Current Practices and Challenges in NZ Thinning Operations: results of a Survey and Workshop in 2023

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EXECUTIVE SUMMARY

The problem

The rationale to increasing mechanised, automated, and robotised thinning operations in the New Zealand (NZ) forest industry is to generate improvements in health and safety, and to address labour gaps (Baker, 2018). Slope and terrain are seen as limiting factors for mechanisation. Nonetheless, there are more than 500,000 ha of planted forests with a slope of less than 15 degrees currently being manually thinned that can arguably be mechanically thinned. This indicates that there are some key questions to answer behind the drivers and opportunities to mechanise thinning in the NZ forestry environment and operating context.

Initiatives

The Precision Silviculture programme (PSP) is a seven-year programme led by Forest Growers Research Limited (FGR). The programme is focused on developing mechanisation, automation, digital technology, and robotics in the silviculture value chain. The aim is to make work in silviculture safer, more productive, and more attractive to workers, and these advancements will also lead to efficiencies that could enable higher value products to be created. For example, in the case of thinning operations, if the recovery of thinning waste was financially viable to the point of opening opportunities for new manufacturing chains, this could ultimately add value to the forest growing business.

This project

One of the workstreams in the PSP is thinning. Under the research of forest system design in the thinning workstream, there was a project with four milestones in 2023:

- Milestone 1 – Industry survey on thinning methods and practices in NZ.
- Milestone 2 – Industry workshop on thinning with focus on tree selection, forest design, and priorities for PSP investment.
- Milestone 3 – Report combining workshop summary and survey results.
- Milestone 4 – Completion of revised workplan and roadmap for PSP forest system design and preselection for pruning and thinning.

This document is the milestone 3 report that captures a summary of the industry survey and workshop results.

Key results

17 practitioners (managers of thinning operations) and 4 associates (e.g., trainers and researchers) took part in the survey, and 20 practitioners and associates combined, participated in the workshop.

With an overarching lens, the results highlight a wide range of views about thinning research, for example, on “Steep terrain – use advanced genetics, plant and leave, with aerial / chemical thin option” through to “Tethering in Nelson will open more area available for thinning (>30 degrees represent >25% of the estate)”. It is worth noting that there are new approaches in thinning already being tried and tested by forest companies, for example chemical thinning, proximity sensors, and new forest designs.

Also, new perspectives emerged, i.e.:

- regen can be a costly problem for manual thinning,
- a reinforced view that the viability of precision chemical thin operations was of high interest to industry,
- the new idea of thinning based on wood properties,
- that tools for operators should be a priority, arguably more so than tools for forest managers. An example provided was to scope a digital forestry setup in the unit of a cab. Having a virtual training tool for thinning selection was identified as a potential quick win.

Implications of results

A key opportunity for the PSP thinning work is to operate where industry activities are already underway (i.e., chemical thinning, proximity sensors, and new forest designs) to enhance these, and to facilitate the learnings that could be shared to the wider industry.

There are wide ranging often conflicting views about thinning research and development priorities, ranging from: moving away from thinning regimes, to enabling machines to operate on steep slopes (yet machines aren't currently prevalent on easier terrain), to focusing on manual thinning improvements and techniques for controlling high densities of natural regeneration. This indicates a need for thinning research to support forest managers with a need for modelling and cost benefit analysis to refine forest system design. However, if the PSP objective is about 'machines' then tools for operators is critical. Taking a strategic long-term view beyond the programme, and how the PSP supports this, could be a worthwhile approach.

Further work

The survey and workshop information in this report were used to inform a revised workplan and roadmap for the thinning activities in the PSP that was presented to the TST in June 2023. Following a prioritisation activity a workplan for a project in forest system design was prepared that proposed to:

- gather knowledge of the global developments in forest design developments,
- scope software for forest planning,
- implement and evaluate new forest design trials,
- facilitate a Think Tank around forest system design.

Aspects of this project are in discussion on what to contract in these activities.

A project on virtual reality for thinning training was also scoped up and this research has been contracted (to Scion). This is running alongside the real time thinning work that is being led by Interpine.

INTRODUCTION

In New Zealand (NZ) partial mechanised felling (extraction and loading) and full mechanised felling (cutting, extraction and loading) has occurred in production thinning since at least the 1960s, and in the late 1990s to early 2000s. However, the area of production thinned forest has declined over the past decade with an 18% reduction in area between 2012 to 2022. The trend is towards minimal tending (e.g., “plant and leave”), with the predominant thinning operation being a waste thin that still largely relies on the manual use of chainsaws.

The rationale to increasing mechanised, automated, and robotised thinning operations in the NZ forest industry is for improvements in health and safety, and to address labour gaps (Baker, 2018). Some key questions behind these drivers to mechanise thinning are how to do this within the NZ environment and operating context, and to know what the opportunity cost is.

Slope and terrain are seen as limiting factors for mechanisation, and the thinning workstream in the FGR Precision Silviculture Programme (PSP) is exploring tethering trials and machine designs to address this. Notwithstanding, indicatively there are more than 500,000 ha of planted forests with a slope of less than 15 degrees that arguably could be mechanically thinned (Figure 1). To better understand this situation, it was decided that ancillary information on the current state of NZ thinning operations was needed.

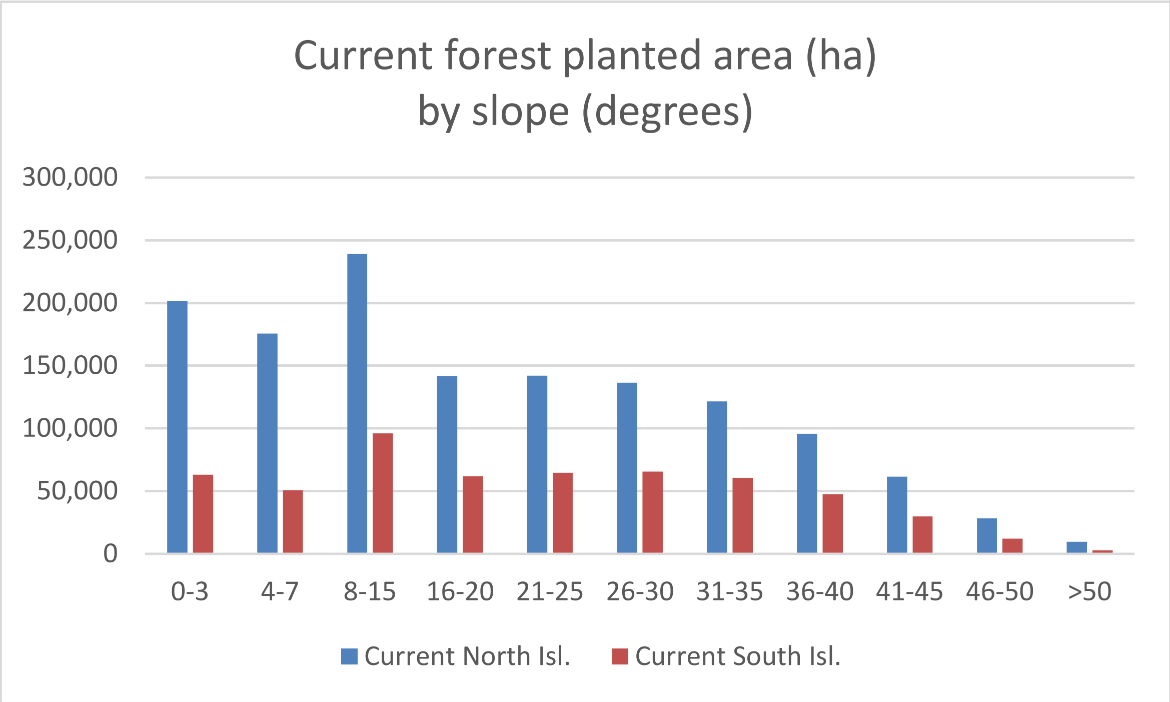


Figure 1, GIS estimate of the current forest planted area by slope classes in NZ (derived in 2023 by D. Palmer, Scion).

This report presents the results of the forest industry survey on thinning. The results of the survey were shared and discussed with industry at a workshop, with the workshop discussion helping to inform a revised high-level workplan for thinning activities in the PSP. The high-level workplan is also presented in the appendix of this report.

METHODS

An online survey with 42 questions focused on thinning was developed in SurveyMonkey[1] for the NZ forest industry (see Appendix A). The survey data was extracted and analysed at an aggregated and anonymous level, with results graphed and key comments extracted. The analysis was presented and discussed with industry people in a workshop, and the discussion was used to inform the development of a high level workplan for the PSP thinning workstream.

The Survey

Details of the survey questions deconstructed for analysis are shown in Table 2. The Level 1 description has the question number and either something general about the question, or a description that forms the question or part thereof. The level 2 description forms part of the question and / or shows the options provided to the respondent for closed questions. The response column shows the type of question, i.e., open or closed (with options). If the response has both options and open responses, then the options have 'other' as an option, allowing an open response.

Analysis of responses answered as either 'major', 'moderate' or 'minor' - used a weighted average approach where major responses were given twice the value of moderate, which in turn was given twice the value of minor responses.

Table 2: Deconstructed view of the Thinning Survey questions

Level 1 description	Level 2 description	Response
0- the survey	I agree to participate in this survey	y/n
1- tell us about yourself	Name, company, role position	Open
2- your main role in the decision regarding thinning	Forest owner operator, manage the forest operations of the owner, other (specify)	Options, Open
3- regions of your current thinning operations	CNI, Northland, East Coast, Nelson Marlborough, Otago, Canterbury, SNI, Auckland, West Coast, Hawkes Bay, Other (specify)	Options, Open
4- scale of operations	Number of thinning crews operating	Open
5- do you currently undertake	Thinning to waste	Options
6- how much area (ha) do you thin to waste annually using	Mechanical, manual methods	Open
7- what is maximum slope thinned to waste	Mechanical - degrees, grade; manual – degrees, grade	Open
8- what do you consider most when making thin to waste decisions (major, moderate, minor)	Tree species characteristics, characteristics of genotype within species, operational costs, labour constraints, forest health (pathogen spread), windthrow risk, wildfire risk, erosion mitigation, carbon sequestration, site quality, aesthetics /amenity/recreation value, environmental outcomes post-thinning, wood or log quality of products from thinning, wood or log quality of products at end of rotation, volume of log produced at end of rotation, current log value, financial return over full rotation, stand productivity over full rotation, mid-rotation financial return, operational	Options, Open

[1] SurveyMonkey is an online survey tool.

	access (for both manual and mechanised), other (please specify)	
9- typical costs for thin to waste ($/ha or $/m3)	Mechanical – easy, difficult; manual – easy, difficult	Open
10- what factors impact most on cost of thinning (select main two)	Soil conditions, length of slope, hindrance, stand access, machine type and setup	Options
11- machine types and considerations for thin to waste (add to 100%)	Manual (saw, pruning shears etc), motor manual (chainsaw), small machinery (bulldozer, tractor etc), excavator with small harvester head	Options, Open
12- do you use any	Dedicated thinning machinery (specify)	Open
13- damage to residual trees observed from thin to waste	Mechanical - <1%, 1-5%, 6-10%, >10%; manual - <1%, 1-5%, 6-10%, >10%	Options
14- damage to soils / site observed from thin to waste	Mechanical - <1%, 1-5%, 6-10%, >10%; manual - <1%, 1-5%, 6-10%, >10%	Options
15- thin to waste	What other concerns/challenges do you have about mechanisation implementation?	Open
16- thin to waste	What other concerns/challenges do you have about manual implementation?	Open
17 to 28-	Repeat of 5 to 10, 12 to 16- for production thinning	Various
29- typical costs for production thin ($/ha or $/m3)	Mechanical - easy, difficult; manual – easy, difficult	Open
30- machine types and considerations for production thin (add to 100%)	Manual (saw, pruning shears etc) with non-motorised extraction, motor manual (chainsaw) with non-motorised extraction, motor manual (chainsaw) with machine skidding, motor manual (chainsaw) with machine forwarding, small machinery (bulldozer or tractor etc), excavator with small harvester head with machine skidding, excavator with small harvester head with machine forwarder	Open
31- list some of the main reasons you have decided to thin your resource	– limited to four reasons	Open
32- if there was a stronger biomass / bioenergy market	How would your thinning considerations change?	Open
33- if there was a stronger biomass / bioenergy market	At what biomass/bioenergy price point would you make changes to your choices (i.e., increase level of production thinning)?	Open
34- who selects the trees for thinning?	Operator at time of thinning, pre-marked by forester following cruise, forestry consultant modelling, other (please specify)?	Options, Open
35- selection of trees for thinning	How are trees selected for removal? e.g., row, geometric pattern spacing vs. individual tree characteristic	Open
36- what characteristics are used most in tree selection?	DBH, tree height, tree health, tree form (e.g., branching, sweep, taper etc), spacing between trees, site characteristics (very important, some-what important, not very important), other (please specify)?	Options, Open

37- selection of trees for thinning	What guidance/criteria/ training are the people selecting trees given?	Open
38- selection of trees for thinning	Do you thin to a final stocking, or thin to intermediate stocking?	Open
39- research needs	Have/do you use tethering systems to thin?	y/n
40- research needs	Would you be willing to assist in a trial of tethered thinning practices? Name.	Open
41- What other technologies do you currently use to assist thinning operations?	e.g., remote sensing; wood quality assessments; augmented reality; decision support tools	Open
42- what value do you see in the development of the following technologies, rank (1-5) in the order you would be willing to support these projects within the PSP	Proximity sensors to ensure manual thinners stay > 2 tree lengths away from each other, near real time monitoring of thinning to track tree density and spacing, virtual reality forests for training thinning crews to select trees, tool in cab of mechanised thinning machine to guide decision on tree selection based on what can be detected/seen from the cab and knowledge of what has already been thinned thus far, tool in cab of mechanised thinning machine to guide decision on tree selection based on knowledge of the entire forest and forest growth projections, with live updating as choices are made by operator	Option
43- either real or imagined	What other technologies would you be interested in?	Open

Workshop
The workshop was a combination of online and in person participation. Divided into two sessions, the first workshop session discussed the NZ forestry context and results from the thinning survey. This was followed by a dive into the opportunities and future of thinning in NZ. See Appendix B for the agenda for the workshop.

RESULTS

Responses from 17 practitioners (managers of thinning operations) and 4 associates (e.g., trainers and researchers) have informed the survey results. Based on area[2] a representative from 60 percent of NZ forestry companies responded. These responses identified being associated with 23,350 ha of annual thinning operations that involved 65 thinning crews. Regional coverage of the response is shown in Figure 3.

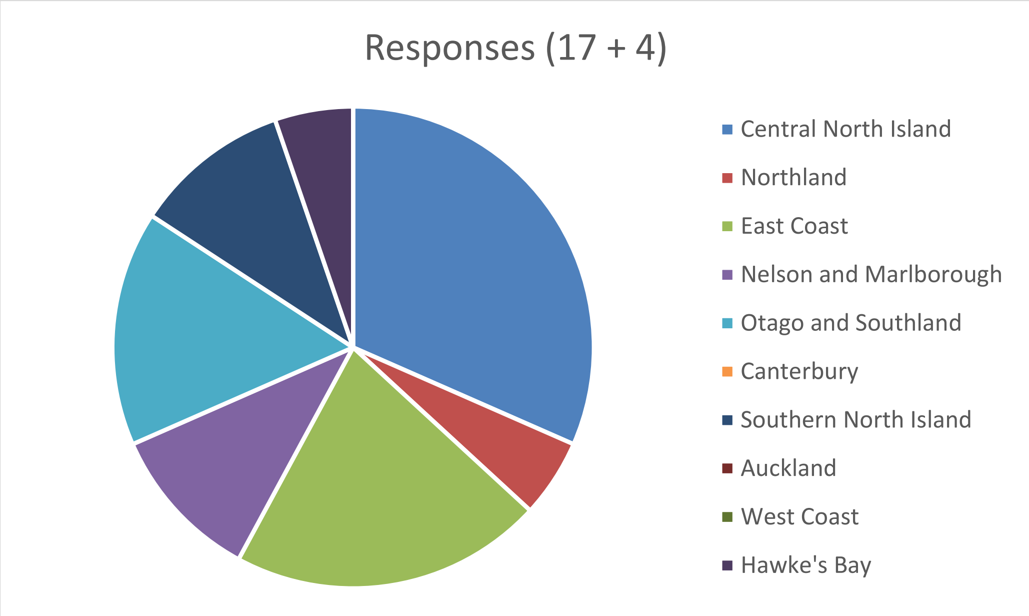


Figure 3: Survey responses by region, on a count percentage basis.

Thin to waste - key results to questions 5-16

Respondents indicated that 89 percent (20,850 ha) of their waste thin operations used manual methods. Manual operations are viewed as being less restrictive on steep slopes then mechanical methods. The costs of manual thin to waste are wide ranging ($450 /ha - $1200 /ha) on easy sites, while on difficult sites the costs of mechanical methods are wide ranging ($850 /ha - $2500 /ha). The overall cost of waste thin operations directly relates to productivity, transport costs and to hindrance. Thin to waste results are summarised in Figure 4.

By type

	Manual	Mechanical
Annual area thinned (ha)	20,850	2,500
Max. slope (degrees)	50+	30-35

Costs ($ per ha)

- **Manual**
  - **Productivity in steeper difficult sites reduces due to > transport costs & hindrance**

Site	Min.	Max.	Av.
Easy – Manual	450	1200	797
Easy – Mechanical	600	700	633
Difficult – Manual	1000	2000	1243
Difficult - Mechanical	850	2500	1483

Figure 4: Area, slope limitations and the costs of manual and mechanical types of waste thinning.

[2] FGT Facts and Figures 2021-22, p.12.

When asked about what specific factors impacted the cost of waste thinning**, hindrance** and **stand access** rated as the most prevalent (see Figure 5). The overarching criteria driving the decisions to waste thin are to optimise the **site carrying capacity**, i.e., stand productivity, log quality and volume, and economic return. Site access, environmental impact, thinning log products and their values are a second criterion, while thinning for value, health, wildfire risk, and aesthetics loosely group into a third criterion (see Figure 6).

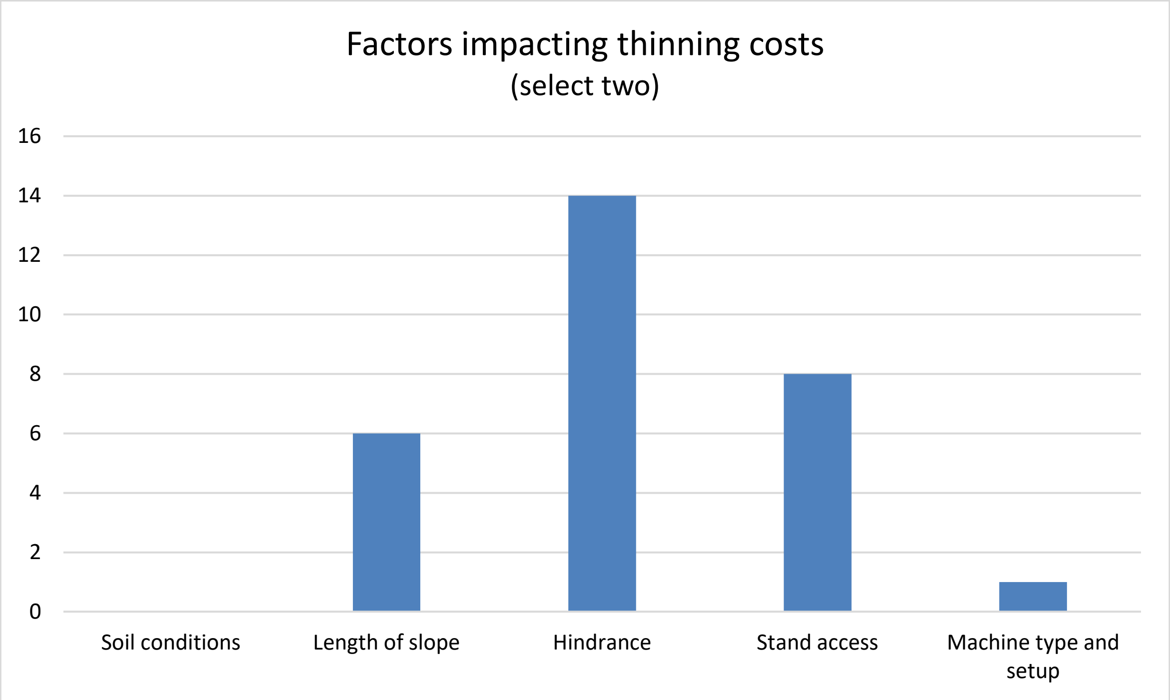


Figure 5: Respondents were asked to select two (of five) factors impacting the cost of thinning.

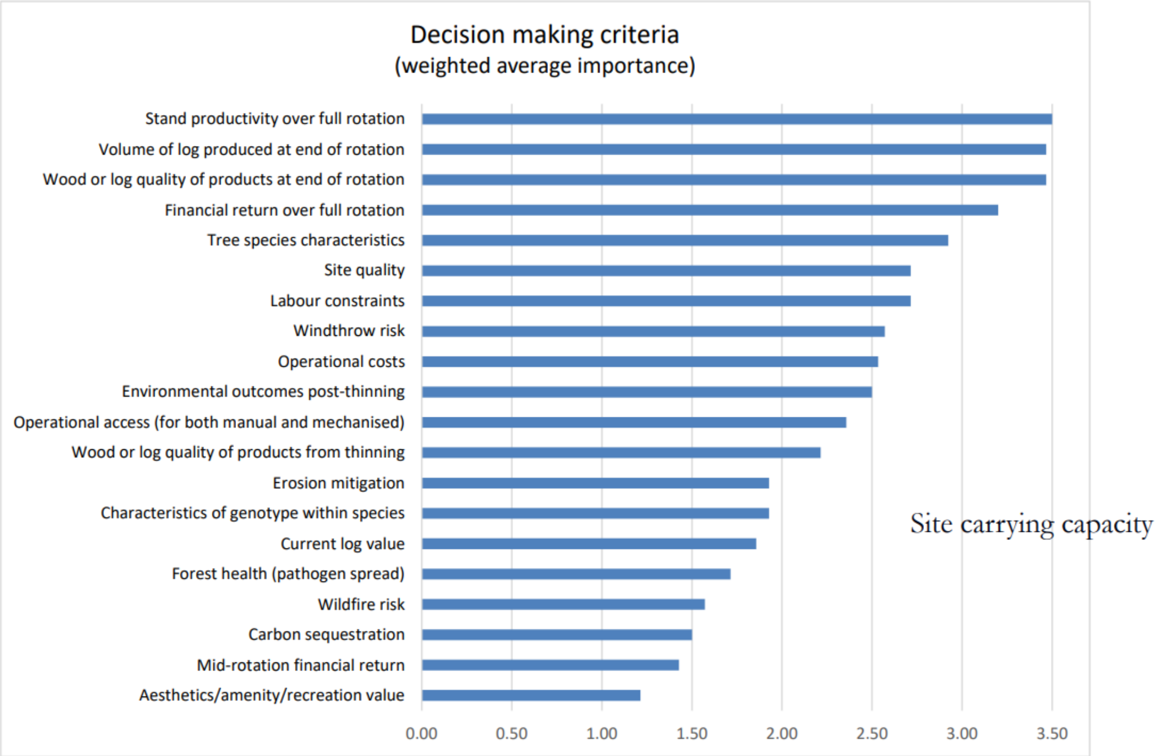
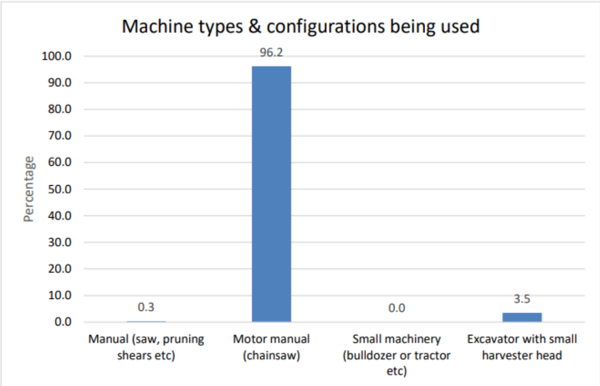


Figure 6: Weighted average ranking of criteria in thin to waste operations, that were identified by respondents as major, moderate, or minor.

Respondents were asked what percentage of machine types and configurations they had. **The average** of all the responses by type (manual to excavator) is shown in Figure 7. The chainsaw featured predominantly at 96.2 percent with just 3.5 percent of waste thin operations being mechanised. When asked about damage and other concerns, manual methods were perceived to be less damaging to residual trees, and to soils and to the site in general in comparison to mechanised methods. The main concerns associated with manual methods were health and safety, tree selection and stocking, and labour costs and availability. The main concerns for mechanical methods were site suitability, cost, and regen (see Figure 8).

Average of responses



Comments

- **Other dedicated machinery**
  - **14 tonne excavator**
  - **Small excavator base with shear heads**

Figure 7: Machine types and configurations being used in waste thin operations.

Damage

	Manual	Mechanical
Residual trees	<1% 1-5%	1-5%
Soils & site	<1%	1-5% 6-10%

Other concerns

- **Manual**
  - **H&S, tree selection & stocking, labour (cost, availability, experience, chemical v chainsaw risks)**
- **Mechanical**
  - **Suitability, low cost extraction, scale / enough work, damage to residual trees, removing too many trees, regen, cost of machinery, contour planting not allowing for access**

Figure 8: Damage and other concerns in waste thin operations.

Production thin - key results to questions 17-30

There were five respondents to production thinning questions in the survey. Results were based on an indicative combined area of production thinning of 3,465 ha annually, with all the production thin operations being mechanised (see Figure 9). Production thin costs ranged from $33/t to $60/t. This is a slightly narrower cost range than that of Taylor's (2021) NZ forest industry survey on production thinning, which ranged from $27/t to $64.40/t.

The use of mechanised methods in production and waste thin operations combined, was 5,965 ha per annum. Production thinning operations were seen to be more limited by slope than manual methods, and the cost per ha (assuming 100 ton / ha) is higher. Taylor (2021) concluded that for production thinning to be viable, logging rates need to be cost competitive relative to the value of the product extracted.

By type

	Manual	Mechanical
Annual area thinned (ha)	-	3,465
Max. slope (degrees)	-	25-30

Costs

- **5 responses, no manual production thinning**
- **Costs $/t**

Site	Min.	Max.	Av.
Easy – Manual	-	-	-
Easy – Mechanical	33	40	38
Difficult – Manual	-	-	-
Difficult - Mechanical	41	60	52

Figure 9: Area, slope limitations and the costs of mechanical types of production thinning.

When asked about what specific factors impacted the cost of production thinning**, soil conditions, stand access** and **machine type and setup** rated as the most prevalent (see Figure 10).

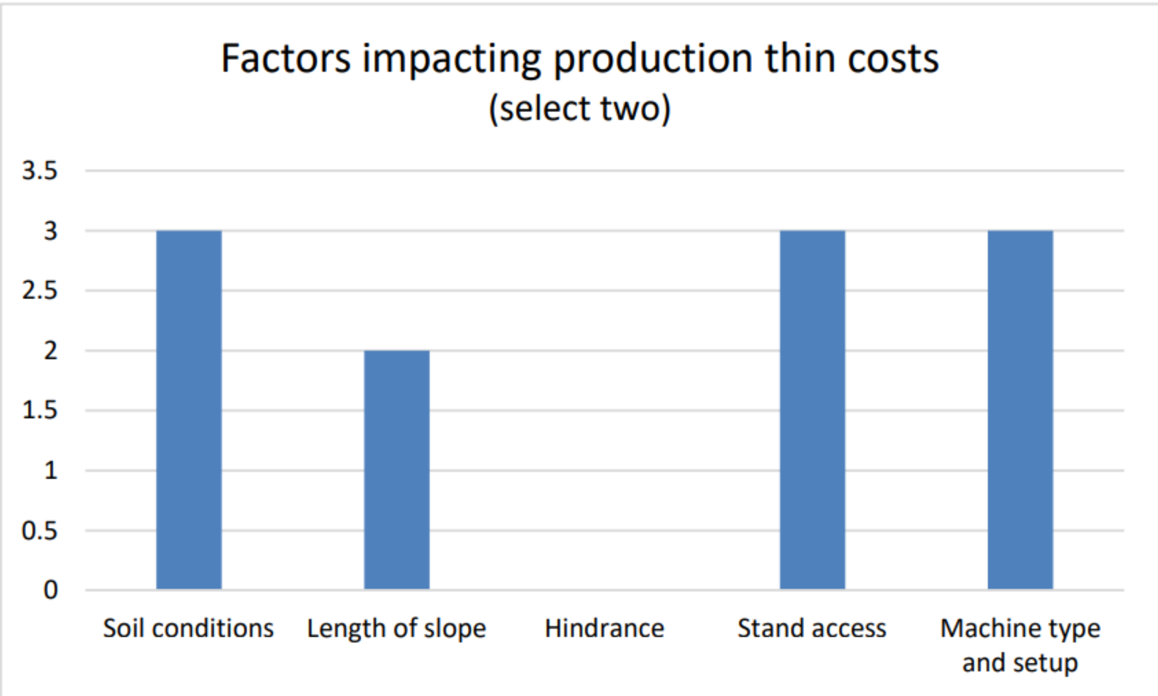


Figure 10: Respondents were asked to select two (of five) factors impacting the cost of thinning.

The overarching criteria driving the decisions to production thin are similar to waste thinning in the first instance, being to optimise the **site carrying capacity**, i.e., stand productivity, log quality and volume, and economic return. The second criteria involves operational cost, current log value, windthrow risk and site quality, and the third criteria involves operational access, economic return mid-rotation, labour, tree characteristics and environmental outcomes post-thinning. Then there is a fourth criteria which is whether thinning is for a reason other than site carrying capacity, such as for genotype characteristics, carbon, erosion mitigation, wildfire risk, forest health and aesthetics. These criteria are shown in Figure 11.

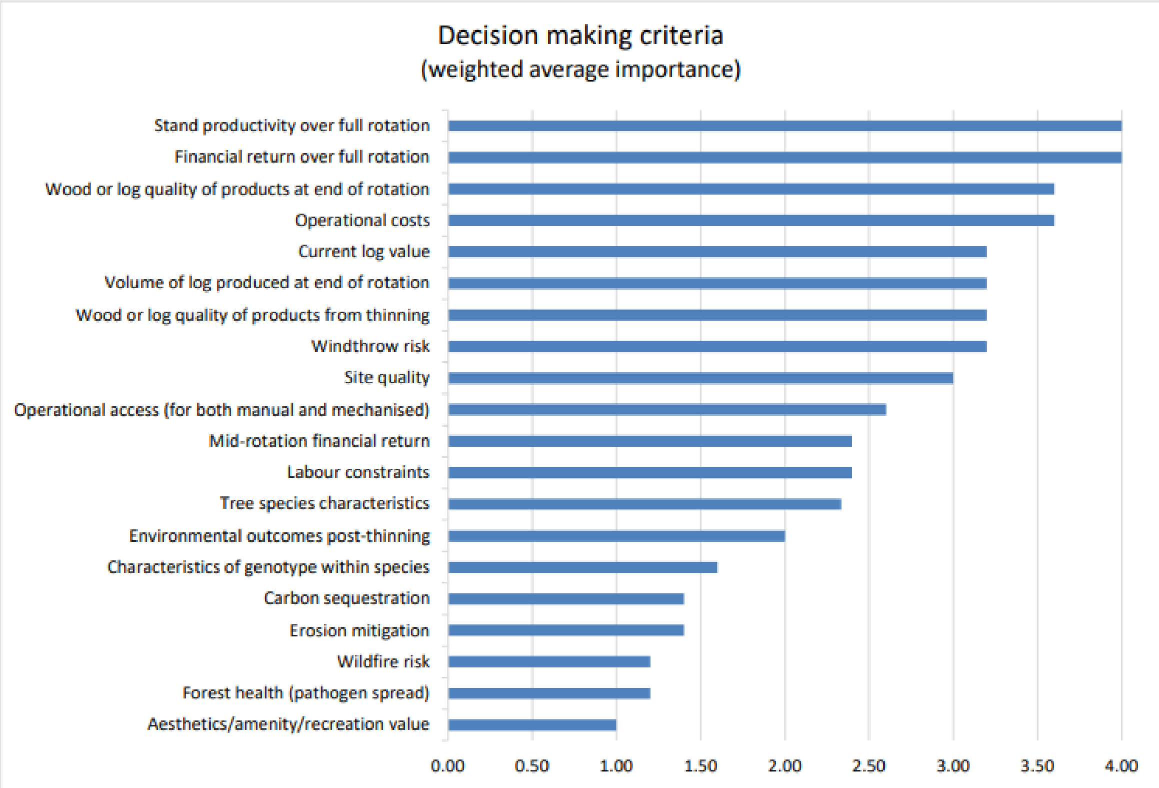
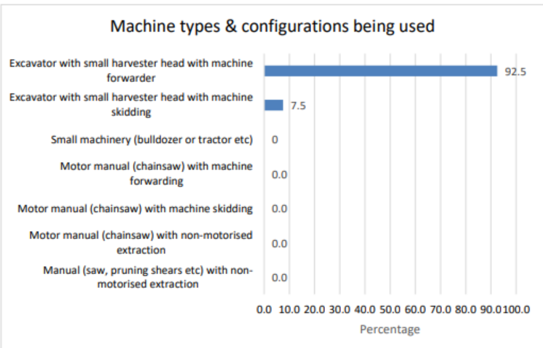


Figure 11: Weighted average ranking of criteria in production thin operations, that were identified by respondents as major, moderate, or minor.

Respondents were asked what percentage of machine types and configurations they had for production thinning. The excavator with small harvester head with machine forwarder featured predominantly at 92.5 percent with 7.5 percent being for an excavator with machine skidding. Other dedicated machinery was identified as summarised in Figure 12. Shown in Figure 13 is information about damage and other concerns.

Average of responses



Comments

- **Other dedicated machinery**
  - **Wheeled harvester & forwarder**
  - **Small wood thinning crew**
  - **Forwarder John Deere, processor**
  - **Track based harvester forwarder combination**
  - **Rubber tyred harvester forwarder combination**
  - **Excavator with small harvester head & forwarder**

Figure 12: Machine types and configurations being used in waste thin operations.

Damage

	Manual	Mechanical
Residual trees	-	<1%, 1-5% 6-10%
Soils & site	-	<1%, 1-5% 6-10%

Other concerns

- **Mechanical**
  - **Rutting, steep slopes, labour constraints, site suitability, productivity, tree selection, stocking, distance to log supply**

Figure 13: Damage and other concerns in production thin operations

Other reasons to thin - key results to questions 31-33

In addition to the criteria identified in previous questions as reasons to thin, respondents further identified having a year-round silviculture workforce, control of branches, and to remove regen as other reasons (see Table 14).

Table 14: Criteria provided in the survey, and additional reasons that were identified for thinning. Reasons not in the criteria provided in the survey are shown in red and with *.

Criteria provided for deciding to thin in question 8	List of reasons identified by respondents for deciding to thin in response to question 31
Aesthetics/amenity/recreation value Carbon sequestration Characteristics of genotype within species Current log value Environmental outcomes post-thinning Erosion mitigation Financial return over full rotation Forest health (pathogen spread) Labour constraints Mid-rotation financial return Operational access (for both manual and mechanised) Operational costs Site quality Stand productivity over full rotation Tree species characteristics Volume of log produced at end of rotation Wildfire risk Windthrow risk Wood or log quality of products at end of rotation Wood or log quality of products from thinning	Improve quality of residual trees Maximise recovered volume Forest health Mid rotation yield, recover costs mid-cycle Add value, maximise return Even stands with best log grades Prevent windthrow *Year round silvi workforce, lack of pruning labour *Control of branches *Remove regen

If there was a stronger biomass / bioenergy market, then there would be:

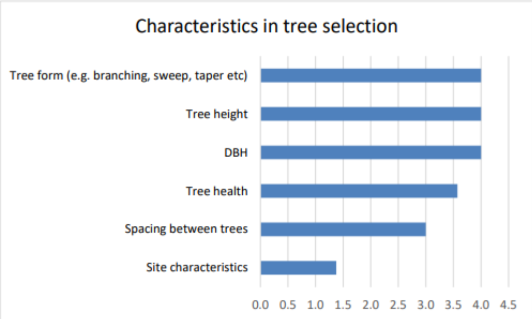
- An improved reason to thin, a change in regimes e.g. energy crops, earlier rotation lengths, leave heavy stocking, spray out stand to leave to dry standing, and chip whole trees.
- More production thinning, including steeper slopes, and in-field chipping or similar – normally the domain of harvesting.
- Biomass / bioenergy price point – this needs to be analysed (could this be by FGR?):
  - Where the production thin cost is in line with the cost of waste thin

- Need to break even, $16-18 per GJ, $80-90 per ton, supersede KIS grade prices, >$70 per ton.

Tree selection - key results to questions 34-38

Respondents unanimously indicated that it was the operator who selected the trees for thinning. Information on the characteristics in tree selection, how trees are selected for removal, and training methods for operators are shown in Figure 15. Most (80%) of respondents are doing one thin to final crop stocking, with the balance (20%) thinning multiple times throughout a rotation.

Weighted average of responses



How are trees selected for removal

- **Size (dominance & vigour), form, spacing**
- **Pruned or not**

- **Training**
  - **Formal modules for thinning, unit standard 6951, on the job training – tree selection manual**
  - **Refreshers, Topspot audits, certification, pre & post assessment plots, tree selection policies**
  - **Supervision, reliant on operator**

Figure 15: Tree selection characteristics for thinning, and operator training

Future thinning research - key results to questions 39-43

There was no respondent that indicated they had used tethering systems for thinning or indicated that they would be willing to trial tethering systems for thinning. Other technologies that are being used to assist thinning operations are: remote sensing, Lidar, UAV photography, terrain mapping (slope assessments), stocking assessments (plots, satellite imagery, UAV post tin on some stands etc.), and decision support tools such as using productivity surfaces, predictions of site and pre-assessment inventory. Proximity sensors for manual thinners followed by near real time monitoring of thinning ranked the highest for thinning technology development (see Table 16).

Table 16: Thinning technology development – respondents asked to rank (1 high - 5 low) in order of their willingness to support these projects.

Technology	Average Ranking (/5)
Proximity sensors to ensure manual thinners stay > 2 tree lengths away from each other	2.5
Near real time monitoring of thinning to track tree density and spacing as you implement treatments.	2.5
Virtual reality forests for training thinning crews to select trees	3.6
Tool in cab of mechanised thinning machine to guide decision on tree selection based on what can be detected/seen from the cab and knowledge of what has already been thinned thus far	3.1
Tool in cab of mechanised thinning machine to guide decision on tree selection based on knowledge of the entire forest and forest growth projections, with live updating as choices are made by operator	3.3

Other technologies (either real or imagined) that respondents would be interested in were:

- Satellite / deep learning to assess stands pre and post thin. Becoming important with an aging workforce and the H&S factors around post TTW thinning on steep slopes.
- Individual pre-tree selection from remote sensing.
- GPS way points of trees thinned to indicate stocking from pre-assessment inventory.
- Terrestrial chemical thinning.
- Aerial chemical thinning.
- Chemical or mechanical thinning from above, i.e. drones.
- Mechanical thinning on steep slopes.
- No thinning stand options (plant and leave) with advanced genetics.
- Aerial, chemical and biological thinning or the removal of the need to thin at all, i.e. plant at close to final stocking.
- Extracting thinned trees at low cost after mechanical thinning.
- Smaller (less capital) production thinning machinery.
- Laser chainsaws, lightsaber.

WORKSHOP DISCUSSION

Key points of the workshop discussion are summarised into two tables. Table 17 lists challenges in thinning and Table 18 lists the ideas and opportunities for thinning.

Table 17: Key notes from the discussion on challenges in thinning in NZ.

Challenges	Key notes
Site factors excluding slope	• Regen increases cost for manual thinning, and the H&S risk (more hang ups etc). • Summer versus winter. • Broken terrain challenge for autonomous vehicles.
Slope	• At what slope do we need to think about tethering and how much area does this apply to? Using wheeled harvesters for production thinning the cutoff is 25 degrees, however self-levelling harvesters can go steeper, but productivity drops unacceptably at the current stumpages. • Tethering in Nelson will open more area available for thinning (>30 degrees represent >25% of the estate). • Typically bench roads on steep slopes resulting in short steep banks on sides of the road, which can limit getting mechanical harvesting equipment on/off roads.
Establishment and tending	• Contour planting restricts ability to use mechanical thinning and tethering. • Techniques to avoid regen earlier in the rotation so it does not need to be a problem at thinning. • Thinning can increase airflow and decrease dothi in some stands, but this is of less concern than volume.
Tree selection	• Should wood quality be a focus during thinning? What is the value? Brian Rawley and Jonathan Harrington are going to start doing a project looking at thinning based on wood properties. • Operators will choose the biggest trees to thin because they have big branches / poor form so not suitable for a sawmill. • Density based production thinning is important for a pulp market. Often age is used to determine thinning timing, however knowing the density of a stand could increase the available area within a wider age range.

	• We assume that thinning improves quality but difficult to quantify this improvement, so we are thinning mainly for site carrying capacity.
Cost	• With production thinning a pinch point is recovery of wood with loaded forwarders.
Damage to crop trees	• Wide variety of equipment could cause a wide variety of damage
Thinning products	• Production thinning and bioenergy options depend on the market / price premium. • Need to think about the loss of the Chinese market.
Situational	• Thinning post-cylone Gabrielle where there are large amounts of slips.

Table 18: Key notes from the discussion on opportunities for thinning in NZ.

Opportunities	Key notes
Planning thinning operations	• Interested to hear from folks about using height versus other traits in selecting trees, and how important this is. Mean top height is used to prioritise areas for thinning, in addition to stocking. • Do we need to identify the trees to thin? Tree density helps set costing rates. • Understanding the cost-benefit analysis and considering the risk factors, e.g. genetic stock, and considering sites for short rotation crops.
Tools for the operator	• Format setup for digital forestry, unit in cab to say where to go, do a basic layout of what can be done now with a staged approach. Need a format to develop this, need some early tools. There are a variety of different technologies being used (are Trimble involved in this?) around the world, no play-by-play instructions. • Access to instant data of what's around you, and feed this back instantly, to take the pressure off the operator. • Similar to what is happening in harvesting. • Ability to give maps and tracking back to the forest manager will provide transparency and more discussion. • Proximity sensors two tree length rule, in trial phase at the moment so don't need to do this. • Live tracking of H&S data (like for high performance athletes) - are they causing the problems? Platform called Everywhere, live update / check in.
Monitoring thinning	• Identify stocking from remote sensing to monitor thinned stocking levels.
Changing approaches to thinning	• Keeping thinning / harvesting crews is challenging. Need to compete for labour workforce. There is a squeeze with increasing afforestation and increased length of planting season. Need to add to the mana of thinning operations. • Chemical thinning could be useful on steeper sites, what about the H&S of dead standing trees with subsequent activities including recreation. What is the research needed for chemical thinning? E-thinning (environmental thinning) being done in Matariki. • Steep terrain – use advanced genetics, plant and leave, with aerial / chemical thin option.

	• Virtual selection training tool is a quick win. Can loose value straight away if not selected well. Give operators the tools. • Testing wood quality.
Forest system design	• There should be a focus on modelling thinning, rather than the practice of thinning. • Alignment with pruning, each tree gets an ID, mixed species. • Regen, not planting across contours. • In the PSP workplan 4.5.1 / 4.5.2 is not a high priority. 4.5.3 tethering is relied on by other programmes. • Talk about data, what gets planted flows through, remove the guess work.

SUMMARY

Machines equipped to address slope and terrain challenges, and to match the efficiency of manual methods of thinning, are the ultimate challenge and opportunity for thinning in NZ. The survey and workshop results highlight a wide range of views about thinning research. For example, on “Steep terrain – use advanced genetics, plant and leave, with aerial / chemical thin option” to “Tethering in Nelson will open more area available for thinning (>30 degrees represent >25% of the estate)”, which also contrasts with the fact that machines aren’t currently prevalent on easier terrain in other places.

Emerging themes were the issue of costly regen in manual thinning, a growing interest in the viability of precision chemical thin operations, the idea of thinning based on wood properties, and that tools for operators should be a priority. New approaches in thinning are already being tried / tested by forest companies (e.g. chemical thinning, proximity sensors, new forest designs). An opportunity for the PSP thinning work is to operate where these activities can be enhanced, and to facilitate the learnings that could be shared to the wider industry. Furthermore, taking a strategic approach to tools for operators, looking beyond the programme and how the PSP supports this, could be a worthwhile approach.

The survey and workshop information in this report have been used to inform a revised workplan and roadmap for the thinning activities in the PSP. This was presented to the TST in June 2023 (see Appendix A for the brief presentation), with an interactive prioritisation session undertaken. Following this a workplan in forest system design was prepared, with aspects of this to potentially be contracted. This workplan proposed to gather knowledge of the global developments in forest design, scope software for forest planning, implement and evaluate new forest design trials, and to facilitate a Think Tank around forest system design from establishment up to harvest.

A project on virtual reality for thinning training was also scoped up and this research has been contracted (to Scion), and this is running alongside the real time thinning work (led by Interpine).

ACKNOWLEDGEMENTS

Authors thank the forest industry respondents to the survey, and to the participants in the workshop.

REFERENCES

Baker, M. (November 2018). Mechanised Silviculture: Opportunities and Challenges for the New Zealand Forest Industry. Report submitted for Kellogg Rural Leadership programme.

Taylor, S., & Visser, R. (2021). Viability of Production Thinning in New Zealand. Thesis submitted in forest engineering final year research project. University of Canterbury.

APPENDICES

Appendix A – Survey questions

#1

COMPLETE

Collector: Web Link 1 (Web Link)
Started: Monday, March 06, 2023 12:31:08 PM
Last Modified: Monday, March 06, 2023 12:51:03 PM
Time Spent: 00:19:54
IP Address: 163.7.4.20

Page 1: About this survey

Q1 **Yes**

I agree to participate in the survey

Page 2: About you

Q2 **Respondent skipped this question**

Tell us a bit about yourself

Q3 **Respondent skipped this question**

What is your main role in the decision regarding thinning processes of this firm?

Q4 **Respondent skipped this question**

In which regions are your current thinning operations?

Q5 **Respondent skipped this question**

Number of thinning crews operating?

Page 3

Q6 **Thinning to waste,**

Do you currently undertake any : **Production thinning**

Page 4: Thinning to waste practices

Q7 **Respondent skipped this question**

How much area do you thin annually (ha) using

Q8 **Respondent skipped this question**

What is the maximum slopes that you thin (degrees or grade) using...

Current practices and challenges for thinning

Q9 Which do you consider most when making thinning to waste decisions in your area	Respondent skipped this question
Q10 Could you comment on your typical costs of thinning for:	Respondent skipped this question
Q11 What factors impact most on the costs of thinning (check the main two)	Respondent skipped this question
Q12 What machine types and configurations do you use for thinning to waste ?Please indicate the percentage of your total thin to waste, for each machine type - must sum to 100	Respondent skipped this question
Q13 Do you use any dedicated thinning machinery (please specify)?	Respondent skipped this question
Q14 How much damage to residual trees do you typically observe for	Respondent skipped this question
Q15 How much damage to soils/site do you get for	Respondent skipped this question
Q16 What other concerns/challenges do you have about the implementation of mechanised thinning to waste?	Respondent skipped this question
Q17 What other concerns/challenges do you have about the implementation of manual thinning to waste?	Respondent skipped this question
Q18 I also undertake production thinning	**Yes**

Page 5: Production thinning practices

Current practices and challenges for thinning

Q19

How much area do you thin annually (ha) using

Respondent skipped this question

Q20

What is the maximum slopes that you thin (degrees or grade) using...

Respondent skipped this question

Q21

Which do you consider most when making production thinning decisions in your area

Respondent skipped this question

Q22

What factors impact most on the costs of thinning (check the main two)

Respondent skipped this question

Q23

What are your typical per hectare costs of thinning ($/ha or $/m3)?Please specify funit

Respondent skipped this question

Q24

What machine types and configurations do you use for thinning to waste ?Please indicate the percentage of your total production thinning, that is thinned by each machine type - must sum to 100

Respondent skipped this question

Q25

Do you use any dedicated thinning machinery (please specify)?

Respondent skipped this question

Q26

How much damage to residual trees do you typically observe for

Respondent skipped this question

Q27

How much damage to soils/site do you get for

Respondent skipped this question

Q28

What other concerns/challenges do you have about the implementation of mechanised production thinning?

Respondent skipped this question

Q29 Respondent skipped this question

What other concerns/challenges do you have about the implementation of manual production thinning?

Page 6: THINNING CONSIDERATIONS

Q30 Respondent skipped this question

Please list some of the main reasons you have decided to thin your resource

Q31 Respondent skipped this question

How would your considerations change with a stronger biomass/bioenergy market?

Q32 Respondent skipped this question

At what biomass/bioenergy price point would you make changes to your choices (i.e. increase level of production thinning)?

Page 7: SELECTION OF TREES FOR PRUNING & THINNING

Q33 Respondent skipped this question

Who selects the trees for thinning?

Q34 Respondent skipped this question

How are trees selected for removal?e.g. row, geometric pattern spacing vs. individual tree characteristic

Q35 Respondent skipped this question

What characteristics are used most in tree selection?

Q36 Respondent skipped this question

What guidance/criteria/ training are the people selecting trees given?

Q37 Respondent skipped this question

Do you thin to a final stocking, or thin to intermediate stocking?

Q38 Respondent skipped this question

Have you/Do you use tethering systems to thin?

Page 8

Q39

Respondent skipped this question

Would you be willing to assist in a trial of tethered thinning practices?

Page 9: RESEARCH NEEDS

Q40

Respondent skipped this question

What other technologies do you currently use to assist thinning operations?E.g - Remote sensing; wood quality assessments; augmented reality; decision support tools

Q41

Respondent skipped this question

What value do you see in the development of the following technologies (please rank in order you would be willing to support these projects within the Precison Silviculture Programme)Options can be clicked and dragged up and down to rank in order

Q42

Respondent skipped this question

What other technologies (either real or imagined) would you be interested in?

Appendix B – Workshop agenda

Agenda

Workshop

Current practices & challenges for Thinning Operations

Wednesday April 19 (10am-2.30pm)

Manaakitanga Room, Scion

Titokorangi Drive (formerly Long Mile Rd), Rotorua, 3010

10am	Tea / coffee	All
10.10am	Welcome – Introduction, thinning within the Precision Silviculture programme	Brian
10.20am	Workshop – agenda, aim	Lania
10.25am	Current situation & practices	
	Present thinning survey results, geospatial analysis of slope	
10.45am	Reality check exercise	
11.15am	Works well / pain points for a thinning contractor (manual, mechanical), Q&A	Practitioner (tbc) / All
11.35am	Works well / pain points for a thinning ops manager, Q&A	Practitioner (tbc) / All
12pm	Lunch	All
12.30pm	Opportunities	Yvette
	Forest system design, silvicultural pre-selection, state of art technologies, methods	Practitioner (tbc) / All
1pm	Transformation, continuous steps to progress	
	Brainstorming exercise	
1.30pm	Roadmap development	Lania
2.15pm	Wrap up	Brian
2.30pm	Workshop – end	

Appendix C – Workplan and roadmap presentation

Precision Silviculture Partnership

Revised Workplan & Roadmap Thinning Activities 4.5 & 4.6

Presenter: Lania Holt

Meeting Date: Kokako PF Olsen, 27 June 2023

FOREST GROWERS RESEARCH

Challenges and opportunities

- The original workplan displayed a disconnected flow of activities, lacking cohesion.
- Milestones within activities often did not align with the overall scope of opportunities, as seen in the example of Forest System Design (to be discussed).
- The scale of funding allocated to certain areas was disproportionate, requiring a reassessment.
- There is an opportunity to reconsider how different activity areas intersect, aiming for enhanced strategic value and coherence.

Original Workplan Review

Activity	Milestone
4.5 Forest System Design	4.5.1 Trials of mechanised felling to waste and commercial thinning have compared tree selection and out row thinning systems
	4.5.2 Analysis of tree crop damage, ground disturbance and system productivity has been completed
	4.5.3 Forest system design to facilitate both mechanised thin to waste and commercial thinning on steep land using cable tethering systems has been completed.
4.6 Silvicultural Pre Selection for Pruning and Thinning	4.6.1 Technology review of the state of automated tree selection for pruning and thinning is completed.
	4.6.2 Selection parameters for stem selection have been confirmed and remote sensing data requirements have been developed.
	4.6.3 Field data collection trials are completed and stem selection algorithms have been tested and refined to proof of concept.
	4.6.3.1 A commercialisation plan, incorporating KPI's to be monitored and reported quarterly, is developed and approved by the PGP.
	4.6.4 Alpha prototype of software tool to deploy stem selection to device to assist operator has been developed and tested.
	4.6.5 Beta prototype construction and field testing is completed.

Milestones narrow in focus and duplicate some of 4.3/4.4 (4.5.1–4.5.3)

Flow of milestones doesn't reflect how we would "stage" the roll out. (4.6.1–4.6.5)

Year One in Review

- The expected progress in terms of funding was not fully realised.
- Challenges were encountered in attempting to rationalise and comprehend the plan, which contributed to the slower progress.
- The milestones achieved in year one, however, form the essential foundations for developing the roadmap:

No.	Milestone
1	Industry survey on thinning methods & practice in NZ (complete)
2	Industry workshop on thinning with a focus on tree selection, forest design & priorities for PSP investment (complete)
3	Report combining workshop summary & survey results (in draft)
4	Real-time thinning assessment (foundation for individual tree assessment) (underway with Interpine)
5	Completion of revised workplan and roadmap for PSP activities 4.5 and 4.6 (to be discussed high level today)

Revised Workplan & Roadmap Y2

4.5: Forest System Design

- The full potential of this area was not adequately captured in previous milestones.
- Redefining the opportunity: Exploring the value of precision throughout the entire rotation process.
- Year two focus: Silvicultural regime optimisation to inform field machine trials in following years. These trials will build on modelling information and provide confidence on the best (quickest/ most effective) pathways to greater precision and mechanization benefits in thinning operations.

Milestone	Informs…	Size (S= $10-30K, M-30K-80k, L= $80k-120k, XL, $120k+
Mechanised management plan: modelling stocking prescriptions and fine scale details of local environment (slope, aspect, terrain, available P)	• Economic evaluation of precision thinning • Future thinning trials	M
Evaluate the level of impact that forest factors (slope, contour planting, interrow spacing, hinderance e.g., regen) have on mechanisation	• Machine design, specific thinning trials identified for thin to waste • Machine design, specific thinning trials identified for production thin	M

Revised Workplan & Roadmap Y2

4.6: Silvicultural Pre-Selection for Pruning and Thinning

- Milestones not representative of full scope of the potential for this area.
- Redefining the opportunity: This activity aims to develop a comprehensive digital forest representation that facilitates individual tree preselection (estate scale). This includes understanding the decision-making process of operators for training purposes, implementing automated pathing to selected trees, and conducting post-thin assessments on a large-scale forest level.
- Year two focus:
  - Virtual thinning training tool
  - Individual tree preselection
  - Automated pathing to tree
  - Post thin assessment (stand scale/ limited to the vicinity that the operator is working within).

Revised Workplan & Roadmap Y2

No.	Milestone	Informs…	Size (S= $10-30K, M-30K-80k, L= $80k-120k, XL, $120k+
4.6.1.1	Virtual Thinning Training Tool: develop a proof of concept for a virtual, realistic experience in thinning decision making including a study into virtual training methods and explicit learning	• Selection capability of thinning operators • Enhancement of existing training methods • Understanding of visual and gaming approaches using virtual forests on thinning operators (human factors assessment)	M
4.6.2.1	Preselection algorithm to identify (and virtual mark) tree is developed. Solve spacing and then tree form decision requirements	• Decision on preselection that frees up time to focus on safer felling • Precursor for automation	S
4.6.2.2	Pathway algorithm to define optimal pathing to tree is developed. What can be seen in the cab, override pre-selection, use of terrestrial LiDAR/ SLAM sensor on harvesting machine	• Safer, more efficient thinning operations • Business case for mechanisation	M
4.6.2.3	Post thin stem maps created	• Forest management, inventory	S

Revised Workplan & Roadmap Y2

4.6: Silvicultural Pre-Selection for Pruning and Thinning

- Other ideas for consideration (and possibly development)
  - Chemical thinning
  - Reducing regen
  - Tree injections and enhancing biomass value