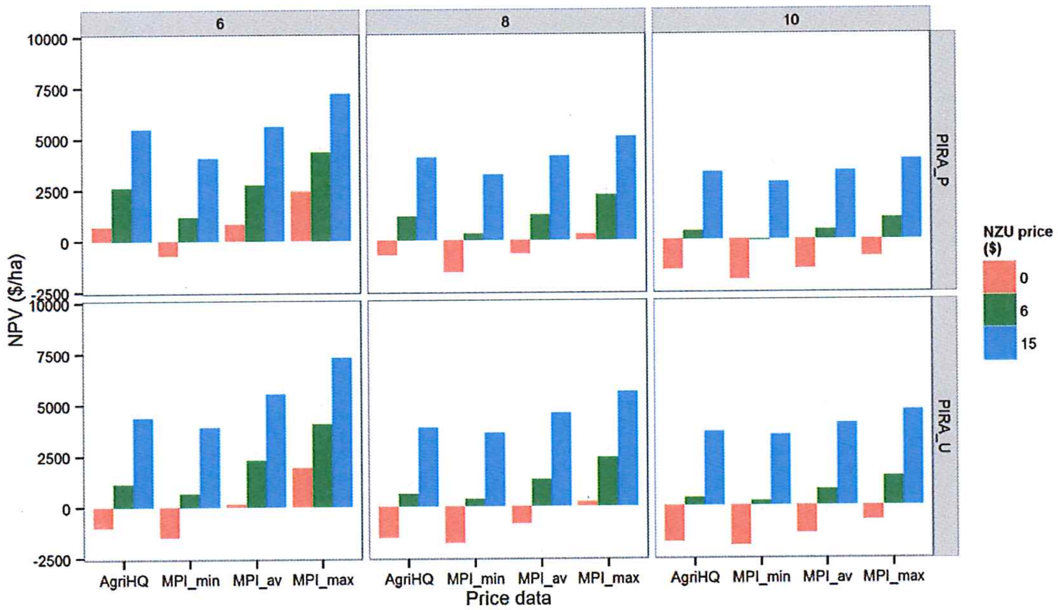

Figure 9. Variation in NPV for pruned and unpruned radiata pine regimes under different log price and carbon price assumptions at the Truebridge Farm site.

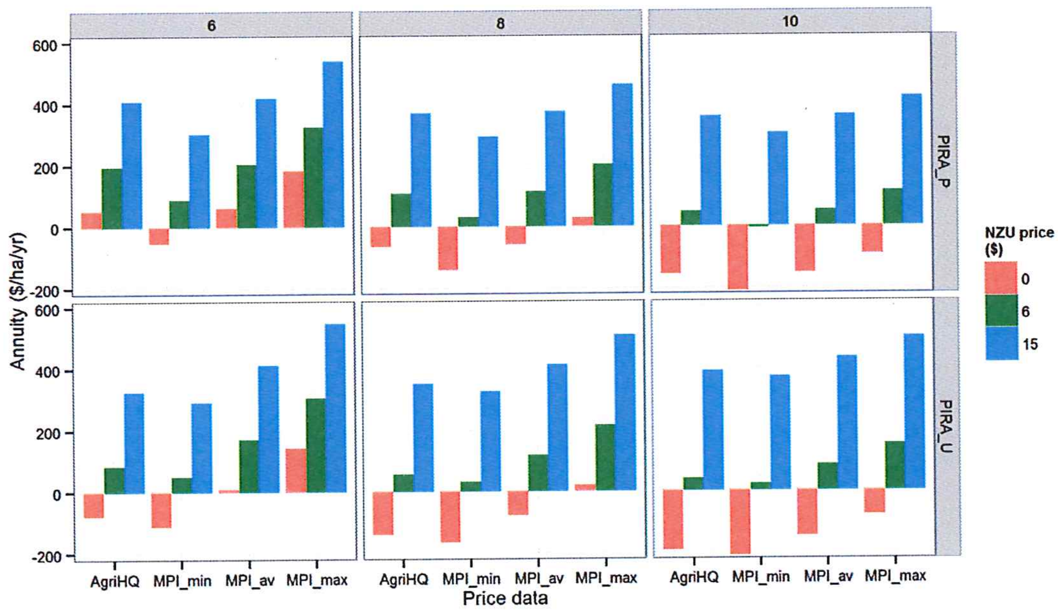

Figure 10. Variation in annuities for pruned and unpruned radiata pine regimes under different log price and carbon price assumptions at the Truebridge Farm site.

4.2. Ngati Whakaue Tribal Lands – Tihiotonga, Rotorua

The Tihiotonga farm is located on the southern boundary of Rotorua City approximately five kilometres from the city centre (Figure 11). The total land area is 818.4 hectares of which 665 hectares are farmed, 90 hectares are in production forestry and 45 hectares are in conservation. In discussion with the farm manager and landowner, an area of 17.9 ha of land located in the south-eastern corner of the property was identified that could be afforested (Figure 12). This area consists of two adjacent paddocks called "Middle Georges" and "Bottom Georges". The area is currently being grazed and consists of some relatively steep south facing slopes, but also contains a significant area of flat land. All of the area is suitable for harvesting using ground-based equipment. There is some gorse and broom in the paddocks and a significant amount of gorse in the adjoining property. Good weed control will be required to ensure that this doesn't become a problem in the future.

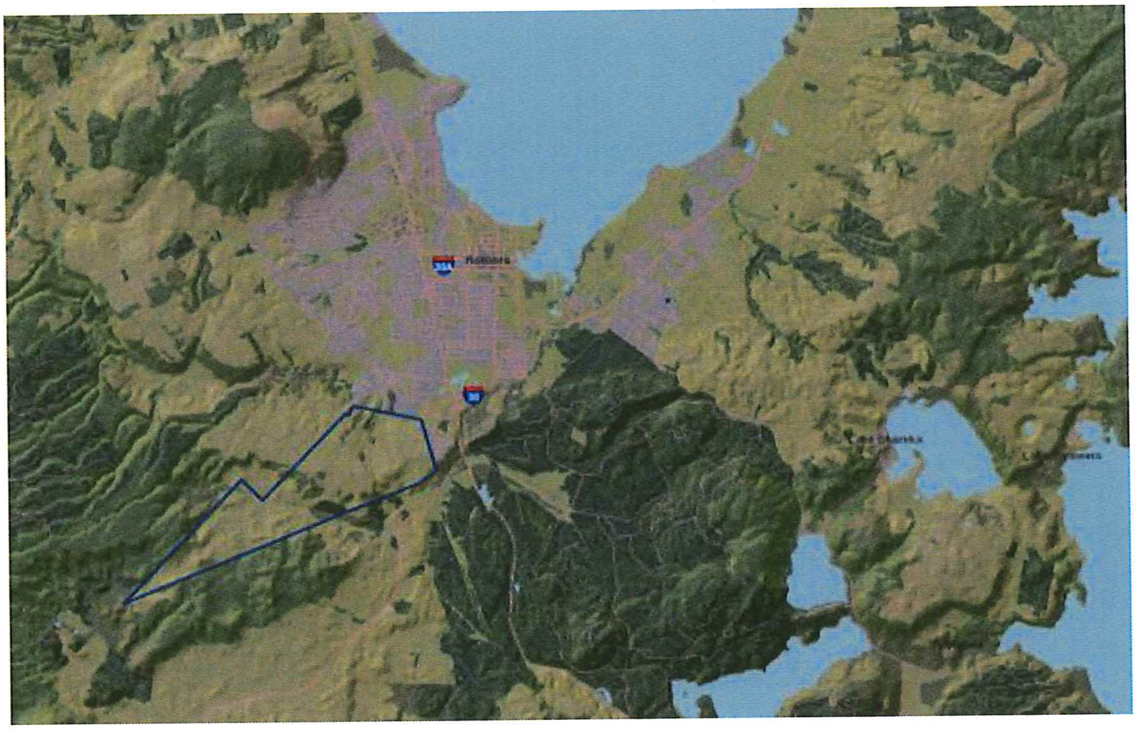

Figure 11. Location of the Tihiotonga Farm on the southern edge of Rotorua.

While this area is close to State Highway 30, access to the highway would require the neighbouring property to be crossed, so we assumed that harvesting will require internal roads to be constructed. To harvest this block in the future 1.5 km of new roads would need to be constructed at an estimated cost of $52,500. As with the other case study sites the growth and yield for each species was modelled using the Forecaster system initialised with the site productivity values given in Table 6.

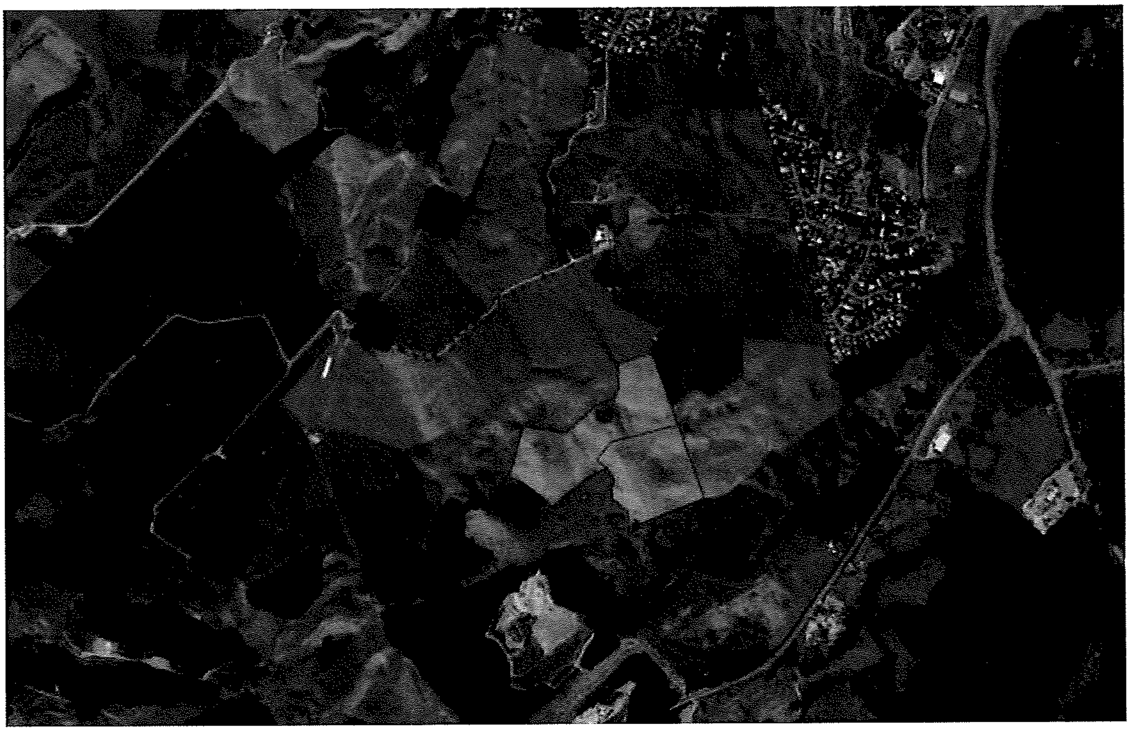

Figure 12. Location of the proposed area for afforestation on the Tihiotonga Farm, which consists of two adjacent paddocks called "Middle Georges" and "Bottom Georges".

Table 6. Site productivity information used to initialise the growth and yield models for different species at the Tihiotonga Farm. See footnotes to Table 3 definitions of Site Index and volume productivity indices.

Species	Site Index (m)	Volume productivity index
Radiata pine	31.7	35.3
Eucalyptus fastigata	32.9	-
Cupressus lusitanica	28.8	-
Coast redwood	35.4	22.7

The total cost of establishing and tending 17.9 ha of forest ranged between $66,821 and $143,630 depending on the option chosen (Table 7). While there are currently no payments for nitrogen reduction for this farm, there is the potential for such payments in the future under the Bay of Plenty Regional Council's scheme for managing lake water quality. If the landowner could receive payments for nitrogen reductions then these would offset some or all of the planting and tending costs. As with the other case study sites, we have also assumed that contract labour is used for all operations. Substantial savings could be made if pruning was undertaken by the landowner and their own labour was treated as a sunk cost. While the proposed afforestation is onto an ex-pasture site, which would normally mean that weed control costs are lower, the presence of some gorse in the area and substantial amounts of gorse in an adjacent paddock means that the cost of comprehensive weed control should be allowed for.

Table 7. Costs associated with establishing and tending 17.9 ha of forest under different combinations of species and silvicultural regime at the Tihiotonga Farm.

Cost ($)	Species and silvicultural regime				
	Radiata pine (clearwood)	Radiata pine (structural)	Coast Redwood	*Cupressus lusitanica*	*Eucalyptus fastigata*
Planting	13,031	15,573	41,814	39,971	37,232
Releasing	8914	8914	9487	14,034	13,962
Pruning	17,632 (lift 1) 13,998 (lift 2)	-	15,931 (lift 1) 13,425 (lift 2) 4833 (lift 3)	17,900 (lift 1) 15,448 (lift 2) 5800 (lift 3)	-
Thinning	9756	9756	9756	9756	-
Administration*	32,578	32,578	46,540	40,723	17,453
Total cost	95,908	66,821	141,786	143,630	68,647
Cost per ha	5358	3733	7921	8024	3835

*Assuming midpoint rotation length

Gross revenues at harvest of over $80,000 per ha were obtained from the two radiata pine regimes, while the *Cupressus lusitanica* had gross revenues in excess of $90,000 per ha (Table 8). As with the Truebridge Farm case study site, the *Cupressus lusitanica* regime had the highest mean log price and the highest net stumpage. The average farm gate log price for the two radiata pine regimes was substantially higher than at the Truebridge Farm site as the transport distances to local sawmills and the Port of Tauranga were much shorter. The gross revenues for the pruned and un-pruned radiata pine regimes were almost identical, but the latter had slightly higher harvesting costs. The net stumpage for both radiata pine regimes was between $35,000 and $40,000 per ha.

Again, the *Eucalyptus fastigata* regime produced the highest wood volume in the shortest period of time. While the average log price at forest gate was higher than at the

Truebridge Farm, due to the shorter distance to the destination pulp mill, it still yielded the lowest gross revenue of all the options examined. The cost of harvesting exceeded the gross revenue resulting in a negative stumpage of approximately $9500 per ha. The Tihiotonga Farm was better suited to coast redwood and this species yielded over 680 m^3 ha^{-1} by age 40 years (Figure 13). A significant proportion of this volume was in the larger, more valuable grades which meant that a positive stumpage was achieved.

Table 8. Costs and revenues associated with harvesting and selling logs from different combinations of species and silvicultural regime at the Tihiotonga Farm. Values shown are for the midpoint harvest age in each scenario and were derived using the MPI average log price for the radiata pine regimes.

Attribute	Species and silvicultural regime				
	Radiata pine (clearwood)	Radiata pine (structural)	Coast Redwood	*Cupressus lusitanica*	*Eucalyptus fastigata*
Total volume of logs (m^3)*	1002	1101	684	683	1097
Mean return ($/$m^3$)**	84	76	107	141	35
Revenue ($/ha)	84,050	83,977	73,756	96,470	38,555
Harvesting costs ($/$m^3$)	41	41	41	41	41
Harvesting costs ($/ha)***	41,220	45,288	28,034	28,132	45,125
Roading cost ($/ha)	2933	2933	2933	2993	2993
Total cost ($/ha)	44,153	48,221	30,967	31,066	48,058
Net stumpage ($/ha)	39,897	35,756	42,798	65,404	-9503
Total net stumpage ($)	714,156	640,032	765,931	1,170,732	-170,104

*Assuming midpoint rotation length
**Total revenue received divided by total standing volume. Includes the cost of cartage.
***Includes cost of pre-harvest inventory

Discounted cashflow analysis showed that the highest net present values (NPV) were achieved for the two radiata pine regimes (Figure 14). Again, these were the only two regimes that achieve positive net present values at an 8 per cent discount rate. While the *Cupressus lusitanica* regime yielded the highest net stumpage it had a negative NPV at 8 per cent discount rate due to the high establishment and silvicultural costs which were compounded over a 35 year rotation. Similarly, the high establishment and tending costs for coast redwood meant that this species failed to achieve a positive NPV at any of the discount rates chosen despite the fact that it returned a positive. Including payments for carbon increased the NPV for all options. At a carbon price of \$15/t CO_2 the *Cupressus lusitanica* regime had a positive NPV at 8% discount rate, while the *Eucalyptus fastigata* regime had a positive NPV at a 6% discount rate (Figure 14).

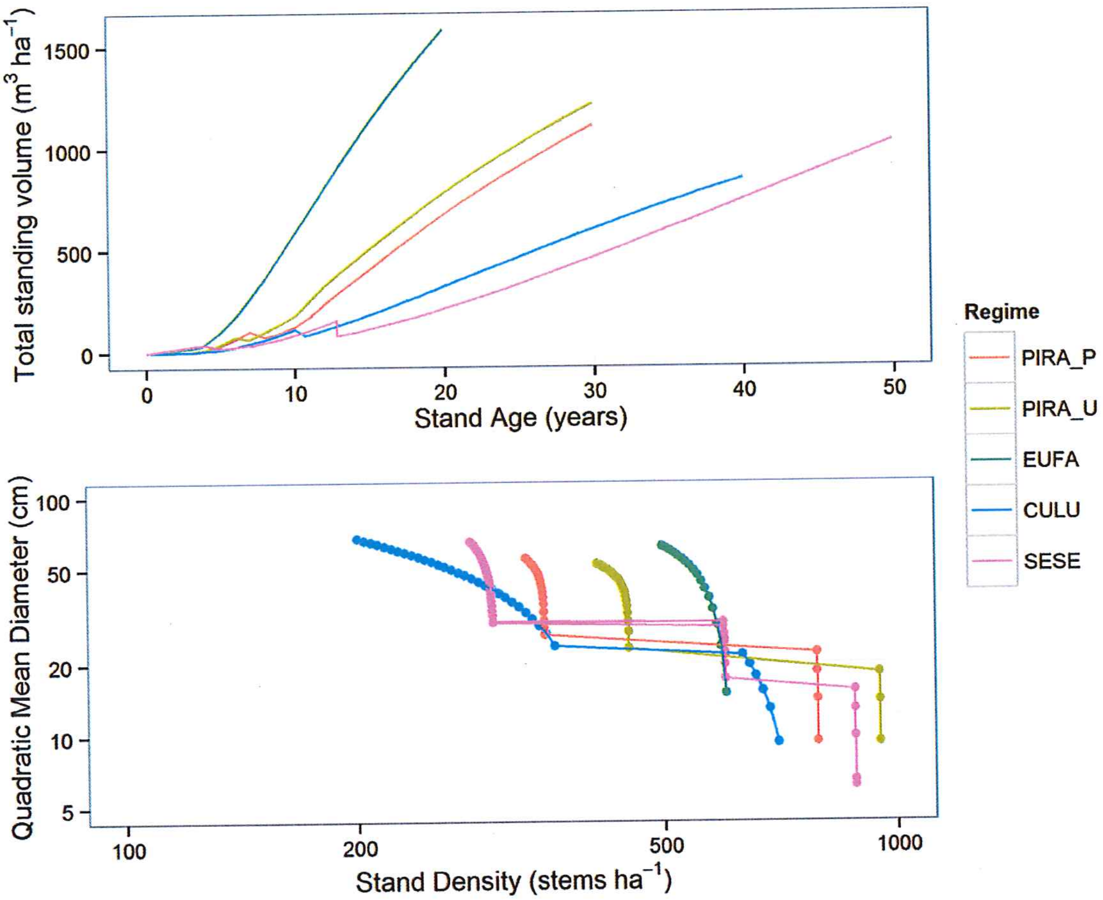

Figure 13. Comparison of yields from the different species and silvicultural regimes at the Tihiotonga Farm (top) and a stand density management diagram showing stand development for each regime (bottom). The following abbreviations are used for the different regimes: radiata pine pruned (PIRA_P); radiata pine unpruned (PIRA_U); *Eucalyptus fastigata* (EUFA); *Cupressus lusitanica* (CULU); coast redwood (SESE).

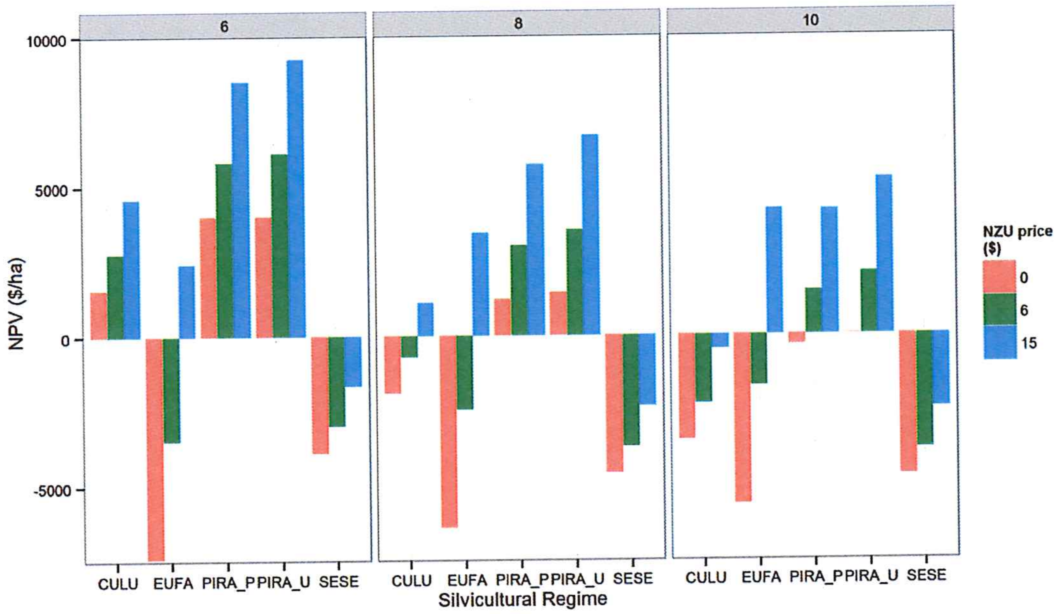

Figure 14. Comparison of net present values between the five different silvicultural regimes and three carbon prices.. The following abbreviations are used for the different regimes: radiata pine pruned (PIRA_P); radiata pine unpruned (PIRA_U); *Eucalyptus fastigata* (EUFA); *Cupressus lusitanica* (CULU); coast redwood (SESE).

Under the assumption of zero carbon revenue the radiata pine regimes had positive NPVs at 6 and 8% discount rates for all four sets of price information used (i.e. minimum, mean and maximum prices from MPI over the last 12 months and AgriHQ prices) (Figure 15). At an 8% discount rate the equivalent annuity for the radiata pine regimes ranged from $31/ha/yr up to $218/ha/yr (excluding carbon) (Figure 16). Including a carbon price of $6/t CO_2 increased the annuity from $197/ha/yr to $408/ha/yr, while including a higher carbon price of $15/t CO_2 increased it further to between $441/ha/yr and $693/ha/yr. The annuities for the unpruned radiata pine regime were generally higher than for the pruned regime, particularly when the higher carbon price of $15/t CO2 was assumed (Appendix 2).

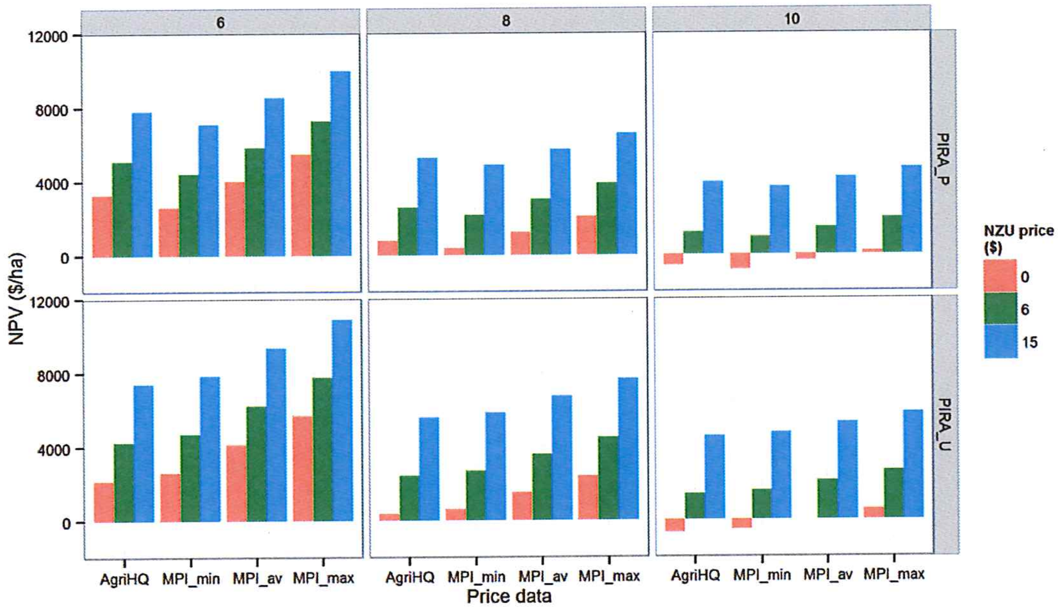

Figure 15. Variation in NPV for pruned and unpruned radiata pine regimes under different log price and carbon price assumptions at the Tihiotonga Farm site.

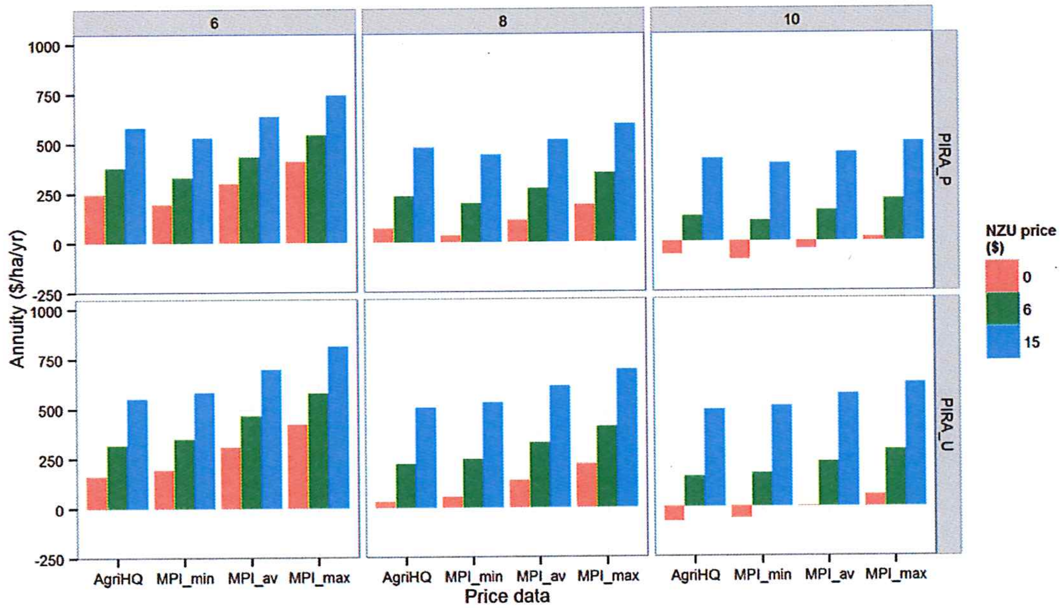

Figure 16. Variation in annuities for pruned and unpruned radiata pine regimes under different log price and carbon price assumptions at the Tihiotonga Farm site.

4.3. Tumunui Trust Farm – Tumunui, Rotorua

The Tumuniu Trust farm is located south of Rotorua alongside State Highway 5 (Figure 17). The total land area is approximately 3200 ha and the farm is divided in to a north block and a south block. There a several different land uses on the farm including dairying (milking approximately 5000 cows), deer farming and forestry (approximately 400 ha). The focus of the case study was on a 17.4 ha area that had been recently harvested (Figure 18). Because this was a second rotation site, the road network had already been upgraded to harvest the previous crop. Only a small amount of road reinstatement would be required in the future at a total cost of approximately $3890 or $225/ha. This is offset somewhat by the slightly higher cost of establishment due to the need for additional site preparation to deal with the harvesting debris from the previous rotation. As with the other case study sites the growth and yield for each species was modelled using the Forecaster system initialised with the site productivity values given in Table 9.

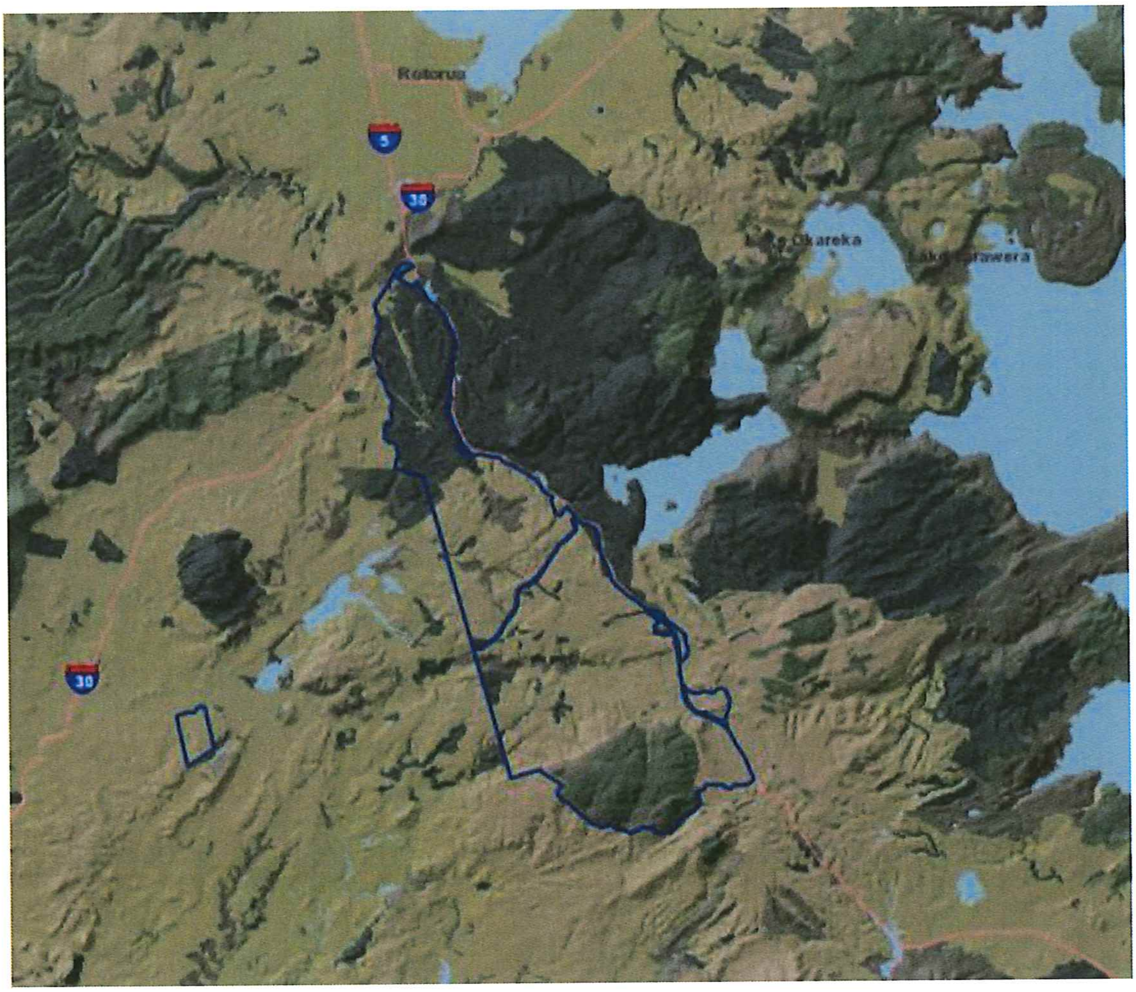

Figure 17. Location of the Tumunui Trust Farm south of Rotorua.

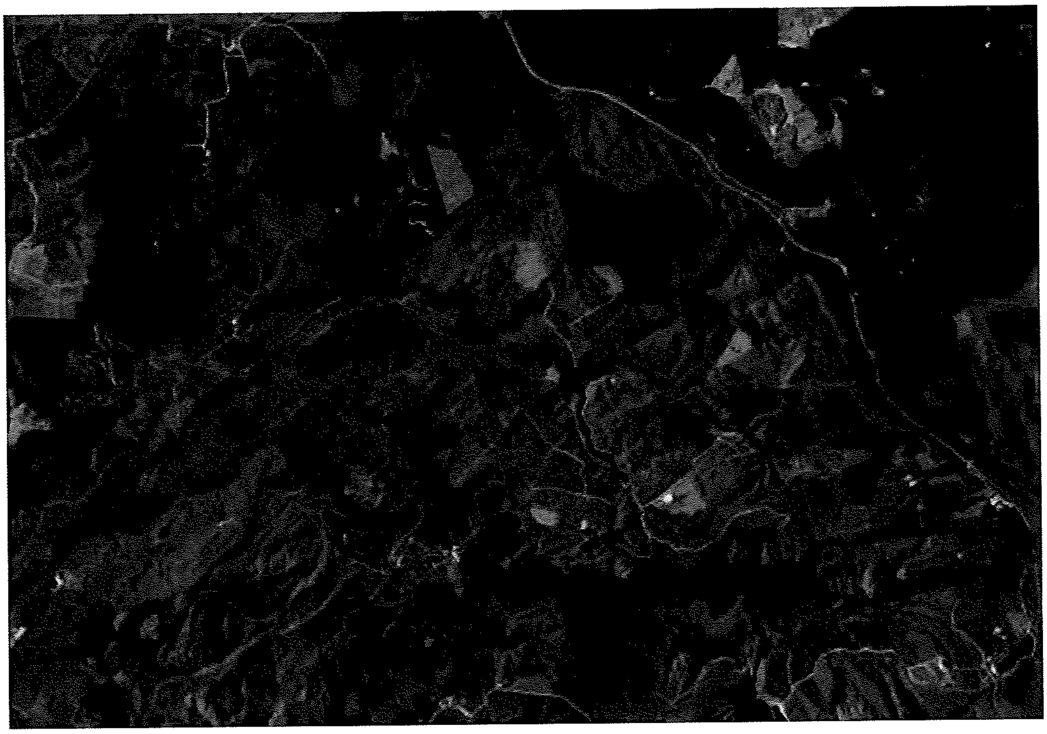

Figure 18. Location of the proposed area for afforestation on the Tumunui Trust Farm, which is a recently harvested block that previously contained radiata pine.

Table 9. Site productivity information used to initialise the growth and yield models for different species at the Tumunui Trust Farm. See footnotes to Table 3 definitions of Site Index and volume productivity indices.

Species	Site Index (m)	Volume productivity index
Radiata pine	31.2	36.7
Eucalyptus fastigata	32.9	-
Cupressus lusitanica	28.8	-
Coast redwood	34.8	22.7

The total cost of establishing and tending 17.4 ha of forest ranged between $64,954 and $139,618 depending on the option chosen (Table 10). Because this was a replanting operation, some of the revenue from harvesting the previous stand of trees could be used to cover the cost of establishing the new stand.

Table 10. Costs associated with establishing and tending 17.4 ha of forest under different combinations of species and silvicultural regime at the Tumunui Trust Farm.

Cost ($)	Species and silvicultural regime				
	Radiata pine (clearwood)	Radiata pine (structural)	Coast Redwood	*Cupressus lusitanica*	*Eucalyptus fastigata*
Planting	12,667	15,138	40,646	38,854	36,192
Releasing	8,665	8665	9222	13,642	13,572
Pruning	17,139 (lift 1) 13,607 (lift 2)	-	15,486 (lift 1) 13,050 (lift 2) 4698 (lift 3)	17,400 (lift 1) 15,016 (lift 2) 5638 (lift 3)	-
Thinning	9,483	9483	9483	9483	-
Administration*	31,668	31,668	45,240	35,985	16,965
Total cost	93,229	64,954	137,825	139,618	66,729
Cost per ha	5358	3732	7917	7943	3834

*Assuming midpoint rotation length

Gross revenues at harvest of approximately $80,000 per ha were obtained from the two radiata pine regimes, while the *Cupressus lusitanica* regime produced a gross revenue of almost $100,000 per ha (Table 11). As with the two other case study sites, the *Cupressus lusitanica* regime had the highest mean log price and the highest net stumpage. The average log price for the two radiata pine regimes was similar to Tihiotonga Farm site as the transport distances to local sawmills and the Port of Tauranga were almost identical. As with the Tihiotonga Farm case study site, the gross revenues for the pruned and un-pruned radiata pine regimes were almost identical, but the latter had slightly higher harvesting costs. Overall, the net stumpage for the pruned and un-pruned radiata pine regimes were approximately $41,000 and $36,000 per ha, respectively.

Again, the *Eucalyptus fastigata* regime produced the highest wood volume in the shortest period of time. While the average log price at forest gate was approximately $35/m^3, this regime still yielded the lowest gross revenue of all the options examined. The cost of harvesting exceeded the gross revenue resulting in a negative stumpage of approximately $6700 per ha. This was the highest (least negative) stumpage for this species across the three case study sites. The Tumunui Trust Farm had similar productivity for coast redwood as the Tihiotonga Farm site and this species yielded approximately 680 m^3 ha^{-1} by age 40 years (Figure 19). A significant proportion of this volume was in the larger, more valuable grades which meant that a positive stumpage of $27,936/ha was achieved.

Table 11. Costs and revenues associated with harvesting and selling logs from different combinations of species and silvicultural regime at the Tumunui Trust Farm. Values shown are for the midpoint harvest age in each scenario.

Attribute	Species and silvicultural regime				
	Radiata pine (clearwood)	Radiata pine (structural)	Coast Redwood	*Cupressus lusitanica*	*Eucalyptus fastigata*
Total volume of logs (m^3)*	945	1034	681	683	1097
Mean return ($\$/m^3$)**	85	77	112	142	35
Revenue ($/ha)	80,024	79,180	76,285	97,082	38,574
Harvesting costs ($\$/m^3$)	41	41	41	41	41
Harvesting costs ($/ha)***	38,882	42,529	46,923	28,133	45,125
Roading cost ($/ha)	219	219	219	219	219
Total cost ($/ha)	39,101	42,748	47,142	28,352	45,344
Net stumpage ($/ha)	40,923	36,432	27,936	68,730	-6769
Total net stumpage ($)	712,060	633,916	486,084	1,195,902	-117,781

*Assuming midpoint rotation length
**Total revenue received divided by total standing volume. Includes the cost of cartage.
***Includes cost of pre-harvest inventory

Discounted cashflow analysis showed that the highest net present values (NPV) were achieved for the two radiata pine regimes (Figure 20). Again, these were the only two regimes that achieve positive net present values at an 8 per cent discount rate and the assumption of a zero carbon price. While the *Cupressus lusitanica* regime yielded the highest net stumpage it had a negative NPV at 8 per cent discount rate due to the high establishment and silvicultural costs which were compounded over a 35 year rotation. Similarly, the high establishment and tending costs for coast redwood meant that this species failed to achieve a positive NPV at any of the discount rates chosen despite the fact that it returned a positive stumpage on this site. Including payments for carbon increased the NPV for all options. At a carbon price of \$15/t CO_2 both the *Cupressus lusitanica* and the *Eucalyptus fastigata* regimes had a positive NPV at 8% discount rate (Figure 20). As this site contains a harvested pre-1990 forest, the new forest is simply replacing carbon that was lost and, therefore, cannot be treated the same as a post-1989 forest for carbon purposes.

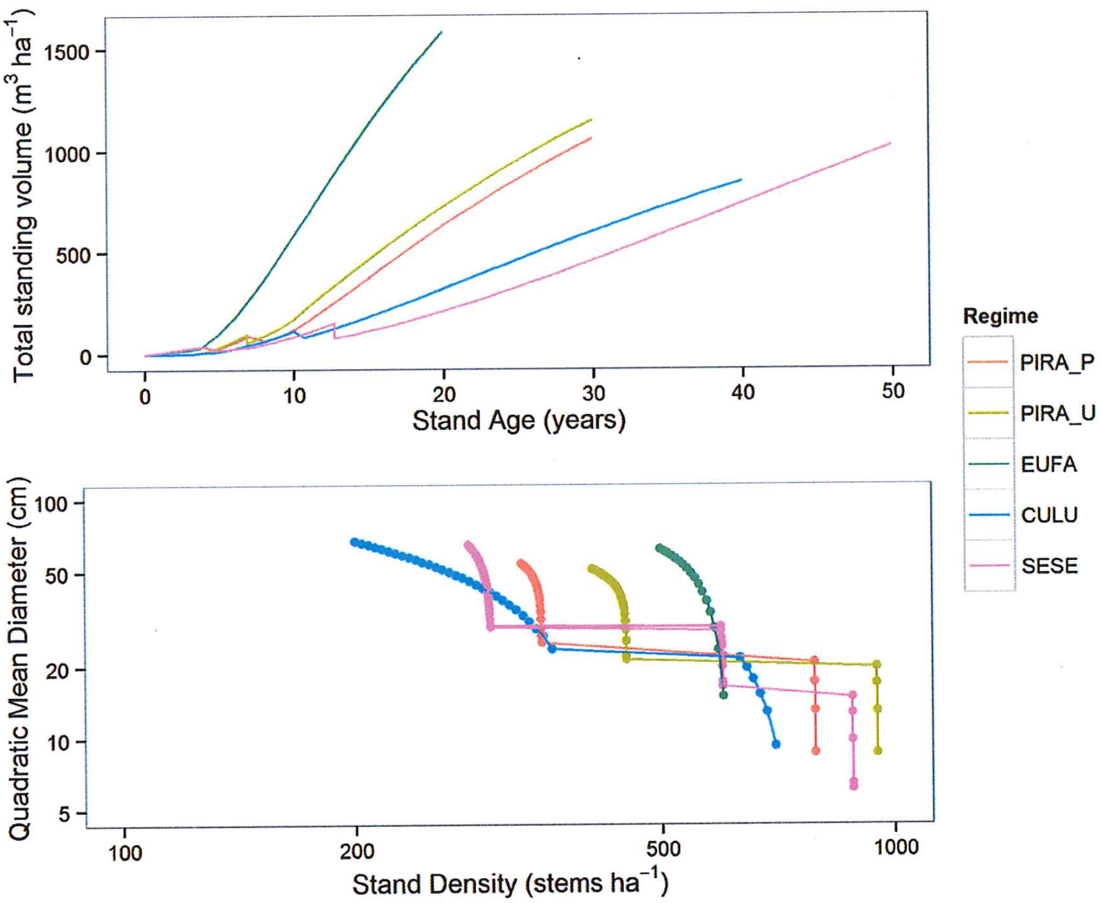

Figure 19. Comparison of yields from the different species and silvicultural regimes at the Tumunui Trust Farm (top) and a stand density management diagram showing stand development for each regime (bottom). The following abbreviations are used for the different regimes: radiata pine pruned (PIRA_P); radiata pine unpruned (PIRA_U); *Eucalyptus fastigata* (EUFA); *Cupressus lusitanica* (CULU); coast redwood (SESE).

Under the assumption of zero carbon revenue the radiata pine regimes had positive NPVs at 6 and 8% discount rates for all four sets of price information used (i.e. minimum, mean and maximum prices from MPI over the last 12 months and AgriHQ prices) (Figure 21). At an 8% discount rate the equivalent annuity for the radiata pine regimes ranged from \$51/ha/yr up to \$233/ha/yr (excluding carbon) (Figure 22). Including a carbon price of \$6/t CO_2 increased the annuity from \$208/ha/yr to \$413/ha/yr, while including a higher carbon price of \$15/t CO_2 increased it further to between \$444/ha/yr and \$683/ha/yr. The range of annuities for the unpruned radiata pine regime were slightly higher than for the pruned regime.

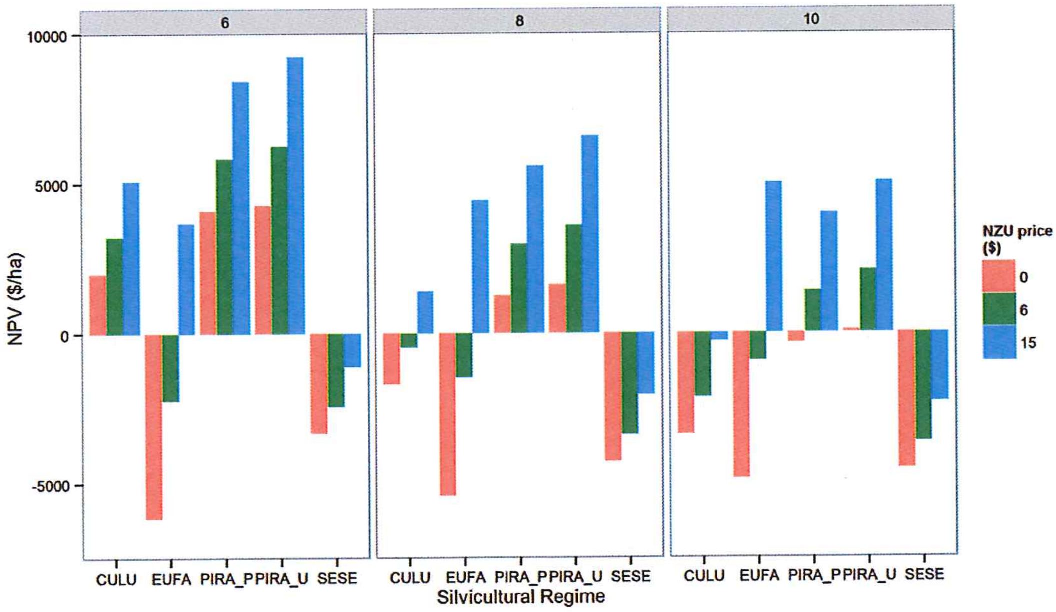

Figure 20. Comparison of net present values between the five different silvicultural regimes. The following abbreviations are used for the different regimes: radiata pine pruned (PIRA_P); radiata pine unpruned (PIRA_U); *Eucalyptus fastigata* (EUFA); *Cupressus lusitanica* (CULU); coast redwood (SESE).

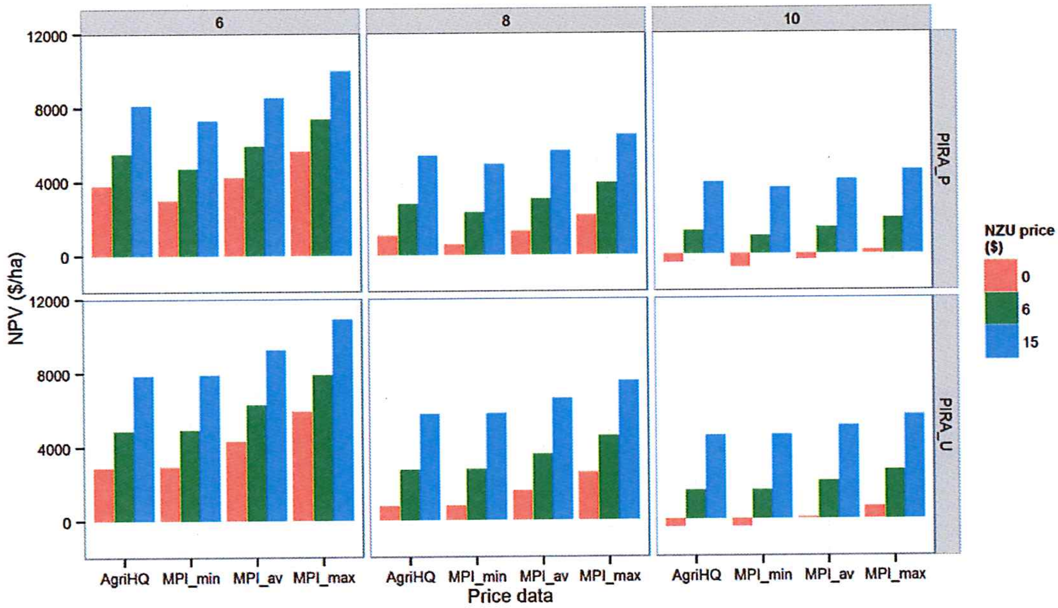

Figure 21. Variation in NPV for pruned and unpruned radiata pine regimes under different log price and carbon price assumptions.

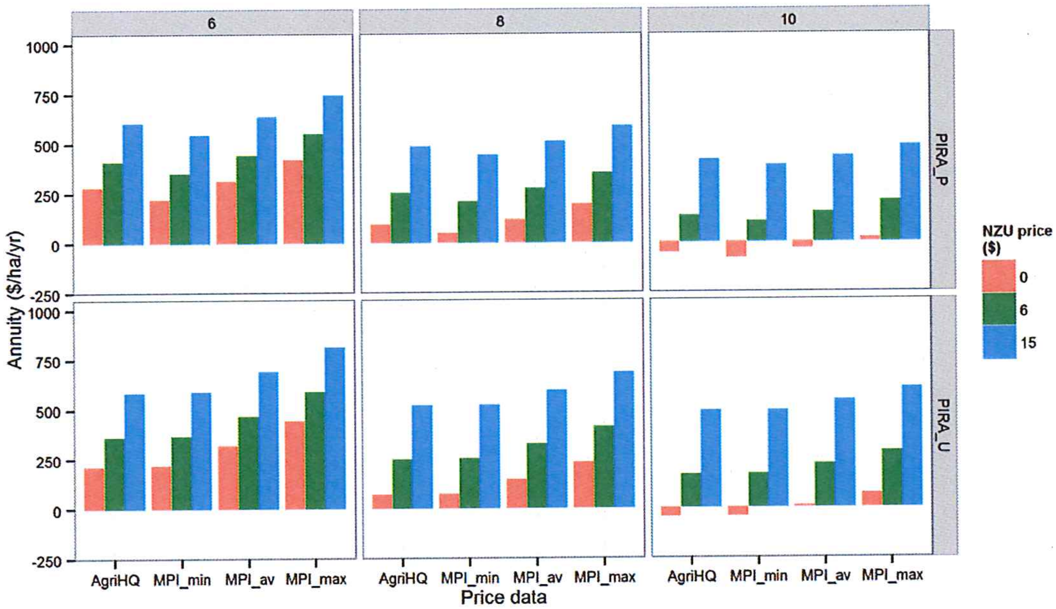

Figure 22. Variation in annuities for pruned and unpruned radiata pine regimes under different log price and carbon price assumptions.

5. Discussion and Conclusions

The results of the three case studies undertaken in this project have shown that forestry can provide a positive financial return to landowners as well as helping them to achieve their goals around nitrogen reduction. Forestry also provides an alternative source of income for farmers and helps to buffer them from fluctuating commodity prices. While it may not achieve the same average returns per hectare as land uses such as dairying, the returns from forestry are generally less volatile to fluctuations in commodity prices. For this reason, it is advisable to try to have a range of forest age classes on a property so that there are areas available to harvest when other income sources are affected by low commodity prices.

Our results are based on the use of simulation models, which include a series of assumptions around growth rates, costs and future prices. We have used the best available information for the different forestry options, but as we have demonstrated the results of our simulations are sensitive to many of these assumptions. When a particular species has not been grown at a site, it is necessary to try to predict productivity from site factors such as climate and soil properties. While maps of site productivity have been developed for many of the main commercial forestry species in New Zealand, these are generally based on very small datasets for species other than radiata pine. Therefore, there is likely to be significant uncertainty associated with growth and yield predictions for some of the forestry scenarios modelled in this study. Another key assumption is the future price for different log grades for different species. The volume of wood that is traded in species other than radiata pine is relatively small, so it is difficult to get robust information on current prices for different log grades. Even for radiata pine, where there is good information on current prices, it is difficult to forecast what future markets will look like. The products made from wood fibre in 30-40 years from now are likely to be very different from those made today. However, we can be reasonably assured that the global demand for wood-based products will increase over time. It is also anticipated that consumers will increasingly demand that this wood will come from sustainably managed sources. Therefore, forestry investment decisions made today are really based on future expectations of demand rather than current prices. What we have shown is that for a certain range of future log prices, forestry can be quite profitable as a land use.

At all three case study sites radiata pine was predicted to be the most profitable forestry option. Differences in stumpage returns for pruned radiata pine at 28 years for the three case study ranged from $23,000 to $39,000 per hectare. The most important difference affecting stumpage returns between the three properties analysed was the transport costs. All properties were considered to have moderate to gently slopes, stable free draining soils and none of the properties required major road upgrades. For this reason neither harvest nor road construction costs contributed significantly to differences in stumpage returns. Predicted growth rates only played a small part for radiata pine with total volumes of merchantable grades ranging from 945m^3/ha to 1001m^3/ha for pruned radiata pine at 28 years. While radiata pine was the most profitable forestry option, other species options should not be discounted as future prices for these timber from these species could increase.

Our analysis of *Eucalptus fastigata* assumed that wood from this species was used for pulp and firewood. Once the cartage cost for this wood had been deducted, the residual price for the wood was not sufficient to cover the harvesting costs. We assumed that the harvesting costs per cubic metre for this species were the same as for radiata pine. This assumption may not be correct as it may be cheaper to harvest *Eucalyptus fastigata* if the trees are only being cut into a single log grade. The smaller piece size may also facilitate more efficient mechanised harvesting. Both the coast redwood and *Cupressus lusitanica* regimes had high upfront costs due to the cost of tree stocks and the intensive silvicultural regimes. Radiata pine seedlings are able to be mass produced by nurseries for around 30 cents per plant (or even less). In comparison, seedlings of other species can cost between $1 and $2 each (and in some cases even more). Not only does this result in a high initial capital outlay to establish forests, but also increases the number of trees that must be tended. These costs are then compounded which has a large negative impact on the net present value of forestry options involving these species. Efforts to reduce the initial stocking will reduce the upfront cost, but will require careful management to control weed competition and maintain good tree form. Also, any early cashflow that can be realised from the sale of carbon credits or nitrogen units will have a very large impact on the economics of forestry, particularly for regimes that have high upfront costs. We did not attempt to model the impacts of selling nitrogen units on the economics of forestry as there are a wide range of scenarios that could occur in practice depending on the situation that individual landowners find themselves in. If a landowner chose to sell 10 kg N/ha/yr (this is approximately half the reduction that would be achieved by converting from dry-stock farming to forestry) at $400 per unit, they would realise $4000/ha. This is sufficient to cover the planting and releasing costs for all the forestry options considered in this analysis.

Early income to offset initial costs can also be obtained from carbon. Under the Emissions Trading Scheme (ETS), forest owners can earn credits (NZUs) for carbon sequestration in forests planted after 1989, but must surrender NZUs to the government if carbon is lost due to harvesting, deforestation or natural disturbances like fire. Under the rules of the ETS, the benefits to post-1989 forest owners from "opting in" to the ETS come from: (1) the ability to sell NZUs as they are earned and have the use of the money before an equivalent number of NZUs must be surrendered at the end of the rotation; (2) the ability to sell "risk free credits" that do not have to be surrendered, due to the fact that some carbon will be retained on site after harvesting; (3) the possibility that the price of carbon will be lower at the time NZUs have to be surrendered; and (4) (until recently) the arbitrage opportunity possible through purchasing cheaper international credits. The arbitrage opportunity has since been closed and the ETS is now under review. For international reporting, the New Zealand government has proposed to account for sequestered carbon only up to the long term average[1], thereby avoiding the contingent liability associated with emissions due to harvesting. It is not yet clear how this and other issues (such as the inclusion of harvested wood products in accounting) will be addressed by the ETS in future. Since there are registration and compliance costs involved in opting in to the ETS and the carbon price will be affected by any changes to the scheme, it is recommended that land owners seek professional advice on the advantages and disadvantages of registering their forests in the ETS.

When the stand is harvested in the future there is a liability for the carbon that has been removed. In our analysis it is assumed that this carbon is instantly lost to the atmosphere, which is not the case, particularly when the trees are processed into products such as structural timber which may have a 50 year life cycle. In the future, it may be possible to retain the credits for this stored carbon in harvested wood products. We have assumed that the stand is replanted following harvest and that the woody debris that is left from harvesting the first rotation will decay over time, but will be replaced with the carbon in the second rotation. Strictly speaking we should have run our analysis over two rotations as the increased NPV from claiming carbon credits is contingent on establishing a second rotation. Of more critical importance was our assumption that the carbon price at the end of the rotation (when the liability is incurred) was the same as that during the course of the rotation when the carbon credits were claimed. Provided that the carbon price is not highly volatile then we can assume that it builds steadily over the rotation so that the value of the

---

1 http://www4.unfccc.int/submissions/INDC/Published%20Documents/New%20Zealand/1/NZ%20INDC%20Addendum%2025%2011%202015.pdf

credits claimed at the end of the rotation and at the start of the next rotation would offset the higher value of the carbon liability when the trees are harvested.

All of our analyses have ignored taxation. There are specific regulations around the treatment of forestry income and the expenditure incurred in generating this income for taxation purposes. It is beyond the scope of this report to include the treatment of taxation. Before embarking on any forestry investment, we would strongly advise that a landowner seeks the advice of a forestry consultant or taxation consultant who has specific expertise around the tax treatment of forestry investments.

Finally, we recommend that any landowner looking to establish forests should engage the services of a professional forestry expert. Two of the key decisions that will affect the future profitability of any forestry investment are location and scale. Both of these decisions are made right at the outset and cannot readily be changed later on (if at all). The cost of harvesting trees and getting this wood to a public road will depend heavily on the location of a forestry block on a property. Steep areas at the back of a farm will be expensive to harvest and the cost of road construction will be high. If the intention is to change the land use in these areas then the scale needs to be sufficient so that the roading cost is distributed over a large volume or wood or an option such as manuka is considered which does not require harvesting or expensive roading. With any forestry regime it is important to fully utilise the potential of a site to grow wood. Significantly underutilising a site will likely be the difference between achieving a marginal return on investment and achieving a good return.

References

Barrett, J. D., & Kellogg, R. M. (1991). Bending strength and stiffness of second-growth Douglas-fir dimension lumber. *Forest Products Journal, 41*(10), 35-43.

Cown, D., Marshall, H., Silcock, P., & Meason, D. (2013). Sawn timber grade recovery from a planted coast redwood stand growing in New Zealand. *New Zealand Journal of Forestry Science, 43*(1), 8. doi:10.1186/1179-5395-43-8

Grace, J., Yao, R., Garrett, L., Heaphy, M., & Katu, G. (2013). *Ngati Rereahu - Scoping the Ginseng Potential in the Central North Island.* Report prepared for Maraeroa C Incorporation. Rotorua: Scion.

Kimberley, M. O., Moore, J., & Dungey, H. S. (2015). Quantification of realised genetic gain in radiata pine and its incorporation into growth and yield modelling systems. *Canadian Journal of Forest Research*. doi:10.1139/cjfr-2015-0191

Knowles, R. L., & Hansen, L. W. (2004a). Profitability of converting pastoral farming to production forestry in the Taupo Basin. *Primary Industry Management, 7*(2), 25-28.

Knowles, R. L., & Hansen, L. W. (2004b). *Profitability of converting pastoral farming to production forestry in the Taupo Basin. Part 1: marginal analysis at the one-hectare level. .* Forest and Farm Plantation Management Cooperative Report 88. Rotorua, New Zealand: Scion.

Knowles, R. L., Hansen, L. W., & Laroze, A. (2004). *Profitability of converting pastoral farming to production forestry in the Taupo Basin. Part 2: farm level sustainability* Forest and Farm Plantation Management Cooperative Report 88. Rotorua, New Zealand: Scion.

Levack, H. (2015). Economies of scale in forestry. *Tree Grower, May*, 9-12.

Ministry for Primary Industries. (2014). *National exotic forest description as at 1 April 2014.* Wellington: Ministry for Primary Industries.

Moore, H. (2015). Options for economies of scale in small forests. *Tree Grower, May*, 13-15.

Palmer, D. J., Watt, M. S., Kimberley, M. O., & Dungey, H. S. (2012). Predicting the spatial distribution of *Sequoia sempervirens* productivity in New Zealand. *New Zealand Journal of Forestry Science, 42*, 81-89.

Park, D. (2011). *Economic wood availability and profitability of small-scale forests in Wanganui District.* University of Canterbury, Christchurch, New Zealand.

Robinson, G. (2015). Life-styler's super fund achieved. *Tree Grower, May*, 7-8.

Stone, J. K., Hood, I. A., Watt, M. S., & Kerrigan, J. L. (2007). Distribution of Swiss needle cast in New Zealand in relation to winter temperature. *Australasian Plant Pathology, 36*(5), 445. doi:10.1071/ap07049

Watt, M. S., Palmer, D. J., Dungey, H. S., & Kimberley, M. O. (2009). Predicting the spatial distribution of *Cupressus lusitanica* productivity in New Zealand. *Forest Ecology and Management, 258*(3), 217-223. doi:10.1016/j.foreco.2009.04.003

Watt, M. S., Palmer, D. J., Kimberley, M. O., Höck, B. K., Payn, T. W., & Lowe, D. J. (2010). Development of models to predict *Pinus radiata* productivity throughout New Zealand. *Canadian Journal of Forest Research, 40*(3), 488-499. doi:10.1139/x09-207

West, G. G., Moore, J. R., Shula, R. G., Harrington, J. J., Snook, J., Gordon, J. A., & Riordan, M. P. (2013). Forest management DSS development in New Zealand. In Tucek, J., Smrecek, R., Majlingova, A. & Garcia-Gonzalo, J. (Eds.), *Implementation of DSS Tools into the Forestry Practice* (pp. 153-163)

West, G. G., & Turner, J. A. (2013). MyLand: a web-based and meta-model decision support system framework for spatial and temporal evaluation of integrated land use. *Scandinavian Journal of Forest Research, 29*(sup1), 108-120. doi:10.1080/02827581.2013.866690

Appendix 1 – Forest Gate Log Price Information

Table A1. Calculation of forest gate prices for different radiata pine log grades at the Truebridge Farm. Average Ministry for Primary Industries radiata pine log price data for the past 12 months are used.

Market	Log Grade	Market Price	Transport Distance (km)	Transport cost ($)	Price at forest gate
Export	Pruned	160	191	38	122
	A grade	110	191	38	72
	K grade	99	191	38	61
	Pulp	79	191	38	41
Domestic	P1	145	94	18	127
	P2	125	94	18	107
	S1	106	124	26	80
	S2	105	124	26	79
	L1 and L2	94	124	26	67
	S3 and L3	95	124	26	69
	Pulp	51	101	20	31

Table A2. Calculation of forest gate prices for different *Cupressus lusitanica* log grades at the Truebridge Farm.

Market	Log Grade	Market Price	Transport Distance (km)	Transport cost ($)	Price at forest gate
Domestic	P1	331	94	18	312
	P2	185	94	18	166
	S30	147	124	26	121
	S20	117	124	26	91
	L	103	124	26	77
	Sleeper	93	124	26	67
	Firewood	15	94	27	-12

Table A3. Calculation of forest gate prices for different *Eucalyptus fastigata* log grades at the Truebridge Farm.

Market	Log Grade	Market Price	Transport Distance (km)	Transport cost ($)	Price at forest gate
Domestic	Pulp	51	101	26	25
	Firewood	15	94	27	-12

Table A4. Calculation of forest gate prices for different coast redwood log grades at the Truebridge Farm.

Market	Log Grade	Market Price	Transport Distance (km)	Transport cost ($)	Price at forest gate
Domestic	P1	325	94	18	307
	P2	185	94	18	167
	S50	250	124	26	224
	S40	95	124	26	69
	S30	50	124	26	24

Table A5. Calculation of forest gate prices for different radiata pine log grades at the Tihiotonga Farm. Average Ministry for Primary Industries radiata pine log price data for the past 12 months are used.

Market	Log Grade	Market Price ($/m^3)	Transport Distance (km)	Transport cost ($/m^3)	Price at forest gate ($/m^3)
Export	Pruned	160	88	18	141
	A grade	110	88	18	91
	K grade	99	88	18	80
	Pulp	79	88	18	61
Domestic	P1	145	7	2	143
	P2	125	7	2	123
	S1	106	7	2	104
	S2	105	7	2	102
	L1 and L2	94	7	3	91
	S3 and L3	95	7	3	92
	Pulp	51	55	12	39

Table A6. Calculation of forest gate prices for different *Cupressus lusitanica* log grades at the Tihiotonga Farm.

Market	Log Grade	Market Price ($/m^3)	Transport Distance (km)	Transport cost ($/m^3)	Price at forest gate ($/m^3)
Domestic	P1	331	7	3	329
	P2	185	7	3	182
	S30	147	7	3	144
	S20	117	7	3	114
	L	103	7	3	101
	Sleeper	93	7	3	91
	Firewood	15	7	3	12

Table A7. Calculation of forest gate prices for different *Eucalyptus fastigata* log grades at the Tihiotonga Farm.

Market	Log Grade	Market Price ($/m^3)	Transport Distance (km)	Transport cost ($/m^3)	Price at forest gate ($/m^3)
Domestic	Pulp	51	55	15	36
	Firewood	15	7	3	12

Table A8. Calculation of forest gate prices for different coast redwood log grades at the Tihiotonga Farm.

Market	Log Grade	Market Price ($/m^3)	Transport Distance (km)	Transport cost ($/m^3)	Price at forest gate ($/m^3)
Domestic	P1	325	7	3	322
	P2	185	7	3	182
	S50	250	7	3	247
	S40	95	7	3	92
	S30	50	7	3	47

Table A9. Calculation of forest gate prices for different radiata pine log grades at the Tumunui Trust Farm. Average Ministry for Primary Industries radiata pine log price data for the past 12 months are used.

Market	Log Grade	Market Price ($/m^3)	Transport Distance (km)	Transport cost ($/m^3)	Price at forest gate ($/m^3)
Export	Pruned	160	81	17	143
	A grade	110	81	17	93
	K grade	99	81	17	82
	Pulp	79	81	17	62
Domestic	P1	145	5	2	143
	P2	125	5	2	123
	S1	106	5	2	104
	S2	105	5	2	102
	L1 and L2	94	5	3	91
	S3 and L3	95	5	3	92
	Pulp	51	52	12	39

Table A10. Calculation of forest gate prices for different *Cupressus lusitanica* log grades at the Tumunui Trust Farm.

Market	Log Grade	Market Price ($/m^3)	Transport Distance (km)	Transport cost ($/m^3)	Price at forest gate ($/m^3)
Domestic	P1	331	7	2	329
	P2	185	7	2	183
	S30	147	7	2	145
	S20	117	7	2	114
	L	103	7	3	101
	Sleeper	93	7	3	91
	Firewood	15	7	3	13

Table A11. Calculation of forest gate prices for different *Eucalyptus fastigata* log grades at the Tumunui Trust Farm.

Market	Log Grade	Market Price ($/m^3)	Transport Distance (km)	Transport cost ($/m^3)	Price at forest gate ($/m^3)
Domestic	Pulp	51	55	15	36
	Firewood	15	7	3	13

Table A12. Calculation of forest gate prices for different coast redwood log grades at the Tumunui Trust Farm.

Market	Log Grade	Market Price ($/m^3)	Transport Distance (km)	Transport cost ($/m^3)	Price at forest gate ($/m^3)
Domestic	P1	325	7	2	323
	P2	185	7	2	183
	S50	250	7	2	248
	S40	95	7	2	93
	S30	50	7	2	48

Appendix 2 – Annuities from growing radiata pine

Table A13. Annuity values ($/ha/yr) for a pruned radiata pine regime growing at the Truebridge Farm based on average MPI prices and different discount rate and carbon price assumptions.

Discount rate (%)	Carbon price ($/t CO_2)		
	0	6	15
6	62	205	419
8	-59	114	374
10	-154	52	360

Table A14. Annuity values ($/ha/yr) for an un-pruned radiata pine regime growing at the Truebridge Farm based on average MPI prices and different discount rate and carbon price assumptions.

Discount rate (%)	Carbon price ($/t CO_2)		
	0	6	15
6	10	171	413
8	-77	119	413
10	-148	85	433

Table A15. Annuity values ($/ha/yr) for a pruned radiata pine regime growing at the Tihiotonga Farm based on average MPI prices and different discount rate and carbon price assumptions.

Discount rate (%)	Carbon price ($/t CO_2)		
	0	6	15
6	300	434	635
8	110	272	517
10	-37	157	447

Table A16. Annuity values ($/ha/yr) for an un-pruned radiata pine regime growing at the Tihiotonga Farm based on average MPI prices and different discount rate and carbon price assumptions.

Discount rate (%)	Carbon price ($/t CO_2)		
	0	6	15
6	308	464	699
8	136	326	610
10	2	227	565

Table A17. Annuity values ($/ha/yr) for a pruned radiata pine regime growing at the Tumumui Trust Farm based on average MPI prices and different discount rate and carbon price assumptions.

Discount rate (%)	Carbon price ($/t CO_2)		
	0	6	15
6	313	412	637
8	117	274	509
10	-34	152	432

Table A18. Annuity values ($/ha/yr) for an un-pruned radiata pine regime growing at the Tumumui Trust Farm based on average MPI prices and different discount rate and carbon price assumptions.

Discount rate (%)	Carbon price ($/t CO_2)		
	0	6	15
6	320	468	690
8	145	325	595
10	9	223	543