Precision Silviculture Programme

TECHNICAL REPORT

Economics of Pruning Radiata

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FOREST GROWERS RESEARCH

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Forest Growers Research: Economics of pruning radiata

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1. Executive summary

Forest Growers Research (FGR) has asked Ngahere Resources Limited (NRL) to review the economics of pruning radiata pine in New Zealand. NRL has had a number of discussions with large and small forest owners, pruned logs processors and forest managers.

Pruned log forecasts and levels of pruning activity

As recorded by the NEFD, from the late 1990's there has been a clear trend of declining intentions to prune stands; this has declined from around 70% to just above 40% in 2021. The Wood Availability Forecast (WAF) also show a declining pruning intention trend. While the WAF indicates a lower proportion intent on pruning, this is not consistent with NRL discussions with the Farm Forestry Association, which represents small owners. The FFA indicated a strong preference for pruning.

In NRL discussions with the larger forest owners the main drivers away from pruned have been:

1. Economics, where the price differential between pruned and sawlog is not large enough to justify the lower total recoverable volume in a pruned regime and associated pruning costs
2. Valuation, the impact on forest valuation can be material
3. Labour shortages.

However, for integrated growers/processors the pruned log is seen as critical to the supply chain.

In NRL discussions with the smaller forest owners and forest managers, there is more enthusiasm for pruning. The main drivers on the decision to prune or not are:

1. Improving profitability, this was the key driver
2. Long term view of appearance lumber gaining in value over knotty lumber
3. Cashflow constraints
4. For the sub 50ha owners much was done by internal labour but with an aging ownership, this is becoming more difficult.
5. Owners wanting to *"grow steak, not dags",* this is also linked to the visual appearance of the forest
6. If in the ETS, then limited or likely no pruning would be undertaken.

While the lower carbon sequestration was raised by some smaller forest owners this did not appear to be a major driver in the decision to prune.

Processors and radiata's competitive advantage

Radiata pine lumber is well regarded for its ability to take treatment and this when combined with radiata's wider lumber widths give radiata pine clearwood a competitive advantage when compared to other softwood alternatives.

Economics of pruned versus unpruned regimes

NRL has compared the option of a pruned regime to unpruned using the common method of financial comparison, Internal Rate of Return (IRR). NRL ran a base case scenario and sensitivity analysis on a higher yield and costs site, final crop pruned stocking, log prices, and the inclusion of a third pruning lift.

The analysis produced the resulting IRR's, these are shown in Table 1-1.

Table 1-1 IRR results (%)

	Unpruned	Pruned
Base	6.5	5.7
High productivity & cost	3.5	3.8
Unpruned log price-10%	5.3	5.1
Log price 1-year ave	5.2	4.9

In all cases except the high productivity and cost scenario, the unpruned IRR are higher than the pruned. The higher unpruned IRR is the result of higher log volumes (higher stocking) and lower silviculture costs, which are not offset by the higher average log prices for the pruned regime. Only on the sites with high productivity and cost does pruning compare favourably.

Further sensitivity analysis:

1. Changes were made to the pruning costs. If the pruning cost was reduced by 70% the IRR matches the unpruned regime (6.5%).
2. Changes were made to the pruned crop stockings from 300 sph up to 450 sph. The increasing stocking has an impact on pruned log quality. The IRR's show a very flat trend with no real reduction in IRR seen with the increased stocking. The trend is more pronounced for the pruned log quality which shows a range of 6.5-7.6 PLI's (17%) and a logical reduction in pruned log quality as the stocking increases.
3. The additional lift (3rd) was incorporated into the analysis with the third lift to 8.5m or 10m. The IRR's for the base case (pruned height 5.5m) and the 8.5m pruned height are reasonably similar. With the increased volume of pruned logs compensating for the loss in total volume. The 10m pruned height shows a lower IRR than the base case. In all cases the pruned regimes show lower IRR's than unpruned.

Log price and pruning costs combined sensitivity

NRL has tested a combination of reduced unpruned log prices and reduced pruning costs (Table 1-2). The green shaded area is where the pruned regime match's or exceeds the unpruned regime. For example, if a 30% reduction in pruning costs is achieved with a 10% reduction in unpruned log price, this gives a pruned regime IRR 5.3% which exceeds the unpruned regime of 5.2%.

Table 1-2 Matrix of unpruned log price and pruning costs (IRR %)

	Pruning costs					
	Unpruned	Pruned				
Unpruned log price	**0%**	**-10%**	**-20%**	**-30%**	**-40%**	**-50%**
0%	6.5%	5.8%	5.9%	6.0%	6.1%	6.2%
-5%	5.9%	5.5%	5.6%	5.7%	5.8%	5.9%
-10%	5.2%	5.1%	5.2%	5.3%	5.5%	5.6%
-15%	4.4%	4.7%	4.8%	5.0%	5.1%	5.2%
-20%	3.3%	4.3%	4.4%	4.5%	4.7%	4.8%

Limitations to this analysis

One of the key drivers in this analysis is log price assumptions. NRL's approach is to use historical pricing as NRL views forecast pricing as having too many variables (USD/NZD FX, shipping costs and lumber supply and demand in various markets) to reliably estimate forward log prices.

Historically the pruned stockings were <300 sph and have been gradually increasing. The increased stocking indicates that care is needed when comparing historical returns from pruned stands.

The costs estimated for the 3rd lift are based on mechanisation of this final lift and the operation incorporating a waste thin. There are a number of different pruning mechanisation operations being investigated currently and the costs of these are yet to be understood. The ability to incorporate a waste thinning technology as well as pruning is also a variable that is not understood well.

Non-financial drivers

There was variety of views on the non-financial drivers in the decision to prune or to not. While some of the drivers were not shared, there was some general themes between large and small forest owners. The largest concern expressed by a number of parties was the lack of market diversity with an unpruned regime.

1. Pruned logs have very different market options, with the balance of the harvest having a strong exposure to export log returns. In some regions having domestic pruned logs sales is critical to cashflow during export market downturns
2. The higher stocking seen in the unpruned regime clearly indicates a smaller tree with its associated small diameter logs. In NRL experience there are few major sites successfully processing of <30cm diameter sawlogs in NZ. The exceptions being Shands Road (Canterbury) and Sequal (CNI). Markets for this smaller diameter are likely export appearance grade for remanufacturing or more likely packaging, as NZ structural lumber demand is currently satisfied with existing larger diameter sawlogs.
3. Consistency of the pruned domestic market can be compared to the volatility of the export log trade and its flow on impact further back through the supply chain
4. A number of parties discussed market options into the future, bioplastic and engineered wood products were mentioned, but all agreed technology (bioplastic) would need to come a long way from its current situation.

2. Introduction

Forest Growers Research (FGR) has asked Ngahere Resources Limited (NRL) to review the economics of pruning radiata pine in New Zealand. This project is under the Mechanised Pruning workstream of the Precision Silviculture SFFF Partnership program.

The Mechanised Pruning workstream targets the reduction in low skilled manual labour and the reduction in costs, by the mechanisation of pruning.

NRL has had a number of discussions with large and small forest owners, pruned logs processors and forest managers. NRL has reviewed the economics of pruning with Tenon, PanPac, Claymark, Juken NZ, PF Olsen, F360, Farm Forest Association and Manulife. It should be noted that NRL has not contacted all forestry management or processors, but considers the parties contacted all have views across the spectrum on the economics of pruning.

NRL produced a draft report in July 2022 and this report (Dec 2022) is an update on the original. Specifically further analysis has been done on a range of pruned stockings as well as higher pruned heights.

NRL would like to thank PanPac for the usage of it pruning evaluation model. This model was constructed by Scion to assist in PanPac's forest management decision making. The model was used to cross check NRL's modelling and provided supporting analysis on the resulting pruned log quality.

This review is subject to the disclaimer at the end of the report.

3. Pruned log forecasts and levels of pruning activity

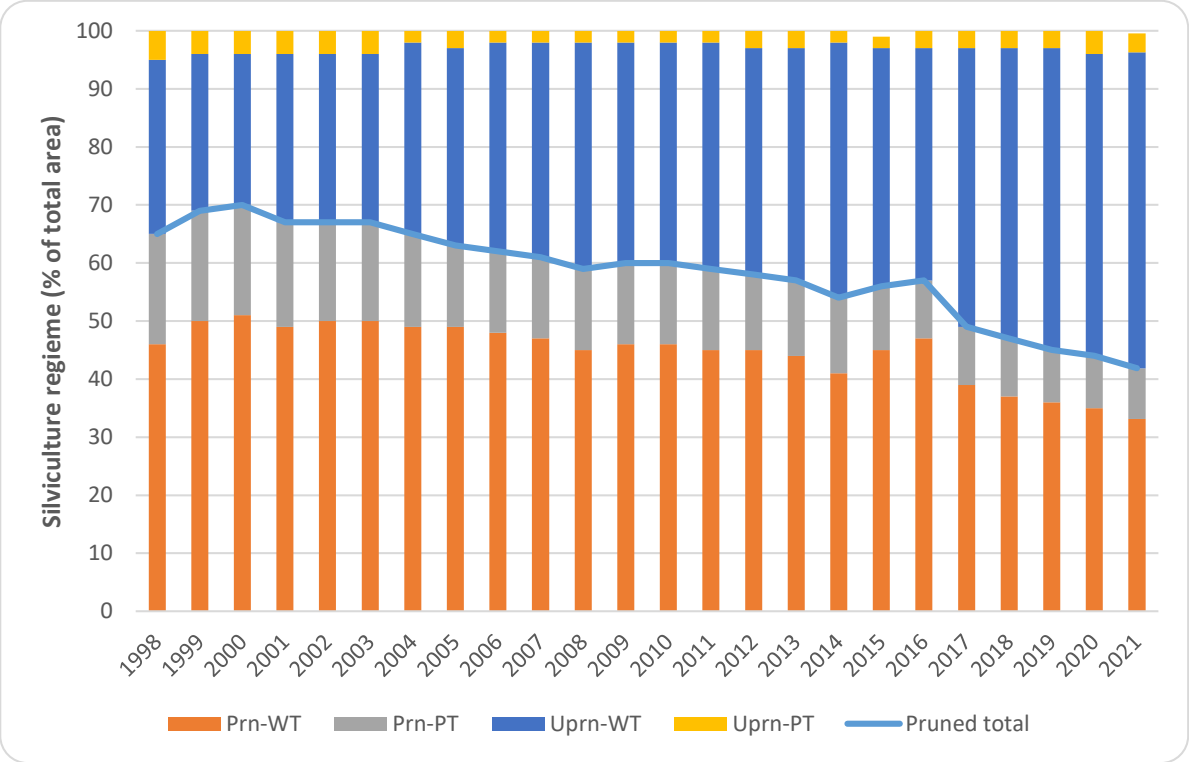
3.1 Pruning levels

NZ's main source of forest information on harvest and silvicultural trends is the National Exotic Forest Description (NEFD). This survey happens every year for major forest owners and less frequently for small forest owners. It is commonly acknowledged that the information on small forest owners is not well understood, given the expense of surveying down at this level.

Figure 3-1 shows the intended silviculture regimes as recorded by the NEFD. The information is collected by either pruned or unpruned regimes and is further split by thinning type (waste-WT or production-PT). From the late 1990's there has been a clear trend of declining intentions to prune stands; this has declined from around 70% to just above 40% in 2021. The sharp decrease from 2016 to 2017 is likely driven by a major CNI forest owner deciding to cease pruning.

The decline of pruning had been steady until 2017, from this date the decline has increased.

Figure 3-1 NZ silviculture regimes (% of area)



In May 2022 Bruce Manley from the University of Canterbury published an article[1] on the trends in silviculture for large forest owners. The largest 19 forest owners were asked about changes in the areas intended to be pruned from 2010 to 2020. Further questions were asked on changes to stocking rates for pruned and unpruned regimes. The results are shown in Table 3-1.

[1] NZ Journal of Forestry, May 2022 Vol 67, No 1

Table 3-1 Manley survey results

	Area pruned (%)		Final crop stocking (Pruned)		Final crop stocking (Unpruned)	
Entity	**2010**	**2020**	**2010**	**2020**	**2010**	**2020**
1	0%	0%			450	450
2	0%	0%			413	500
3	0%	0%			400	550
4	0%	0%			475	450
5	0%	0%			550	550
6	0%	0%			425	500
7	0%	0%			475	475
8	0%	10%		350	600	600
9	2%	20%	320	363	450	450
10	10%	33%	250	313	500	600
11	30%	80%	335	335	400	613
12	40%	0%	370		400	500
13	66%	80%	270	300	388	388
14	70%	60%	330	330	450	450
15	95%	90%	350	350	475	475
16	100%	0%	250			500
17	100%	40%	325	375		550
18	100%	65%	350	350		475
19	100%	100%	375	375		

The key findings are:

1. Seven entities have not changed regime and continue not to prune
2. Two entities have stopped pruning
3. Three entities have decreased pruning levels
4. Seven entities have continued at 2010 levels or have increased pruning levels
5. Manley calculated, using a weighted average, that the area intended to be pruned has declined from 28% to 19%, with the majority of the reduction from one entity ceasing pruning.

In 2021 MPI commissioned an update[2] on the Wood Availability Forecast (WAF). These are done periodically with the previous revision done in 2014-2015. As part of the forecasting process, the authors investigated the regime intentions for large and small forest owners. These are presented in Table 3-2 by region. As indicated by the NEFD results, the current area pruned will be substantially

[2] https://www.canopy.govt.nz/forestry-data-research/wood-availability-forecasts/

reduced after harvest for large owners. This trend is more marked in the South Island with its lower growth characteristics.

Table 3-2 WAF pruned replanting constraints

	Large scale owners		Small-scale owners	
	From pruned to		From pruned to	
Wood Supply Region	Pruned %	Unpruned %	Pruned %	Unpruned %
Northland	0	100	25	75
Central North Island	25	75	50	50
East Coast	0	100	50	50
Hawke's Bay	25	75	50	50
Eastern Southern North Island	50	50	35	65
Western Southern North Island	5	95	50	50
Nelson	0	100	10	90
Marlborough	0	100	10	90
West Coast	0	100	0	100
Canterbury	0	100	5	95
Otago/Southland	40	60	70	30

The WAF indicates that small forest owners are more likely to continue pruning, again with a trend of lower proportion in the South Island, with an exception for Otago/Southland.

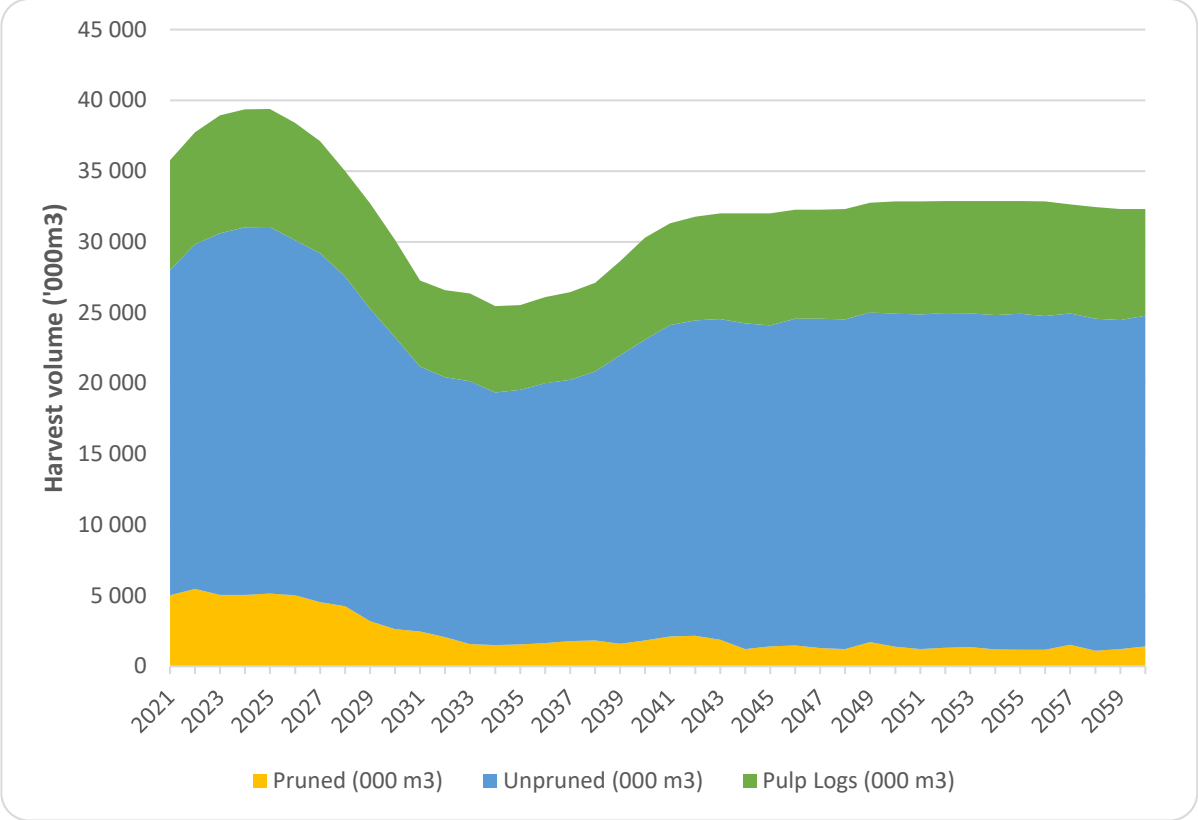
While the WAF indicates a lower proportion intent on pruning, this is not consistent with NRL discussions with the FFA, which represents small owners. The FFA indicated a strong preference for pruning. F360 and to a lesser extent PF Olsen also indicate a higher level of pruning among small owners. The discrepancy could be due to the size of the smaller owners. Potentially the small owners are well represented at the sub 50ha level by FFA and owners over this level tend to get a forest manager. Both F360 and PF Olsen report variable levels of knowledge and effectiveness of pruning operations in small growers.

3.2 Pruned log forecast

As stated earlier, MPI updated its the WAF in 2021.

Figure 3-2 shows the NZ potential wood availability from 2021 through to 2060. As can be expected from this exercise, the accuracy of the information on small forest owners (39% of the area) is not great but this represents the best available data on potential volumes.

Figure 3-2 **WAF radiata volumes 2021-2060**



In NRL's view, the harvest pattern is unlikely to rise as high as 39 million m^3/pa given capacity constraints. The radiata harvest levels (34 million m^3/pa) in 2018-2019 would seem to indicate the supply chain has little further capacity to get to 39 million m^3/pa. This would likely mean harvesting is delayed and this will help the trough in volume seen into the 2030's.

Forecast pruned log volumes are reasonably consistent for the next five years at around 5.0 million m^3/pa however, from there it declines rapidly over the next five years to about 2.0 million m^3/pa, then sits at around 1.5 million m^3/pa to 2.0 million m^3/pa for the next 20 years. Based on their own studies, a number of pruned processors think there is still reasonable volumes of pruned available from the smaller growers and the drop in volume won't be as pronounced as indicated by the WAF. It would be difficult to estimate the accuracy of the processors view. There continues to be a reasonable amount of inter-regional volume, mostly coming into the key CNI region.

3.3 Views on pruning viability

Large forest growers

In NRL discussions with the larger forest owners and also in reference to the Manley article, the main drivers away from pruned have been:

4. Economics, where the price differential between pruned and sawlog is not large enough to justify the lower total recoverable volume in a pruned regime and associated pruning costs
5. Valuation, the impact on forest valuation can be material
6. Labour shortages

However, for integrated growers/processors the pruned log is seen as critical to the supply chain. With a pruned regime leading to lower recoverable volume, there is less carbon sequestration. Carbon sequestration was not raised by larger forest owners as the majority of these owners are not able to enter the ETS, due to the land being pre-1990.

However there has been some renewed interest over the last 6 months from some larger owners, this appears to be based on the following:

1. Market risk diversification, with unpruned regimes' heavy outturn of smaller diameter knotty logs
2. Utilisation of existing labour, although the labour market is very tight, pruning is seen as an operation that can provide a more consistent work program
3. A higher stocking would be used than historically, which would in part alleviate the issues with the lower total recoverable volume from the pruned regime.

There still remains a steady proportion of larger owners who still prune. These estates are all smaller than the average size of the large owners.

As would be expected from the larger owners, there is a high degree of analysis in regime choice, with most using an IRR analysis for the comparison of regimes with current and forecast log prices used.

Small forest growers

In NRL discussions with the smaller forest owners and forest managers, there is more enthusiasm for pruning. The main drivers on the decision to prune or not are:

7. Improving profitability, this was the key driver
8. Long term view of appearance lumber gaining in value over knotty lumber
9. Cashflow constraints
10. For the sub 50ha owners much was done by internal labour but with an aging ownership, this is becoming more difficult.
11. Owners wanting to *"grow steak, not dags",* this is also linked to the visual appearance of the forest
12. If in the ETS, then limited or likely no pruning would be undertaken.

While the lower carbon sequestration was raised by some smaller forest owners this did not appear to be a major driver in the decision to prune.

There was a number of comments on the knowledge and quality around pruning in small growers forests. The growers associated with FFA were knowledgeable and appear to grow a quality pruned log. The balance of smaller growers tend to be farmers, and the quality and timing of pruning operations was highly varied, leading to variable pruned log quality.

3.4 Summary

The large owners have a well described area and yields, leading to accurate prediction of harvest volumes of pruned logs. There appears to be 2 tiers of small owners, sub 50ha and 50ha to 1,000ha. It appears little is known about the sub 50ha silviculture and areas. The 50ha to 1,000ha would

generally be managed by a forest manager, with these areas being better described. Given the lack of forest information, the WAF pruned volumes for small owners does lead to a level of uncertainty.

4. Processors and radiata's competitive advantage

NRL has discussed the processing of pruned logs with integrated forest owners and stand-alone processors. The traditional clear lumber market has been the USA, there the lumber is used as a replacement for ponderosa pine for the mouldings and millwork sector. This sector continues (particularly clear boards) to be an important part of the clear lumber market for processors.

Starting in early-mid 2000s radiata pine lumber started to be used for wood modification, initially for trials and process development in Europe, followed by small regular shipments commencing around 2006, and larger volumes from 2010. The wood modification can be either thermal or acetylation processes.

Initially the European demand was restrictive on sizes, but more recently the market has opened up and now a whole mill cut-pattern can be directed to this market, which is hoped to improve returns. The Australasian and Asian markets are still steady and viable markets, particularly for the differing lengths and sizes.

The key factors in radiata's demand for wood modification:

1. The ability to take treatment much better than other lumber alternatives
2. Given radiata's lower density when compared to other competing species, this leads to less chemical usage as well as better reaction to thermal and pressure processes
3. Given radiata is nearly all sapwood there is less contrast in the between early and late wood, giving a more consistent uptake of chemical.

The usage of modified radiata to replace the traditional tropical hardwoods applications is now common practise.

A critical advantage of NZ radiata is the ability to produce wide clear lumber, with the widths of 8, 10 and 12 inch being critical to a sales mix. Other species and countries are unable to provide these widths.

The major processors agree there will be consolidation of the pruned log processing in the CNI, the extent of this is uncertain, and processors commented that if the pruned log supply reduced, they would have to process other grades. This would come at a considerable cost and uncertainty with the differing markets.

5. Economics of pruned versus unpruned regimes

NRL expectations are that forest owners perform silvicultural analysis at regular intervals. This may involve investigating initial stocking or final crop stocking and variations of intensity of pruning. NRL has compared the option of a pruned regime to unpruned using the common method of financial comparison-Internal Rate of Return (IRR).

NRL has assumed a thinning to 350 sph of the pruned and 500 sph for the unpruned regime. These stockings come from the Manley study.

Detailed cashflows are shown in Appendix A.

5.1 Key inputs

NRL has attempted to reflect a NZ-wide analysis on the comparison of regimes. It is likely that different IRR's will result, with differences of factors like mill/port location lead distance. In cases where the data is available, an area weighted NZ average is used.

Silvicultural and annual costs

The forestry and annual costs for the two different regimes are shown Table 5-1. The pruned regime assumes two lifts to 5.5m and a single waste thin down to 350 sph. The unpruned regime assumes a single waste thin to 500 sph. The costs are taken from NRL wider work with the pruning costs checking against current costs. There is a wide variance in pruning costs seen across NZ. Many factors influence pruning costs, most notably hindrance, operator skill levels and distance to the forest.

Table 5-1 Silvicultural and annual costs

Operation	Age	% of area	Cost/treated ha	Pruned (cost/ha)	Unpruned (cost/ha)
Land Prep-Aerial	0	100%	275	275	275
Land Prep-Mechanical	0	50%	500	250	250
Planting (833 sph)	0	100%	1,150	1,150	1,150
Release-aerial	0	100%	350	350	350
Blank	0	5%	1,150	58	58
Dothisitroma	3,5,7,9	50%	50	25	25
Prune 1st lift	6	100%	1,470	1,470	
Prune 2nd lift	8	100%	1,225	1,225	
Waste thin pruned	9	100%	950	950	
Waste thin unpruned	9	100%	900		900
Annual costs	All ages	100%	125	125	125
Land rental	All ages	100%	168	168	168

Base yields

The base yields are shown in Table 5-2. The NZ average of the site index (29.9) and 300i (26.6) are used, with the yields are estimated from the Radiata Pine Calculator Version 4.0.

It is assumed that the pruned, S30 and pulp are sold domestically with the balance of the grades sold to export markets. This gives a domestic sales ratio of 41% or 50% depending on the regime.

Table 5-2 Base yields comparison (age 28 years)

Product	Pruned (m3/ha)	Pruned (% of TRV)	Unpruned (m3/ha)	Unpruned (% of TRV)
Pruned	146	22%	0	0%
S30	102	15%	227	30%
A	184	28%	194	25%
K	114	17%	199	26%
KI	14	2%	10	1%
KIS	21	3%	48	6%
Pulp	81	12%	85	11%
Total	**662**	**100%**	**764**	**100%**

As can be expected, the unpruned regime has a higher recoverable volume (by 15%) but the grade outturn of smaller diameter log grades is higher (by 28%).

High yields

A higher site productivity regime comparison is also considered (Table 5-3). This uses the NZ average for farm site with a site index (30.0) and 300i (29).

It is assumed that the pruned, S30 and pulp are sold domestically with the balance of the grades sold to export markets. This gives a domestic sales ratio of 39% or 50% depending on the regime.

Table 5-3 High yields comparison (age 28 years)

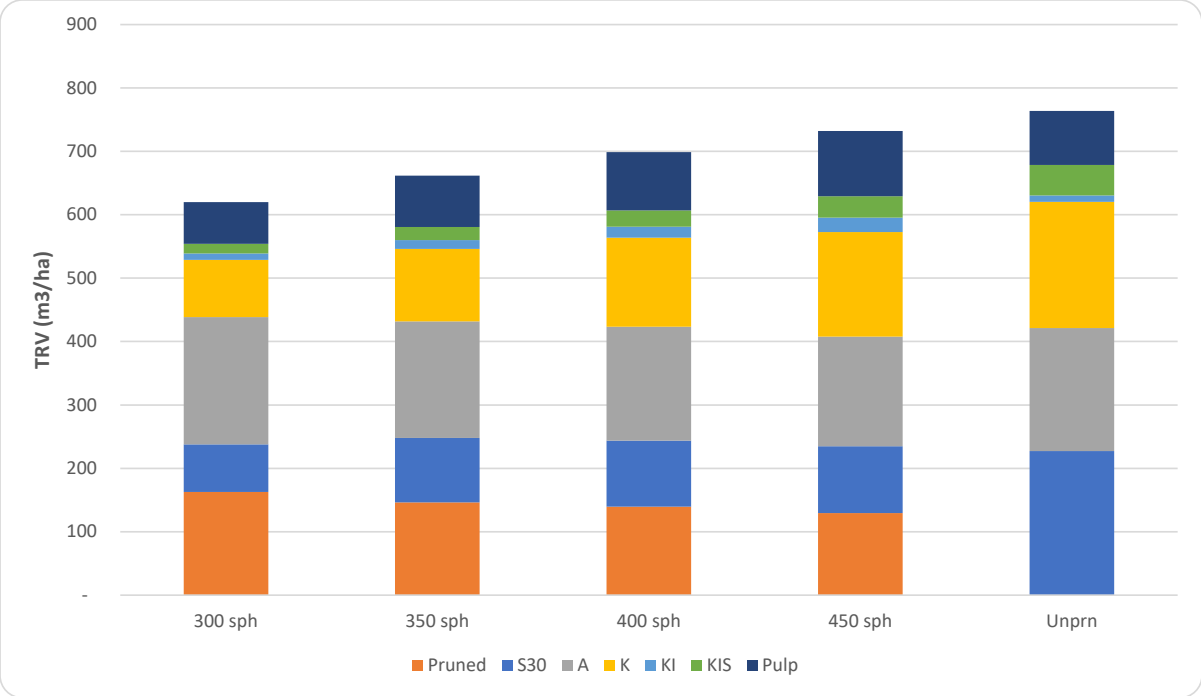
Product	Pruned (m3/ha)	Pruned (% of TRV)	Unpruned (m3/ha)	Unpruned (% of TRV)
Pruned	180	25%	0	0%
S30	99	14%	246	30%
A	227	31%	251	30%
K	108	15%	195	23%
KI	12	2%	13	2%
KIS	17	2%	49	6%
Pulp	78	11%	78	9%
Total	**720**	**100%**	**832**	**100%**

As can be expected the unpruned regime has a higher recoverable volume (by 16%) but the grade outturn of smaller diameter log grades is higher (by 35%).

Higher pruned stocking

Utilising the same settings as the base yields, the pruned stockings were altered from 300 sph up to 450 sph. The resulting yields are shown Figure 5-1. As can be expected the yields rise as the stocking increases, almost reached the unpruned yields. The pruned and larger diameter (S30 and A) sawlogs reduce as a proportion of the total volume as the stocking increases.

Figure 5-1 **Pruned stocking yield comparison (age 28yr)**



Third lift pruning

A third pruning lift is also considered. The base case assumes only two lifts and a third lift is incorporated with options to prune to 8.5m or 10m. While there is an increase in pruned log volume from the additional lift there has been a trend away from three lift pruning due to the smaller pruned length generally achieved on this lift and the predominant market demand for pruned logs of 5.0m length to suit the US 16-foot lumber market.

NRL has assumed that this will not be a manual task and this will be done mechanically. NRL views one of the potential issues with mechanical pruning is the time taken to position the machine prior to pruning. With the 3rd lift being done mechanically there is the opportunity to configure the operation to waste thin as well. As the mechanical pruning operations are in very much the protype phase, costs are yet to be understood, especially with the incorporation of an ability to thin at the same time.

NRL has assumed a daily cost of $1,344 and a 350-400 stems pruned per day in addition to the waste thinning. This gives a per hectare cost of $1876 to $2,044 dependant on pruned lift length.

Using the same settings as the base case and incorporating the additional lift, the yields (Table 5-4) show less total volume but higher pruned volumes. An additional pruned grade (P30) is included in the below yields as the higher pruned length well generate a reasonable proportion of smaller pruned logs (<35cm) from the 2nd log.

The two pruned heights are selected to give options on the second pruned log length. The 10m lift gives options of two 5m pruned logs which is the preferred length in the US market. The 8.5m option could be a mix of 6.1m and 2.4m or 4.9m and 3.7m lengths which would suit the Asia and European markets.

Table 5-4 High pruned heights comparison (age 28 years)

Product	Pruned to 8m (m3/ha)	Pruned (% of TRV)	Pruned to 10m (m3/ha)	Pruned (% of TRV)
Pruned	193	30%	169	29%
P30	31	5%	76	13%
S30	90	14%	49	8%
A	93	15%	65	11%
K	122	19%	132	22%
KI	14	2%	14	2%
KIS	27	4%	24	4%
Pulp	62	10%	61	10%
Total	**632**	**100%**	**591**	**100%**

The yields show a reduction of 4% for a pruned height of 8.5m and 11% for 10m when compared to the base yields. The yields show a substantially higher pruned log proportion of total volume (35% and 41%) when compared with 22% in the base case yields.

Log prices

The prices were derived from NRL log price database for export logs and AgriHQ survey domestic prices. The NRL export log price has a high correlation (+/- 1%) to AgriHQ survey export prices. The prices (NZD/t or NZD/JAS) were converted to $/m^3 after applying a NZ weighted average conversion factors then were inflation adjusted using the NZ stats CPI index to result in a real log price.

The prices represent a real 4-year average (Table 5-5).

Table 5-5 Log prices (delivered NZD/m3).

Log grade	Market point	Log prices
P35	Domestic	200
P30	Domestic	163
S30	Domestic	144
A	Export	142
K	Export	126
KI	Export	118
KIS	Export	106
Pulp	Domestic	58

5.2 Stumpage

Base

NRL has used the latest FGR logging (HTH14-Draft) benchmark costs, with 66% assumed as hauler and 34% ground-based. This gives an average logging cost of \$36.08/m^3. A piece size gradient is also incorporated to reflect differing logging productivity. Cartage leads are assumed to be 110km (\$29.10/m^3) for the port and 80km (\$22.80/m^3) for the domestic grades. Roading construction is assumed to be mostly upgrade of existing infrastructure with a cost of \$3,000/ha. Other costs assumed are harvesting and marketing overheads, roading repairs and maintenance and other production costs. Stumpage estimates are shown in Table 5-6. These are shown at the optimum harvest ages of 27 years for unpruned and 29 years for pruned.

Table 5-6 Stumpage estimates at optimum harvest age, base

	Pruned @ 29yrs		Unpruned @ 27yrs	
	\$/ha	\$/m3	\$/ha	\$/m3
Log Price	98,807	142.05	92,307	126.55
Cartage	18,079	25.99	19,422	26.63
Harvest and load	24,911	35.81	26,254	35.99
Road construct	3,000	4.31	3,000	4.11
Other Production Costs	696	1.00	729	1.00
Road R&M	1,217	1.75	1,276	1.75
H&M costs	2,782	4.00	2,918	4.00
Total	**48,122**	**69.18**	**38,707**	**53.07**

High cost and productivity

For smaller forest owners the costs tend to be higher due to the size of the volumes harvested. These blocks are generally more productive. NRL has increased the logging and cartage costs by 20% and the roading by 120%, from base estimates. The resulting stumpage estimates are shown in Table 5-7

Table 5-7 Stumpage estimates at optimum harvest age, high cost and productivity

	Pruned @ 29yrs		Unpruned @ 27yrs	
	$/ha	$/m3	$/ha	$/m3
Log Price	108,971	144.26	101,989	128.07
Cartage	27,168	35.97	30,690	38.54
Harvest & load	38,957	51.57	41,275	51.83
Road construct	6,600	8.74	6,600	8.29
Other Production Costs	755	1.00	796	1.00
Road R&M	1,322	1.75	1,394	1.75
H&M costs	3,022	4.00	3,185	4.00
Total	**31,147**	**41.23**	**18,049**	**22.66**

5.3 IRR results

Base case

The resulting IRR by the two regimes are shown in Table 5-8. The unpruned regime shows a higher IRR range difference from 0.6% to 1.0%, dependant on the rotation age. This is the result of higher log volumes (higher stocking) and lower silviculture costs, which are not offset by the higher average log prices for the pruned regime.

Table 5-8 Base comparison of regime IRR (%)

	Rotation age			
Regime	**25**	**27**	**29**	**31**
Pruned	5.4%	5.6%	5.7%	5.7%
Unpruned	6.4%	6.5%	6.5%	6.4%

The higher IRR for the framing regime is not an unexpected result and shows why the larger forests have reduced pruning levels.

High site productivity and production cost forests

The resulting IRR by the two regimes are shown in Table 5-9, the high cost and productivity site. The unpruned regime shows a lower IRR range difference from 0.3% to 1.0%, dependant on the rotation age. This shows on this type of site pruning compares favourably.

Table 5-9 High cost and productivity comparison of regime IRR (%)

	Rotation age			
Regime	**25**	**27**	**29**	**31**
Pruned	2.7%	3.3%	3.6%	3.8%
Unpruned	1.7%	2.5%	3.0%	3.5%

5.4 Sensitivity analysis

Log price

Changes were made to the pruned log price assumptions with the resulting sensitivity analysis is provided in Table 5-10. At a pruned log price of NZD257/m^3, the IRR matches the unpruned regime at 6.5%.

Table 5-10 Sensitivity analysis pruned log price

Pruned log price ($/m3)	IRR (%)
200	5.7%
220	6.0%
240	6.3%
260	6.5%
280	6.8%
257	**6.5%**

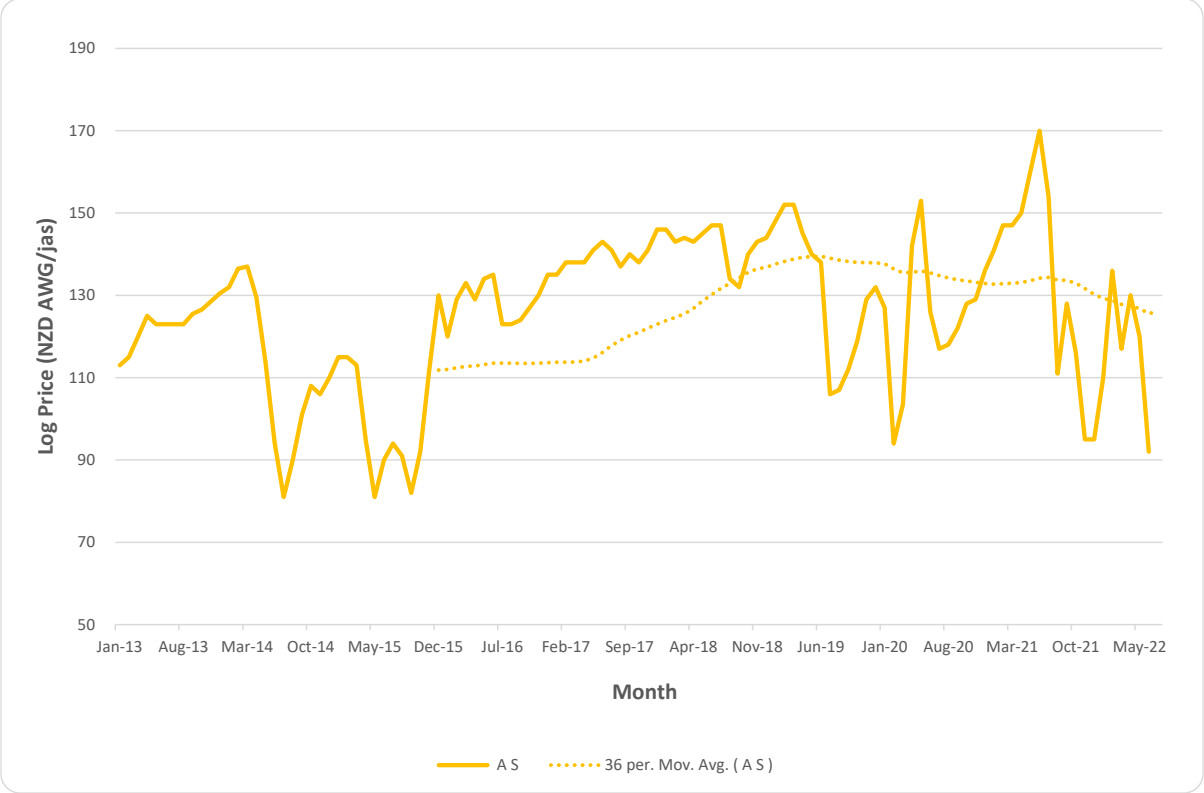
Changes (-10%) were made to the unpruned (S30, A, K, KI, KIS) log prices assumptions with the resulting sensitivity analysis provided in Table 5-11. The unpruned regime still shows a higher IRR range difference from 0.1% to 0.3%, however the IRR difference has reduced by 65-78% when compared to the base case.

Table 5-11 Sensitivity analysis unpruned log price IRR (%)

	Rotation age			
Regime	**25**	**27**	**29**	**31**
Pruned	4.6%	4.9%	5.0%	5.1%
Unpruned	4.9%	5.2%	5.3%	5.3%

The A Grade short price is seen as an industry key benchmark grade. The price for the last nine years ex Tauranga is shown in Figure 5-2. The price series is monthly and shows a high level of volatility. A 36-month rolling trend line shows since the peak of late 2018 early 2019 of 140 NZD/jas, the trend as declined to be currently under 130 NZD/jas.

Figure 5-2 **Tauranga A grade short log price (Nominal NZD/jas)**



In reflection of the declining log price trend NRL has tested the regimes over a shorter time frame (one year average) than the base analysis (4 year average). The resulting sensitivity analysis provided in Table 5-12. The unpruned regime still shows a higher IRR range difference from 0.3% to 0.5%, however this has reduced when compared to the base case.

Table 5-12 **Sensitivity analysis one year prices (IRR %)**

	Rotation age			
Regime	**25**	**27**	**29**	**31**
Pruned	4.2%	4.6%	4.7%	4.9%
Unpruned	4.7%	5.1%	5.2%	5.2%

Pruning costs

Changes were made to the pruning costs with the resulting sensitivity analysis provided in Table 5-13. If the pruning cost was reduced by 70% the IRR matches the unpruned regime (6.5%).

Table 5-13 Sensitivity analysis pruning costs (IRR %)

Pruning cost (%)	IRR (%)
10%	5.8%
20%	5.9%
30%	5.3%
40%	6.1%
50%	6.2%
70%	6.5%

Pruned crop stocking

Changes were made to the pruned crop stockings. The increasing stocking has an impact on pruned log quality so the results (Table 5-14) are shown for a range of stockings, the resulting Pruned Log Index's (PLI) and IRR's. The IRR's show a very flat trend with no real reduction in IRR seen with the increased stocking. The trend is more pronounced for the pruned log quality which shows a range of 6.5-7.6 PLI's (17%) and a logical reduction in pruned log quality as the stocking increases.

Table 5-14 Sensitivity analysis pruning stocking (IRR %)

Pruning stocking (SPH)	Pruned Log Index	IRR (%)
300	7.6	5.7%
350	7.2	5.7%
400	6.8	5.8%
450	6.5	5.7%
Unpruned	Unpruned	6.5%

As discussed earlier in this report radiata advantage is its ability to produce wide boards and there is a strong price premium for larger widths. While the PLI is a good indicator of pruned log quality it does not take into account the price differential for the wides so does need to be used with some caution.

Third lift pruning

The additional lift (3rd) was incorporated into the analysis the, IRR's are shown in Table 5-15.

The IRR's for the base case and the 8.5m pruned height are reasonably similar. With the increased volume of pruned logs compensating for the loss in total volume. The 10m pruned height shows a lower IRR (5.4% v's 5.7%) than the base case. In all cases the pruned regimes show lower IRR's than unpruned.

Table 5-15 Sensitivity analysis of pruned heights (IRR %)

	Rotation age			
Regime	**25**	**27**	**29**	**31**
Pruned to 5.5m (base case)	5.4%	5.6%	5.7%	5.7%
Pruned to 8.5m	5.4%	5.5%	5.7%	5.6%
Pruned to 10m	4.2%	5.0%	5.2%	5.4%
Unpruned	6.4%	6.5%	6.5%	6.4%

With the increased pruned height, the 2nd pruned log will clearly be smaller in diameter. The resulting PLI's by pruned height, are shown in Table 5-16.

Table 5-16 PLI comparison by pruned height (age 29)

Regime	PLI
Pruned to 5.5m (base case)	7.2
Pruned to 8.5m	7.0
Pruned to 10m	5.8

There is minimal difference in PLI's between the base case (pruned height 5.5m) and the pruned height of 8.5m. However, once the pruned height is raised to 10m the PLI drops to 5.8. At this pruned height 27% of the pruned volume would therefore be below PLI 5.0, which is generally considered the minimum marketable PLI.

Log price and pruning costs

NRL has tested a combination of reduced unpruned log prices and reduced pruning costs (Table 5-17). The green shaded area is where the pruned regime match's or exceeds the unpruned regime. For example, if a 30% reduction in pruning costs is achieved with a 10% reduction in unpruned log price, this gives a pruned regime IRR 5.3% which exceeds the unpruned regime of 5.2%.

Table 5-17 Matrix of unpruned log price and pruning costs (IRR %)

	Pruning costs					
	Unpruned	Pruned				
Unpruned log price	**0%**	**-10%**	**-20%**	**-30%**	**-40%**	**-50%**
0%	6.5%	5.8%	5.9%	6.0%	6.1%	6.2%
-5%	5.9%	5.5%	5.6%	5.7%	5.8%	5.9%
-10%	5.2%	5.1%	5.2%	5.3%	5.5%	5.6%
-15%	4.4%	4.7%	4.8%	5.0%	5.1%	5.2%
-20%	3.3%	4.3%	4.4%	4.5%	4.7%	4.8%

5.5 Limitations to this analysis

One of the key drivers in this analysis is log price assumptions. NRL's approach is to use historical pricing as NRL views forecast pricing as having too many variables (USD/NZD FX, shipping costs and lumber supply and demand in various markets) to reliably estimate forward log prices.

Historically the pruned stockings were <300 sph and have been gradually increasing. The Manley work indicated that large forest owners have increased the stocking from 320 sph (2010) to 344 sph (2020). The increased stocking indicates that care is needed when comparing historical returns from pruned stands.

The costs estimated for the 3rd lift are based on mechanisation of this final lift and the operation incorporating a waste thin. There are a number of different pruning mechanisation operations being investigated currently and the costs of these are yet to be understood. The ability to incorporate a waste thinning technology as well as pruning is also a variable that is not understood well.

6. Non-financial drivers

There was variety of views on the non-financial drivers in the decision to prune or to not. While some of the drivers were not shared, there was some general themes between large and small forest owners.

The smaller owners raised the following considerations on their decisions making:

1. The main driver for pruning is to add value. This was deemed critical in the very small (<40ha) owners, as it made harvesting more viable
2. Climate change was mentioned by a number of parties and the impact on holding higher stockings on stressed trees with the resulting tree health issues
3. The ability to graze under pruned regime was regarded as a positive, both in terms of a grazing but also mitigating fire risk
4. Cashflow constraints and the ability to prune by family/farm labour
5. Visual impacts, pruned stands were viewed more favourably

The largest concern expressed by a number of parties was the lack of market diversity.

5. Pruned logs have very different market options, with the balance of the harvest having a strong exposure to export log returns. In some regions having domestic pruned logs sales is critical to cashflow during export market downturns
6. The higher stocking seen in the unpruned regime clearly indicates a smaller tree with its associated small diameter logs. In NRL experience there are few major sites successfully processing of <30cm diameter sawlogs in NZ. The exceptions being Shands Road (Canterbury) and Sequal (CNI). Markets for this smaller diameter are likely export appearance grade for remanufacturing or more likely packaging, as NZ structural lumber demand is currently satisfied with existing larger diameter sawlogs.
7. Consistency of the pruned domestic market can be compared to the volatility of the export log trade and its flow on impact further back through the supply chain
8. A number of parties discussed market options into the future, bioplastic and engineered wood products were mentioned, but all agreed technology (bioplastic) would need to come a long way from its current situation.

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Gareth Buchanan

March 2023

Registered Forestry Consultant

Ngahere Resources Limited

Appendix A Detailed Cashflow

	Unit						Age 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
Aerial Dessication	$/ha	100%			-	275	-275																				0	0	0	0	0	0	0
Rip and Mound	$/ha	100%		50%	-	250	-250																				0	0	0	0	0	0	0
Planting Labour	$/ha	100%	833	0.75	-	625	-625																				0	0	0	0	0	0	0
Planting Stock	$/ha	100%	833	0.55	-	458	-458																				0	0	0	0	0	0	0
Planting other	$/ha	100%	833	0.08	-	67	-67																				0	0	0	0	0	0	0
Releasing	$/ha	100%			-	350	-350																				0	0	0	0	0	0	0
Dothi control	$/ha	100%			-	25			-25		-25			-25																			
Blanking	$/ha	100%			-	57		-57																			0	0	0	0	0	0	0
Regen Thin	$/ha	100%	3			-			0																		0	0	0	0	0	0	0
Prune1	$/ha	100%	6			-							0														0	0	0	0	0	0	0
Prune2	$/ha	100%	8			-									0												0	0	0	0	0	0	0
Prune3	$/ha	100%	9			-										0											0	0	0	0	0	0	0
Waste Thin	$/ha	100%	9		-	900										-900											0	0	0	0	0	0	0
Silvi Mgmt	% of Silvi	100%				15%	-304	-9	0	-4	0	-4	0	-4	0	-139	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Annual costs	$/ha	100%			-	125	-125	-125	-125	-125	-125	-125	-125	-125	-125	-125	-125	-125	-125	-125	-125	-125	-125	-125	-125	-125	-125	-125	-125	-125	-125	-125	-125
Land Rental	$/ha	100%				-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Land cost-PPA	$/ha	100%			-	168	-168	-168	-168	-168	-168	-168	-168	-168	-168	-168	-168	-168	-168	-168	-168	-168	-168	-168	-168	-168	-168	-168	-168	-168	-168	-168	-168
Land cost (imp+unprod)	$/ha	100%					0																										
Stumpage	$/ha							0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	38,707
Carbon costs	$/ha	0%					0										0					0				0					0		
Carbon revenue	$/ha	100%																															
Cashflow	$/ha						-2,621	-359	-293	-322	-293	-322	-293	-322	-293	-1,357	-293	-293	-293	-293	-293	-293	-293	-293	-293	-293	-293	-293	-293	-293	-293	-293	38,414
Stumpage	$/m3						0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	53
Cashflow	$						-262,122	-35,910	-29,300	-32,175	-29,300	-32,175	-29,300	-32,175	-29,300	-135,675	-29,300	-29,300	-29,300	-29,300	-29,300	-29,300	-29,300	-29,300	-29,300	-29,300	-29,300	-29,300	-29,300	-29,300	-29,300	-29,300	3,841,407
Cashflow-cumlative	$						-262,122	-298,032	-327,332	-359,507	-388,807	-420,982	-450,282	-482,457	-511,757	-647,432	-676,732	-706,032	-735,332	-764,632	-793,932	-823,232	-852,532	-881,832	-911,132	-940,432	-969,732	-999,032	########	-1,057,632	########	-1,116,232	-1,145,532	2,695,876

Harvest Age	27	Set to 0 for no harvest	Rotation	1	
Log price factor	100%				
Area-PPA	100.00				
Gross area	105.00				

			Input	$/ha equivalent	$/m3	Total $
Log Price	$/ha	100%	$ 92,307	92,307	$ 126.55	9,230,745
Cartage	$/ha	100%	$ 19,422	19,422	$ 26.63	1,942,242
Harvest & load	$/ha	100%	$ 26,254	26,254	$ 35.99	2,625,439
Road construct	$/ha	100%	$ 3,000	3,000	$ 4.11	300,000
Other Production Costs	$/m3	100%	$ 1.00	729	$ 1.00	72,942
Road R&M	$/m3	100%	$ 1.75	1,276	$ 1.75	127,648
H&M costs	$/m3	100%	$ 4.00	2,918	$ 4.00	291,768
				$ 38,707	$ 53.07	3,870,707

Look	Grade	M3/ha	%	$/m3
2	Pruned	-	0%	$ 200.0
3	S30	206	28%	$ 144.0
4	A	190	26%	$ 142.4
5	K	198	27%	$ 126.3
6	KI	10	1%	$ 118.3
7	KIS	46	6%	$ 106.3
8	Pulp	81	11%	$ 58.0
9	Spare	-	0%	$ -
10	Spare	-	0%	$ -
11	Spare	-	0%	$ -
12	Spare	-	0%	$ -
13	Spare	-	0%	$ -
14	Spare	-	0%	$ -
15	Spare	-	0%	$ -
16	Spare	-	0%	$ -
17	TRV	729	100%	$ 126.5

Carbon price senerio	2		
Carbon profile	MPI Look up		
Max Carbon	0	Use 0 for no carbon	

	$NPV/ha 6%	$/ha	Total $
Carbon	0	-	-
Timber	778		

TRV	m3/ha	729
Total TRV	m3	72,942
Stumpage	$/m3	$ 53.07
IRR	%	6.52%

Carbon Profiles

	Unit						0	1	2	3	4	5	6	7	8	9	10	Age 11	12	13	14
Aerial Dessication	$/ha	100%			-	275	-275														
Rip and Mound	$/ha	100%		50%	-	250	-250														
Planting Labour	$/ha	100%	833	0.75	-	625	-625														
Planting Stock	$/ha	100%	833	0.55	-	458	-458														
Planting other	$/ha	100%	833	0.08	-	67	-67														
Releasing	$/ha	100%			-	350	-350														
Dothi control	$/ha	100%			-	25				-25		-25		-25		-25					
Blanking	$/ha	100%			-	57		-57													
Regen Thin	$/ha	100%	3			-			0												
Prune1	$/ha	100%	6		-	1,470							-1,470								
Prune2	$/ha	100%	8		-	1,225									-1,225						
Prune3	$/ha	100%	9			-										0					
Waste Thin	$/ha	100%	9		-	950										-950					
Silvi Mgmt	% of Silvi	100%				15%	-304	-9	0	-4	0	-4	-221	-4	-184	-146	0	0	0	0	0
Annual costs	$/ha	100%			-	125	-125	-125	-125	-125	-125	-125	-125	-125	-125	-125	-125	-125	-125	-125	-125
Land Rental	$/ha	100%				-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Land cost-PPA	$/ha	100%			-	168	-168	-168	-168	-168	-168	-168	-168	-168	-168	-168	-168	-168	-168	-168	-168
Land cost (imp+unprod)	$/ha	100%					0														
Stumpage	$/ha							0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carbon costs	$/ha	0%					0										0				
Carbon revenue	$/ha	100%																			
Cashflow	$/ha						-2,621	-359	-293	-322	-293	-322	-1,984	-322	-1,702	-1,414	-293	-293	-293	-293	-293
Stumpage	$/m3						0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cashflow	$						-262,122	-35,910	-29,300	-32,175	-29,300	-32,175	-198,350	-32,175	-170,175	-141,425	-29,300	-29,300	-29,300	-29,300	-29,300
Cashflow-cumlative	$						-262,122	-298,032	-327,332	-359,507	-388,807	-420,982	-619,332	-651,507	-821,682	-963,107	-992,407	-1,021,707	-1,051,007	-1,080,307	########

	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
Aerial Dessication							0	0	0	0	0	0	0	0	0
Rip and Mound							0	0	0	0	0	0	0	0	0
Planting Labour							0	0	0	0	0	0	0	0	0
Planting Stock							0	0	0	0	0	0	0	0	0
Planting other							0	0	0	0	0	0	0	0	0
Releasing							0	0	0	0	0	0	0	0	0
Dothi control															
Blanking							0	0	0	0	0	0	0	0	0
Regen Thin							0	0	0	0	0	0	0	0	0
Prune1							0	0	0	0	0	0	0	0	0
Prune2							0	0	0	0	0	0	0	0	0
Prune3							0	0	0	0	0	0	0	0	0
Waste Thin							0	0	0	0	0	0	0	0	0
Silvi Mgmt	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Annual costs	-125	-125	-125	-125	-125	-125	-125	-125	-125	-125	-125	-125	-125	-125	-125
Land Rental	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Land cost-PPA	-168	-168	-168	-168	-168	-168	-168	-168	-168	-168	-168	-168	-168	-168	-168
Land cost (imp+unprod)															
Stumpage	0	0	0	0	0	0	0	0	0	0	0	0	0	0	48,122
Carbon costs	0					0					0				
Carbon revenue															
Cashflow	-293	-293	-293	-293	-293	-293	-293	-293	-293	-293	-293	-293	-293	-293	47,829
Stumpage	0	0	0	0	0	0	0	0	0	0	0	0	0	0	69
Cashflow	-29,300	-29,300	-29,300	-29,300	-29,300	-29,300	-29,300	-29,300	-29,300	-29,300	-29,300	-29,300	-29,300	-29,300	4,782,860
Cashflow-cumlative	########	########	########	########	########	########	########	########	########	########	########	-1,461,207	########	-1,519,807	3,263,053

Harvest Age	29	Set to 0 for no harvest	Rotation	1
Log price factor	100%			
Area-PPA	100.00			
Gross area	105.00			

			Input	$/ha equivalent	$/m3	Total $
Log Price	$/ha	100%	$ 98,807	98,807	$ 142.05	9,880,691
Cartage	$/ha	100%	$ 18,079	18,079	$ 25.99	1,807,931
Harvest & load	$/ha	100%	$ 24,911	24,911	$ 35.81	2,491,097
Road construct	$/ha	100%	$ 3,000	3,000	$ 4.31	300,000
Other Production Costs	$/m3	100%	$ 1.00	696	$ 1.00	69,556
Road R&M	$/m3	100%	$ 1.75	1,217	$ 1.75	121,723
H&M costs	$/m3	100%	$ 4.00	2,782	$ 4.00	278,224
				$ 48,122	$ 69.18	4,812,160

Look	Grade	M3/ha	%	$/m3
2	Pruned	154	22%	$ 200.0
3	S30	112	16%	$ 144.0
4	A	195	28%	$ 143.1
5	K	121	17%	$ 126.9
6	KI	15	2%	$ 118.9
7	KIS	22	3%	$ 106.8
8	Pulp	76	11%	$ 58.0
9	Spare	-	0%	$ -
10	Spare	-	0%	$ -
11	Spare	-	0%	$ -
12	Spare	-	0%	$ -
13	Spare	-	0%	$ -
14	Spare	-	0%	$ -
15	Spare	-	0%	$ -
16	Spare	-	0%	$ -
17	TRV	696	100%	$ 142.1

Carbon price senerio	2	
Carbon profile	MPI Look up	
Max Carbon	0	Use 0 for no carbon

	$NPV/ha 6%	$/ha	Total $
Carbon	0	-	-
Timber	-589		

TRV	m3/ha	696
Total TRV	m3	69,556
Stumpage	$/m3	$ 69.18
IRR	%	5.7%

Carbon Profiles