Precision Silviculture Programme

TECHNOLOGY REVIEW

Project Number: 4.1.1

Mechanised Thin to Waste and Production Thinning Technologies: an International and Domestic Review

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FOREST GROWERS RESEARCH

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Executive Summary

Plantation thinning and extraction is profitably mechanised in many parts of the world. Information on the machines used is easily accessible on the internet. There is a plethora of machinery, much with overlap into mature tree logging.

Mechanising thinning in hill country NZ is unique because of production pressure, economic constraints, limited markets and the steep erodible soils that require protection.

In New Zealand in 2020, around 50,000 hectares of radiata pine were thinned, 87% to waste. Much of the waste thinning was by labour intensive, potentially dangerous manual chainsaw operation. This manual process needs to have a mechanical solution, with the capability to also extract the thinnings.

Manual chainsaw operations still exist because of the complexity of using mobile machines to do the job. Complexity includes steepness, broken ground, and economics. Economics, market access, and mechanical capability play the major roles in limiting extraction.

Current successful, mechanised, thin to waste operations in NZ are characterised by using around 13 tonne excavators with fixed wrist shear felling heads on flatter country.

There are also successful commercial extraction operations on flatter country that may point the way for steeper extraction.

Mechanisation must handle thinning and extraction on steeper country while being cognisant of maximising personnel safety, attracting personnel, and dealing with limited skilled labour. Mechanisation also must encompass economic and environmental sustainability, and carbon zero expectations, while being aware of bleeding edge technical, world forestry and agricultural trends.

The challenge to this programme is to have mobile machines that achieve the balance.

Introduction

This paper presents a literature review on approaches to mechanised thinning internationally and in New Zealand. Mechanisation is important to overcome challenges of labour shortages, health and safety and productivity/work rates for both waste and extraction thinning. The real challenge will be mechanisation on steeper country where a lot of New Zealand's planted forests are located. Much of this forested land is on fragile, erodible soils, so technical solutions for mechanised thinning must account for potential soil impacts and risks posed by extreme weather events that are increasing in frequency due to climate change.

Overview

Purpose of Project (as stated by FGR)

To provide a preliminary review of international technology developments that have potential application in New Zealand and to summarise current domestic developments and trends in respect of mechanised thinning to waste and commercial extraction thinning. The review should focus on technology that is suitable for steep land operations or is capable of adaption to steep land operations. The outcome of the project will inform recommendations on thinning approaches and new technologies to be presented in a second document.

Objectives (as stated by FGR)

Tasks

1. Undertake a literature review of international technology that is currently available or being developed for both mechanised thinning to waste and commercial extraction thinning for small wood and biomass recovery and that has potential to operate on steep land in New Zealand.

2. Review domestic operations to ascertain the extent of thinning to waste, the degree of mechanisation in waste thinning and identify new developments with potential application to steep land.

3. Review current commercial extraction thinning technology in use and the potential for extending this to steep land.

4. Prepare a report on the findings of the review that can be used to guide the development of the work programme for the Thinning Workstream.

Task 1 – Literature Review

Undertake a literature review of international technology that is currently available or being developed for both mechanised thinning to waste and commercial extraction thinning for small wood and biomass recovery and that has potential to operate on steep land in New Zealand.

Definitions

- *Crane is the whole arm of a machine.*
- *Boom is the part of the arm that attaches to the rotator.*
- *The stick attaches to the boom and becomes a telescopic stick if it has a sliding extension.*

Other considerations

A literature review of international technology for tree thinning must keep in mind the application of these technologies in the context of NZ operational parameters in NZ need to be kept in mind. These parameters include:

- Definitions of "steep land" including slope, soil stability and slope uniformity.
- Definitions of the pre thinned crop in terms of tree type, spacing, and age/diameter/height.

1.1 Manual Thinning

Chainsaw felling accounts for most thinning, generally to waste. There is potential to move to electric chainsaws as battery power advances. Potential advantages of electric chainsaws are:

- Simple to start.
- Less pollution both to the environment and the operator.
- Much less noise and greater safety as the saw is not always running.
- More operator awareness of surroundings through less noise and the potential to use lesser hearing protection.
- Less noise and no fumes lessen fatigue.
- Cheaper running costs dependent on the charging regime.
- Theoretically the electric saw should have less maintenance and a longer life although petrol chainsaws have evolved into extraordinary machines.
- Potential to build in electronic safety, location technology etc.

A separate project within the Precision Silviculture Programme will be evaluating the benefits of electric chainsaws.

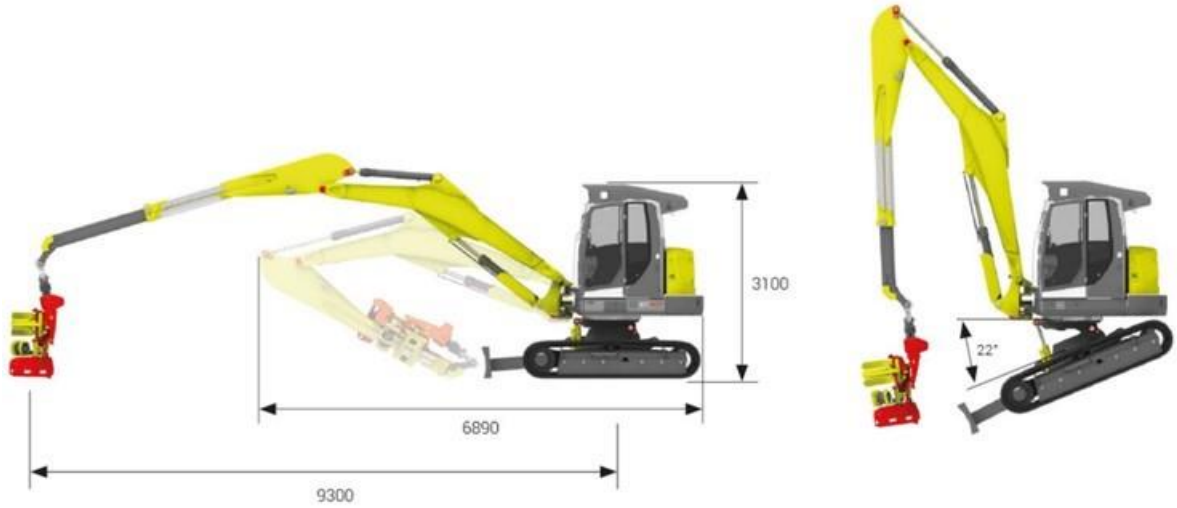
1.2 Felling, Processing and Extraction Machines

Internet links are used throughout. They are blue underlined type.
(NZ thinning machines are covered in **Task 2**).

1.2.1Tracked skid steer

This type of machinery would seem an obvious fit for thinning because of the ease of turning in tight situations. Currently tracked skid steer is the go-to machine type for thinning in NZ. Self-levelling machines of this type have an advantage by keeping the centre of gravity appropriate, the motor reasonably level, the operator comfortable, and allowing the crane slew to be horizontal, thus more powerful, when rotating the crane up hill. Because trees are generally vertical, a vertical turret aligns more easily.

Konrad Forsttechnic KDH40-1. Base machine approximately 10 tonne. Front tilt (no side tilt) and crane has a telescopic stick. The machine is a refitted Wacker-Neuson ET90.



https://www.forsttechnik.at/products/harvester/kdh

Besten was a remote-control harvester (a robot) that never really hit production. The impressive machine was a tyred skid steer and had some pretty useful features, but it was perhaps a little before its time. The below link gives more information about its history.
https://www.forest-monitor.com/en/death-forest-beast/

Pictures from a Russian pamphlet downloaded early this year

Mecalac 8MRC. Base machine approximately 7200kg

https://www.earthmoversmagazine.co.uk/news/view,mecalac-a-multitrick-pony_2481.htm

The crane has a 2-piece boom then stick. Because of this configuration it can lift heavy loads in close and has a tight rotation circle. Top speed 10 kph. The contractor uses it with a trailer which he often disconnects, then ferries logs to the trailer.

Neuson Forest GmbH 103HV / 103HVT (Tilt) and 104HV / 104HVT (Tilt)
This is a 14 tonne, self-levelling machine.
https://www.neuson-forest.com/neuson-forest-103hv-103hvt-neuson-forest-104hv-104hvt/

https://www.holzvermittlung.at/galerie

1.2.2 Walking (spider) machines

Examples of this machine type are Menzi Muck, Kaiser and Euromach.
These excavators have a reputation of being able to go anywhere. With 4 independent legs, often assisted by the crane, this would seem to be a reasonable statement. A limitation is perhaps traction at reasonable speed with only a single drive wheel on each leg. Crane assist along with push legs fitted to some machines can however certainly keep this type of machine moving.
Kaiser at one point fitted quad tracks (triangle track bolted to wheel studs) to a machine.

https://www.euromach.com/eng/spider-forestry-excavator.php#example4-2

https://www.unusuallocomotion.com/pages/locomotion/walking.html

Euromach**,** seems to have the largest number of models, so their Forester is featured here. The Forester is produced in multiple sizes 5800kg, 8900kg, 1100kg, 11500kg, 13550kg, and 17500kg. Accessories like winches are available. https://www.euromach.com/eng/

https://www.euromach.com/eng/spider-digger-with-steering-wheels.php#example5-9

https://www.euromach.com/eng/spider-digger-with-steering-wheels.php#example5-8

1.2.3 Pivot steer

Pivot steer forest machines are the go-to machine in Europe. This is probably because they are gentle on the environment. Pivot steer machines pivot vertically in the middle, between the wheel pairs in the above photo. This steering pivot allows the machine to bend by up to 45 degrees using hydraulic cylinders. It can also rotate horizontally in the same area allowing the rear frame to tilt say 20 degrees in either direction relative to the front frame. Because the 4 bogie wheel pairs also pivot individually, the machine can drape itself over the ground in 5 axes allowing excellent ground conformity and traction on rough slopes. However, pivot steer machines are generally long, so it is hard to see them pivoting and traversing sideways easily on steep slopes avoiding contact with standing trees. Generally, the cabs and cranes have levelling capabilities.

There are many different manufacturers. Eight wheel (can fit 4 tracks) pivot steer machines have the best traction of this machine type, so they are featured here.

Komatsu, as a common name in NZ may be a good way to start, but their latest thinning harvester the 901XC weighs approximately 20.2 tonne which seems heavy.

https://www.komatsuforest.com/forest-machines/our-wheeled-harvesters/901xc-2020

https://www.woodbusiness.ca/komatsu-launches-new-901xc-extreme-conditions-8wd-harvester/

Logset 8H GTE hybrid electric harvester

https://www.logset.com/en/harvesters/logset-8h-gte-hybrid

https://www.forestry.com/editorial/logset-12h-gte-electric-hybrid-harvester/

This machine is mentioned because it represents a step toward the future. It is however a 23 tonne machine. It is hybrid-electric but instead of using a diesel motor and a lithium ion storage battery, it uses super capacitors (super caps) for electric storage. Super caps store much less energy than a battery but can release that energy at a higher rate. In the Logset, a less powerful than usual diesel motor charges the super caps when the machine is doing less work than the diesel motor's output. The super caps then release this extra power when the machine requires more capacity than the diesel motor can supply. An electric unit, consisting of a generator / electric motor combination, couples the diesel motor to the driven hydraulic pumps. The rest of the machine can then use normal hydraulics. Later note 14/4/22: Forest Talk announced that Mike Hurring has one of these machines.

The upside of this technology is the Logset can deliver 45% extra power and 39% extra torque for the short periods normally required. The hybrid technology results in up to 25% fuel saving.

This in-forest approach to hybrid technology is sensible as there is no power cords available to charge a storage battery at night with the accompanying savings and green energy potential.

Terri-34c
This machine is a small 8 wheel-drive weighing 6.5 tonne and has 700 mm ground clearance.

https://www.terri.se/sv/

The editorial below says the machine can compete on thinning with bigger machines. Larger trees noted were 30 cm diameter.
https://www.forestry.com/editorial/thinning-small-harvester-terri-34c-8wd/
There is also a forwarder version or a combo harvester / forwarder.

https://www.forestry.com/editorial/thinning-small-harvester-terri-34c-8wd/

Tracks can be fitted for traction, flotation and stability. Tracks can be configured with side bars to limit side slipping moving across slope. An advantage of tyres is that they can be less damage to root systems and the environment.

1.2.4 Ground carriage

The ***Konrad pully*** is a cable driven carriage by Konrad Forsttechnic but it is not listed on their site anymore. The machine is said to be for downhill extraction. The wheels do not drive and are mounted as 4 double bogies. The winch rope from the remote winch (truck below) goes through a roller guide at one end of the carriage, around a double sheave capstan winch, which drives the carriage (presumably) then out through a roller guide at the other end of the carriage. It is fastened to an anchor above the travel route. The truck winch applies appropriate tension on the rope, to eliminate slippage at the capstan winch, as well as acting as a guide for the carriage. The carriage returns to the truck using the tensioned cable as a guide. It would seem this type of setup would also work uphill if the carriage had sufficient engine torque and enough rope wraps on the capstan winch sheaves. The telescoping crane in the lower right illustration (below) is one of multiple setups that can be fitted to the carriage. Resetting this carriage in multiple thinning corridors, could have time and complexity constraints.

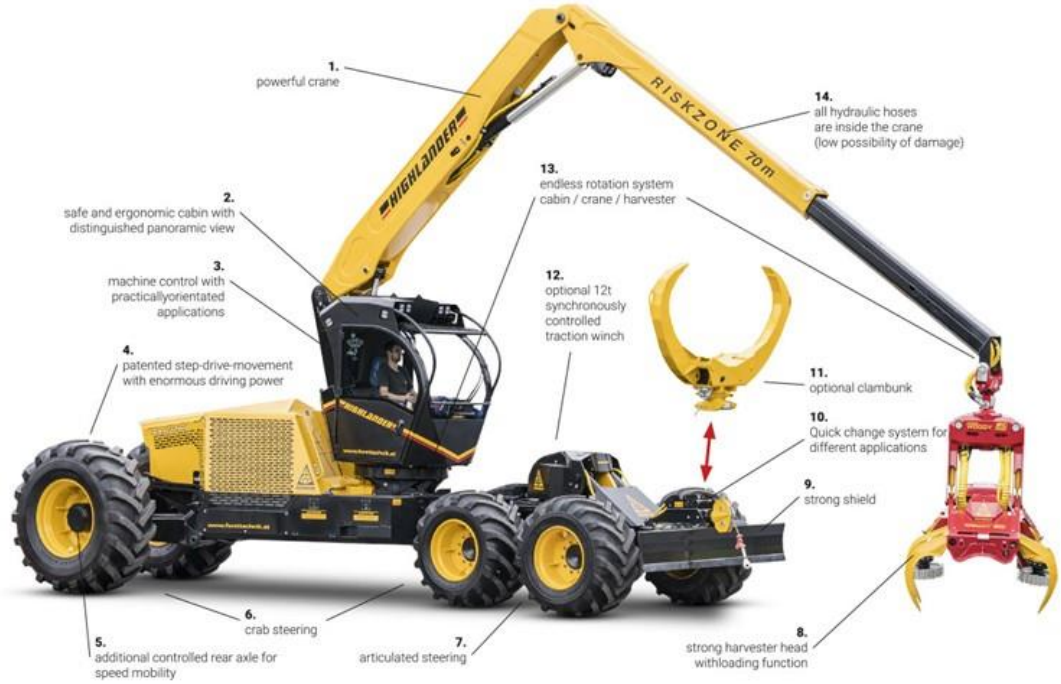
Pictures from a pamphlet I downloaded some years ago.

1.2.5 Remote Control crawler (small skid steer machines that are used for extraction).
The ***HSM CTL250-FR Forest crawler***. It weighs only 2.5 tonne with an extraction winch, a blade/skid plate and has a 100 m, 6 tonne tethering winch fitted. It can be transported on a ute trailer.

http://www.excavators-uk.com/forest.html

Highlander HL20-1 https://www.forsttechnik.at/products/harvester/highlander/highlander-hl20-1
This is the only 6-wheeler featured. It is included because it has extra traction capability through a push drive system. This is a big machine at 26 tonne and 11.5m long but its technology is worth

reviewing. The machine can pivot steer the twin wheel bogie, and the large rear wheels also steer. This gives it the capability to crab steer as well. Crab steer is to move sideways at an angle. Pivot steer machines can't do that. The push drive system means the rear wheels can extend telescopically rearward independently. View video 3minutes in. https://www.youtube.com/watch?v=T5MfaJ94MmQ



1.2.6 Forwarders

These machines generally follow the configuration of the pivot steer as illustrated above. They are used in cut to length extraction thinning. A forwarder generally drives down a slope with the log bunk behind. This allows log loads to stay in place without chaining. The forwarder then backs up the slope (operator rotates) when loaded but as it is a pivot steer this is not a problem to a skilled operator. Note: downhill extraction could make the operation easier.

Ponsse from Finland is a major player in pivot steer, tyred machines.
https://www.ponsse.com/#/

https://forestnet.com/LSJissues/2016_july-august/steep-slope-logging.php

Terri 3020A

At 1970 kg this is a sample of the small machines available overseas.

https://www.terri.se/sv/maskiner/

1.2.7 Log Trailers

Trailer configurations suitable for steeper country would include features such as mechanically or hydraulically driven bogies fitted with tracks and hydraulically pivoting drawbars which make backing a simpler proposition. The trailer would usually be below the towing machine on a slope, when extracting up hill. This approach would require securing the load by some means.

1.2.8 Clambunks

Clambunks are like an upside down skidder and can be fitted onto the machine, a trailer and sometimes a forwarder.

https://www.bmf.ee/products/accessories/clambunk

1.2.9 Skidders

Skidders come in all shapes and sizes. They are useful for longer log length or tree length extraction.

nz.pfolsen.com/market-info-news/wood-matters/2009/july/production-thinning-offers-best-way-to-ensure-production-of-high-value-sawlogs-at-final-harvest/

https://www.rayonier.com/stories/what-happens-during-a-timber-harvest/

1.3 Felling and Processing Heads:

1.3.1 Dangle heads

Generally, these heads are capable of felling, delimbing and cutting to length so they are a great tool for extraction thinning.

Woody feed roller head

A very popular head in Europe, Woody is a harvesting head that has 6 different models. The WH40 is a thinning head delimbing between 40 and 400mm. It has an extremely useful and unique grapple function as well, capable of opening to 750mm.

https://www.forsttechnik.at/products/harvester-heads/woody-wh40 https://ofertas.finanzauto.es/wh40-1-3/

Logmax 2000T is another example.

https://www.forestry.com/editorial/log-max-2000t-new-harvester-head-small-harvesters/

1.3.2 Crane movement assist with a dangle head.

Fixed wrist heads are useful to assist machine movement on slopes. Dangle heads can utilise the crowd ram attachment (picture below left) for similar functionality. This design type can also be used as a live heel for moving wood.

FMS 575 stroke head

Stroke heads (picture below) move along the stem delimbing and, if required, cutting logs by gripping the tree with grapple arms then sliding the delimbing knives along the stem using a telescopic stick principle. The movement, per extension, is approximately a metre and can aggressively delimb. The delimb knives then clamp the stem while the grapple limits its grip so the head can move toward the delimb knives. Like a caterpillar's movement but the mechanism is linear.

https://www.forestmachineservices.com/portfolio-item/fms-575-stroke-head/

1.3.3 Fixed wrist heads

TMK tree shear

The biggest model of this head cuts up to 400mm. It is fitted with vertical delimbing capability, and a collector can be added. The collector allows multiple cuts to be held before grounding. A head of this type is used by Rayonier Matariki Forests in Canterbury.

https://tmktreeshear.com/products/tmk-400/

Collector

Delimber

https://www.ncdequipment.com/tmk/tmk-300/

Vertical delimbing occurs by grasping the unsevered tree and vertically moving the crane, allowing the head to slide up or down the tree.
The length of vertical delimbing can be extended using an underslung squirt stick arrangement shown in the following picture.

Woodcracker
There are multiple products from this Austrian company: https://www.westtech.at/en/

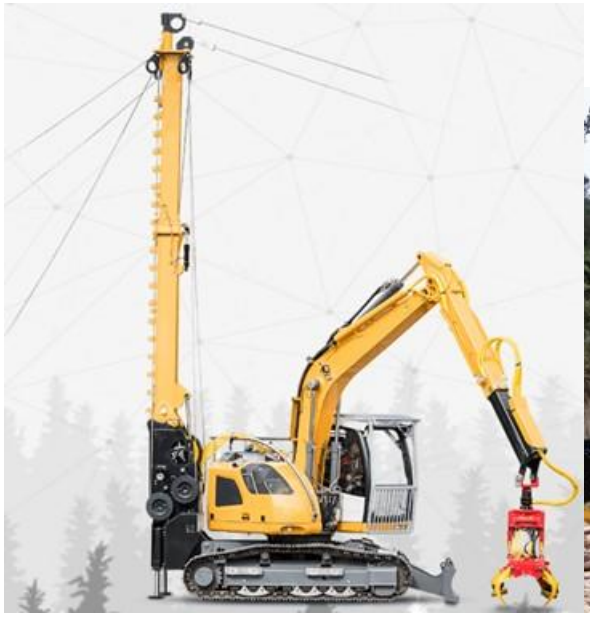

The fixed wrist head is what Tombleson Logging uses on their Cat 315F machines for thinning (Photo above courtesy Nick Tombleson article – see Task 2).

Tree Lopper
The Exac-one British tree shear comes in varying degrees of sophistication.

https://www.exac-one.co.uk/

Jak Shear
The company features both fixed head and dangle head shear: https://www.jak.fi/all-products/

1.3.4 Cable extraction
In Europe, logging is often carried out in corridors, and by cable yarding machines. This corridor approach is similar to thinning extraction requirements. Small yarder systems may prove useful in NZ. It does however seem problematic to shift the cableway to conform with different corridors. At one end this could be done with a yarder which doesn't require guy ropes.



https://www.forsttechnik.at/products/tower-yarders/combi-yarder https://www.emsnewzealand.co.nz/harvestline

1.4 Futuristic machines:
1.4.1 – Chemical thinning
Killing trees instead of thinning them may have some merit in thin to waste. For example, manual chemical thinning (drill-and-fill) or a drone or small ground machine may be able to spray, ringbark or inject undesirable trees to kill them.

1.4.2 Robotic approaches

Robotic tree-to-tree felling machine
The latest documentation for this unique machine seems to be Report No. H030: (Contact Forest Growers Research for more information). The machine has twin booms and two heads. It moves by grasping one tree after another and is capable of felling trees as it moves.

There is merit in evaluating this prototype for its potential for thinning. Some of the limiting factors that apply to felling mature trees are minimised in thinning because of scaling realities.

Courtesy Keith Raymond FGR. No link.

Walking robot
If an operator with a saw can thin trees then perhaps a quadruped can! These types of robots are becoming sophisticated. Spot from Boston Dynamics is very agile.
In this picture Spot has a robotic arm.

https://www.cnet.com/science/see-boston-dynamics-spot-robot-dog-play-jump-rope-and-pick-up-laundry/

Lower left is another robot climbing steep terrain.

https://www.anybotics.com/anymal-autonomous-legged-robot/

There is also a Chinese yak that outsizes the above robots considerably.
https://www.techeblog.com/china-yak-quadruped-robot/

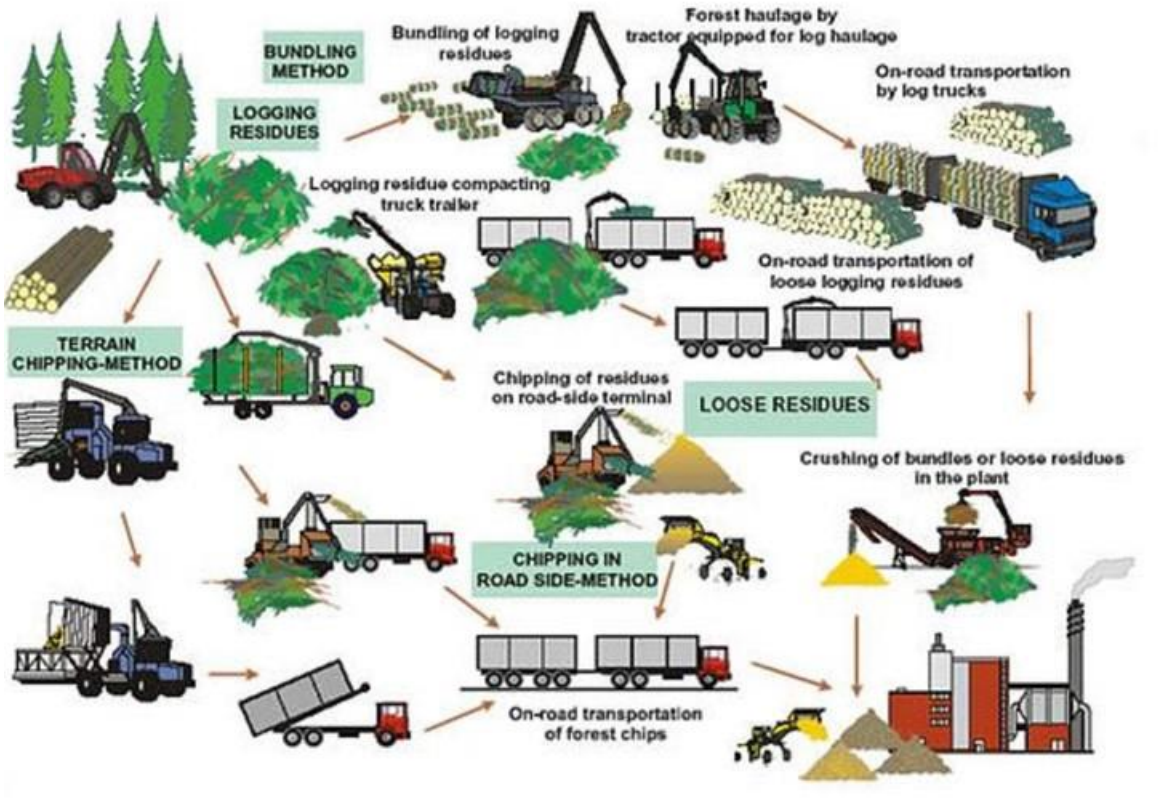
1.5 Biomass

Extracting biomass is an established process outside NZ and is currently getting airtime here. An example from NZ Logger Magazine November 2021 page 30 (Requires payment).

https://issuu.com/nzlogger/docs/lg_20211101_60

There are a number of different uses for biomass and its potentially green energy. Obviously, extraction economics work in some situations, but would biomass extraction work in thinning on hill country? The simplest solution may be to mulch the whole tree, or parts of the tree that don't have other uses, on the slope to create density.

Chippers, bundlers and grinders create the biomass. Below are some illustrations of machines and procedures.



There is more data on the website below.
https://www.eubia.org/cms/wiki-biomass/biomass-resources/challenges-related-to-biomass/recovery-of-forest-residues/

The trailer (above) is a useful instrument for creating biomass from thinnings in the field.
https://all.biz/skorpion-350rbp-drum-chipper-trailer-forest-g266806PL
The trailer or forwarder (lower) is extracting bulk biomass to be processed elsewhere.

There is an argument expressed by a number of foresters that some biomass (branching) should be left on the slope as nutrient, to dampen rain runoff and to improve access.
This reasoning probably has increasing relevance on steeper slopes.

Note: Perhaps as the world moves to greater fire risk, this reasoning may evolve.
https://www.canadianbiomassmagazine.ca/a-chip-off-any-block-1129/

A tracked chipper can fill a trailer on the slope.

https://www.fwi.co.uk/machinery/forst-tracked-woodchipper-munches-8-inch-timber

Task 2 – Domestic Operations

Review domestic operations to ascertain the extent of thinning to waste, the degree of mechanisation in waste thinning and identify new developments with potential application to steep land.

2.1 NZ Thinning Data

The following data are derived / estimated from the table in Appendix 1 and is for the year ending 31 May 2020.

- Waste Thinning – 43,500 hectares per annum
- Production Thinning – 6,500 hectares per annum

2.2 Domestic Operations

Disclaimer: the expressed opinions may change through more discussions with people already applying mechanised thinning. Discussions on mechanised thinning to waste in NZ were with Nick Tombleson and Acacia Farmery.

Nick Tombleson – waste thinning and logging contractor with operations in multiple arenas.
https://www.pressreader.com/new-zealand/new-zealand-logger/20190225/282265256720586
Some of Nick's experiences are covered in the above link which is very informative reading. The article was originally in the NZ Logger magazine. Nick uses a Cat 14.9 tonners fitted with a woodcracker shears. He believes an 8m reach is necessary as it allows reach to 2 rows on either side of the access row.

Picture courtesy of Nick Tombleson – Tombleson Logging

Acacia Farmery – Forest Estate Manager (Rayonier/Matariki). Mechanised waste thinning operations in Rayonier Matariki Forests Canterbury are progressing well using a high and wide,14 tonne Kobelco, fitted with a TKM shear. Limitations mentioned were simply the 20 degree slope.

Picture courtesy of Acacia Farmery – Rayonier Matariki Forests Canterbury

2.3 New developments with potential application for steep land.

The thinning to waste operations in NZ described above are relatively new developments. One challenge is to extend these practices onto steeper land. The acceptable slope figure mentioned for machine capability described above is 20 degrees. However, it is relatively easy to envisage machines going onto steeper land as that has been achieved in harvesting with similar machinery.

Tethering (winch assist) has taken off in harvesting in NZ and should have a useful role in thinning to waste dependent on the thinning machine type (see **Task 3**)**.**

Apart from the above, we can look at the technology outlined in Task 1 and pick out the best features from across these designs that could be incorporated into a new and novel approach.

Teleoperation (remote, out of sight control) also has a role to play.

Task 3 – Current Commercial Extraction Thinning

Review current commercial extraction thinning technology in use and the potential for extending this to steep land.

Discussions about commercial extraction thinning technology in NZ were with:
Patrick Dravitzki – commercial extraction thinning Rayonier / Matariki Forests Northland.

Picture, Valmet 860 courtesy of Patrick Dravitzki – Rayonier Matariki Forests Northland

Type of harvesting machine, Valmet/Komatsu 430 Rayonier also uses a small Waratah harvesting head.

There is potential to extend current commercial extraction thinning technology to steep land because the machines that are relevant to this in **Task 1** were selected for that reason. Tethering would have to be used in many situations which may not suit contour planted slopes. Some of the machines currently being used in NZ are big. Bigger is not necessarily better, a point which was also noted by some interviewees. One major reason is that big machinery is clumsy with the environment, and the steeper the slope, the worse it gets. Other reasons include: big machinery costs more, requiring greater productivity, and also requires bigger winches and anchors.

Commercial extraction may need better road access on hill country, increasing costs. Forwarders and trailers could be used on lower quality roading, while wire rope skyways could be an alternative. Understand in the economics of these options is key.

3.1 Tethering

Argiuably, the winch is better mounted on the machine. It is a simpler, more versatile and generally a more cost-effective setup for smaller machinery. Because the rope is not dynamic there is less chance of damage to standing trees. If the machine can be used parallel to the slope tethering is an obvious tool. Anchoring, exacerbated by smaller trees to anchor to, is a challenge that can be overcome.

3.2 Current forest plantings in NZ

Forest planting in NZ is predominantly manual and follows contours on steep slopes. Contour planted thinning is likely to need a nimble machine because of the potential sideways movement required. The sideways movement may discount tethering because of tree damage but short run winching and synthetic cable would be helpful. A tracked skid steer (self-levelling) or a walking machine would be best suited to sideways movement. Safety is a more obvious concern in this scenario because of sidling around steep hills.

3.3 Future machine-oriented forest plantings.

To optimise machine performance, future tree plantings could utilise parallel to slope rows that are spaced to suit extraction. Roading should also be taken into this mix. Electronic guidance for planting, mixed with other rules and tools, would aid this operation. Pivot steer and perhaps ground carriage technologies would be useful. The use of tethering, where necessary, would allow extraction to be practical. A forwarder tethered may not need chains fitted all of the time so be able to keep going on second grade accessways to the truck access road.

Transport out of a woodlot is a potential challenge where roads are not up to standard or not yet developed. Potential here is to use forest trailers and tractors or forwarder.

Task 4 – Guide to Develop Work Programme

Prepare a report on the findings of the review that can be used to guide the development of the work programme for the Thinning Workstream.

4.1 Opportunities and challenges

Low fruit – what operators of current thinning machinery see as improvements to their operations.

Biggest bang for the short-term buck – modify current machinery, potentially from **Task 1.**

Can we design better machinery? – This topic will be the focus of a mini-workshop scheduled for September. It is important to start with creative thinking that considers a wide range of possibilities e.g. ***Thinning to waste.*** Spot (Task 1), with an electric chainsaw, could do that. But what if Spot gets stuck or the chain comes off the bar? Could Spot use a tungsten carbide brushcutter blade? What if the blade hits a rock? How will Spot directionally fell? What if Spot can't get through the undergrowth? Another example would be the use of a drone for either chemical thinning or (with a heavy-lift drone) for cutting and extraction.

Existing machinery**.** Much of the machinery highlighted in Task 1 is useable for thinning to waste and / or extraction on steep country in NZ. Some of the larger machines need to be scaled down in size to be useful. It is useful to consider machine size:

- We are dealing with trees that weigh say 200kg, 10 times lighter than the 2000kg mature tree.
- Do we need a thinning machine around half the weight of a standard feller buncher?

Commercial requirements. How expensive can an operation be? This defines machine sophistication, slope capability, projected work rate, running costs, etc.

Physically and electronically define the operating environment.

- Define "steep land" including slope, soil stability and slope uniformity.
- Define the pre thinned and thinned crop in terms of tree type, age of thin, spacing, and age/diameter/height. This relevant to new plantings

Data generation and management. Any process in plantation forestry going forward will be data-driven by the exponential evolution of electronic technology (digital forestry). This is also part of the extended programme. Forest data overlays will provide a progressively complete data matrix for different operational phases. Drones and satellites will play a major role in this, and 5G networks and private 5G networks (evolving rapidly) will allow at least 2D teleoperation (similar to our vision) capability for remote machines. On board sensors and drone data (above and below canopy) will allow machines to move semi autonomously in mostly predefined situations. Eg: preselection of work path and tree selection. In forest signal capability is a potential problem, exacerbated by stand trees. This capability will be improved by tech evolution and other practical initiatives.

The tough ask is to mechanically design something better than existing solutions**.** Initiatives Awdon has researched are drones, tethered drones, tethered balloons, small tracked robots, signal core winch cable, to name some. Another important consideration is to develop flexible machinery, that can thin to waste or extract in the same setting, dependent on precalculated conditions.

A mechanical solution wish list:

- Maximised personnel safety.
- Attractive to personnel.
- Economically viable, carbon neutral, and an environmentally sustainable footprint.
- Easily transported and robust.
- Consider teleoperated machinery, hybrid / electric technology, regenerative energy, and cross over capability into pruning and planting. Teleoperation will ultimately lead to multiple unit control.

Summary

Silviculture in steep land NZ is still mostly a manual process.
It is necessary to bring appropriate mechanisation to thinning and other operations on steep land in NZ.
Plantation forestry on steep land has a major and growing part to play in the future of NZ.
Mechanisation morphing to robotics is fast becoming the way of the world.

Appendix 1.

Waste Thinning – 43,500 hectares per annum
Production Thinning – 6,500 hectares per annum

This data is derived from the table below and is for the year ending 31 May 2020

New Zealand Planted Forestry in Summary

Area and standing volume statistics	As at 1 April 2018[4]	As at 1 April 2019	As at 1 April 2020
Forest area			
Net stocked area (ha)	1,704,494	1,696,584	**1,665,237**
Harvested area awaiting restocking (ha)[1]	50,072	51,609	**45,192**
Total forest area	1,754,566	1,748,193	**1,710,429**
Growth characteristics			
Standing volume (000 m^3)	482,511	494,618	**501,116**
Average standing volume (m^3/ha)	283	292	**301**
Area-weighted average age (years)	17.63	17.91	**18.25**
Area by species[2]			
Radiata pine (ha)	1,532,444	1,525,711	**1,494,429**
Douglas-fir (ha)	104,258	103,410	**98,380**
Cypress species (ha)	9,928	9,825	**9,987**
Other softwoods (ha)	23,378	23,381	**24,295**
Eucalypts (ha)	22,148	21,777	**21,485**
Other hardwoods (ha)	12,339	12,481	**12,662**
Radiata pine area by tending regime			
Pruned with production thinning (ha)	145,859	140,318	**138,754**
Pruned without production thinning (ha)	574,564	547,042	**530,346**
Unpruned with production thinning (ha)	51,664	50,733	**52,931**
Unpruned without production thinning (ha)	760,358	787,617	**772,398**
Planting statistics	**Year ended 31 Dec 2017**	**Year ended 31 Dec 2018**	**Year ended 31 Dec 2019**
New planting[3]			
Total estimated new planting (ha)	6,000	7,000	**19,000**
Restocking (ha)	36,616	41,073	**41,207**

https://www.nzfoa.org.nz/images/FGT_3704_Facts_and_Figures_202021_Web_FA1.pdf

Approximate figures are used to derive thinning figures above.
Total area of radiata pine – 1,500,000 ha
Area of production thinning – 190,000 ha = 13% of total area
Planting 60,000 ha. Assume constant figure of 50,000 ha per yr? Higher than the above average.
13% production thinned = 6,500 ha.
Assume the rest thinned to waste = 43,500 ha

References and other:

Most references are embedded above.

Silviculture Solutions required.

https://www.rnz.co.nz/news/country/464301/wairoa-farmers-face-devastating-effects-of-consistent-rain

https://www.1news.co.nz/2022/04/09/flood-stricken-wairoa-still-faces-long-road-to-recovery/

Radiata Pine Growers' Manual – J. P. Maclaren 1993

https://cdm20044.contentdm.oclc.org/digital/collection/p20044coll6/id/9/rec/1

https://www.nrc.govt.nz/media/nvgdfkxq/plantation-forestry-best-practice-for-northland-july-2020.pdf
page 16.
Recommended regime: Plant at 600-1200 stems per hectare. For clearwood production prune to 6-8m in 3-4 lifts and thin down to 200-400 stems per hectare for a 25 year harvest. For unpruned framing regimes final crop stocking can be as high as 600 stems per hectare.

Mechanised Silviculture
Opportunities and Challenges for the New Zealand Forest Industry – Mike Baker
"waste thinning generally involves trees that are 10-30cm in diameter". Page 11
"small bobcats" used by Ken Holmes in Kaiangaroa page 11.

Konrad highlander bunk trailer
https://www.youtube.com/watch?v=ZxKRPh08pVA

Farm Forestry New Zealand
https://www.nzffa.org.nz/farm-forestry-model/species-selection-tool/species/pine/radiata-pine/
Planting spacing: 600-1500 stems per hectare, or between 2 and 3 times the planned final crop stocking to allow choice in selecting the final crop trees. Spacings of 2 x 5 metres, 2.5 x 4 metres, or 3.16 x 3.16 metres will all give 1000 trees per hectare.

https://www.nzffa.org.nz/farm-forestry-model/resource-centre/information-leaflets/nzffa-guide-sheets-2007/nzffa-guide-sheet-no-1/

Autonomous John Deere
https://www.powermotiontech.com/video/video/21238695/john-deere-autonomous-tractor-benefits-from-deep-learning-and-computer-vision?oly_enc_id=7985D5064734E2B

Robots are coming
https://www.stuff.co.nz/science/102182695/robots-are-coming-to-nz-forests

Teleoperation

FPInnovations

USING TELEOPERATION IN FORESTRY: IMPROVED SAFETY AND GREATER ACCESS TO TIMBER

Why teleoperation of harvesting machines?

A further stage in the evolution of harvesting is teleoperation, which would enable harvest machines to be operated remotely and out of the operator's sight. This provides an opportunity to combine human attributes such as awareness, perception, and decision making, with the advantages of autonomous machine functions such as precision, accuracy, and task repetition.

Video screen of teleoperated Caterpillar feller buncher
(Courtesy of ARA)

Benefits and challenges

Teleoperation may improve machine productivity and consequently, reduce harvesting costs. This could be realized by having one operator operating two machines simultaneously, safely, and offsite. Increased machine utilization and reduced operator fatigue would result in this scenario and lead to productivity gains. This could enable more access to timber at a lower cost.

Reducing working fatigue and enabling operators to work offsite in a safe and comfortable environment would also make operator positions more attractive to new workers and could extend the career of existing operators.

Virtual reality-based teleoperation of forwarder
(Courtesy of Skogforsk's Tröndsson Forestry Teleoperation Lab)

It also increases the safety. For instance, operating harvesting machines on steep slopes is hazardous since the steep pitches cause machine instability. This increases the risk of the operator losing control of the machine and potentially causing serious injuries and costly machine damage. By removing the operator from the machine, these risks are mitigated.

Teleoperation requires human-machine interaction using advanced autonomous navigation, machine sensors, and sophisticated communication protocols. Some of the challenges to implementing this technology include developing a robust communication system, improving productivity, reducing ownership and operating costs, integrating teleoperation with winch assist technology, as well as finding early adopters.

Development of teleoperation technology in forest operations

Applied Teleoperation Limited (ATL) (New Zealand) and Applied Research Associates (ARA) (U.S.) have developed teleoperation systems for forest operations. These systems allow an operator to remotely control harvest machines from an onsite trailer. There are also several other teleoperation technology providers that are currently developing virtual reality-based technologies that may be applicable to harvesting machines. However, the technology still needs further refinement to meet the requirements of the Canadian forest sector.

Lead the initiative and pilot teleoperation in the Canadian forest industry!

FPInnovations has identified winch-assisted skidders as the most feasible entry-point for the implementation of teleoperation technologies in Canadian forests due to the relative simplicity of operations compared to other harvesting phases (e.g., feller buncher, harvester, etc.). If this is proven successful, then teleoperation could be adopted by other machines, such as feller bunchers or loaders, and possibly in equipment used at mills.

Early adopters of these technologies stand to gain from reduced operating expenses through better machine availability and being at the forefront machine design improvements and modifications. A pilot study of teleoperated skidders operating on steep slopes in Canada is proposed to determine the feasibility of teleoperation technology. An incentive program could be developed to offset some of the financial and operational risks for the participating contractor. Key technology providers have been identified, and life cycle requirements such training, parts availability, and technical support could all be examined within this pilot program.

More information

Logging contractors and forest companies in Canada interested in piloting the teleoperation in their operations are invited to contact Mithun Shetty, Senior Researcher, at mithun.shetty@fpinnovations.ca.

http://magazine.woodbusiness.ca/publication/index.php?m=853&i=709833&p=24&ver=html5
May/June 2021

https://mydigitalpublication.com/publication/?m=853&i=737097&p=18&ver=html5
Canadian Forest Industries January/February 2022
Connected Forests – p 18 – setting up a remote digital network