Small Growers Harvesting
TECHNICAL NOTE

SGH-TN03
Date: November 2021

Small Scale Forest Grower Options, Full Mechanisation – Production Thinning

Summary

Production thinning has long been an option for corporate foresters in New Zealand. The past 50 years or so has seen a progression of production thinning systems ranging from simple motor manual with wheeled machine extraction on easy topography to more complicated rope and even manual chute systems for short length post and pulp production in steeper country.

Fully mechanised systems were introduced as far back as the 1980s. As the industry trends away from chainsaws, in-bush cut-to-length processing and extraction thinning can be as financially viable as thinning to waste. Mechanised production thinning operations are usually found only where large-scale forests are located close to product markets, however. For smaller-scale growers, production thinning is rarely considered as a viable option. Poor economies of scale, lack of market access, and lack of specialised small-scale contractors with appropriate equipment, have all resulted in thinning to waste remaining the preferred management option.

Small scale processing and extraction options using lower cost equipment, and which consider the environment, safety, and residual stand protection over a straight-out focus on production, do exist and could be considered by smaller-scale growers.

This FGR Technical Note describes a study of one such example currently operating in small forest blocks in the southern South Island where the prime objective of the thinning is to enhance the value of the residual stand over a longer than normal rotation.

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Introduction

Most forest growers ‘thin to waste’ to reduce forest stands to final crop stocking. For small growers of *Pinus radiata*, thinning to waste is often delayed or in many cases not undertaken at all. Reasons may include lack of capital, absence of skilled contractors or simply lack of knowledge that ultimately results in a less than optimally managed stand.

For growers of higher value species, production thinning may feature in the management plan for the stand. The thinnings may be commercially valuable or the stand may be being managed under continuous cover principles.

Every year of delay in thinning results in larger trees, and in today’s world, increasing concerns around safety of manual thinners. Recruiting and retaining personnel to undertake manual thinning is becoming increasingly difficult.

Mechanised systems for both in-stand processing and log product extraction are common practice overseas and now most likely an unstoppable trend for thinning in New Zealand forests.

A review of the New Zealand literature provides insights into mechanised production thinning systems. These include full length, cut-to-length, out-row, skidder, forwarder and a range of other variations and options. These have all been employed at some time, almost exclusively in *Pinus radiata* or Douglas-fir stands.

Developments in the efficiency and effectiveness of production thinning systems have been somewhat spasmodic due to inconsistent demand for thinnings products for chipping or as specific export grades of log. As a result, establishment of a highly skilled specialised contractor resource has been constrained in many regions.

However, one small-scale production thinning operation continues in Southland where the forest owner engages a small, mechanised crew to undertake a delayed thinning operation in 20-year-old radiata stands.

Stands were planted at 1000 stems per hectare (4m x 2.5m spacing), have received variable pruning but have not received any previous thinning. Markets exist for thinnings products at the nearby Daiken

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Mataura MDF plant as well as small export grade logs therefore providing a viable production thinning option.

In addition, the thinning operation to approximately 500 stems per hectare is improving the health and vigour of the final crop for growing through to a later harvest age (30 years) rather than the untenable alternative of clearfell and replant at current age. *Nectria fuckeliana* (Nectria canker) is a problem in some lower South Island crops, and removing infected stems, which are distorted by the canker, is added reason for production thinning on these sites.

Studies were undertaken and supporting information collected in contractor John Fodie's operation over four days in early June 2021 in wet and cold weather conditions that resulted in poor ground conditions.

Fodie's harvest system

The system which is the focus of this study consisted of:

- Hyundai Robex 14t excavator with Satco 214 felling and processor head
- John Deere 1210E forwarder equipped with bogie wheel band tracks
- Hitachi Z-Axis 225 excavator loader stationed at the roadside for forwarder unloading, stacking and truck loading.

Fig 1: Hyundai harvester/processor.

Fig 2: Forwarder unloading at roadside.

The crew consists of the owner who operates the feller/processor and controls the bush operations and the forwarder/loader operator who also loads trucks.

The forest stand was pre-roaded with relatively small log accumulation and load-out waysides spaced over the road network.

There was no forest stand data available. Estimated extracted tree size was 0.5 – 0.7m^3/stem. Extracted processed log length was variable with billet – 6m with min 10cm SED (small end diameter) for chip product destined for the MDF plant and 3.9m – 5.2m for export grade K and KX logs.

Fig 3: 20-year-old stand prior to thinning.

Study approach

Time studies were carried out on the bush machine thinning and processing, and the forwarder load, unload and travel elements. Operational time was analysed and delays, although recorded, were not used in any data analysis.

The weather was wet and soil conditions boggy and waterlogged, therefore quite demanding on forwarder performance, albeit with wheel bands fitted. Forwarder extraction routes generally fell within 0 – 10 degrees with slope having no noticeable impact on forwarder speeds so all data was grouped within this slope band.

The single-pass nature of the processing machine's felling and processing activities meant that these were not affected by ground conditions.

The prime objective of the time studies was to determine forwarder and processor cycle times to enable optimising of production performance within the harvesting system.

While it was not possible to measure load weight, either via load cell or measurement, the number of logs for each load was counted, enabling some high-level estimates of weight.

Time studies were supplemented by UAV videography that captured both forwarder and processor activity within the system.

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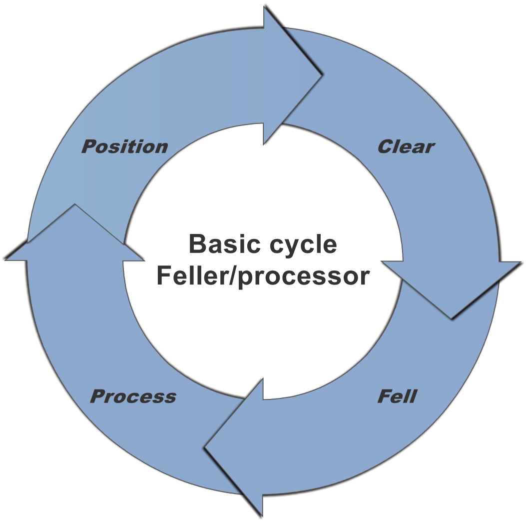
Production data presentation

Data presented in tables below follow a simple work study approach. These represent activity at the studied site and are therefore specific to that site.

Feller/processor

The cycle of tree-felling and processing follows a normalised pattern



Position – the machine is positioned adjacent to the tree to be felled.

Clear – clearing of under-scrub or low branches to access the stem.

Fell – clamp the tree, fell, and bring to ground.

Process – de-limb, cut to length, and stack.

NB: Felling and processing elements occur for each tree cycle, clearing and positioning may not occur during each cycle. Felling of dead trees will not incur any processing time but may involve some dead stem reduction to separate from residual stems or spread to enable better decomposition.

Table 1: Feller/processor - basic operation times.

Element	std. time/tree (mins)
Clear	0.280
Fell	0.579
Position	0.493
Process	1.342
Fell dead	0.086
Total	**2.780**

As noted earlier individual tree measurement at time of felling and processing was not undertaken and high-level yield and stem data per hectare was used to estimate mean tree size as 0.5 – 0.7m³. Our observations strongly suggest that total tree fell and process time depends more on tree shape, size and distribution of branching rather than tree size.

Table 3a provides a mechanism for additional machine and operator specific allowances. For this we have adopted a historical work study figure of 31.8%. This accounts for extra time, usually non-productive, that includes rest, contingency, and process allowances. Daily production (m^3/day) estimates have been provided for two tree size scenarios that represent the observed tree size range (0.5 m^3 and 0.7m^3 trees, processed into logs 0.125 and 0.175/piece).

Forwarder

Forwarder extraction tracks were measured and machine travel time, both loaded and unloaded, plus loading, and unloading activities were recorded.

Elements noted were as follows:

Travel unloaded – forwarder travel from unloading site at roadside to positioning for first log pick-up.

Load – pick logs from bush stack and load. Includes forwarder travel to next bush stack.

Position – major machine re-position to a new area of pick-up.

Travel loaded – forwarder travel from bush upon placement of last log to unload site.

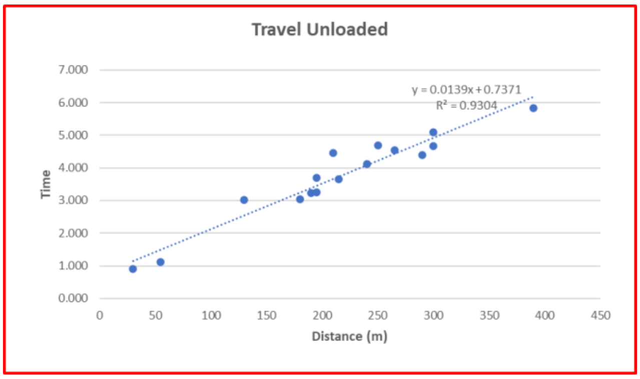
Unload – logs unloaded by roadside excavator and placed in log stacks.

Travel Times

Forwarder travel times are obviously impacted by distance, slope, and ground conditions. Observed slopes during the study were within a range of 0 – 10° and no further breakdown was required, and ground conditions were consistent for the study duration.

Simple travel time regression analysis was undertaken, and results are displayed in the following graphs:

Graph 1: Travel unloaded time = .01399 (dist) + .7371



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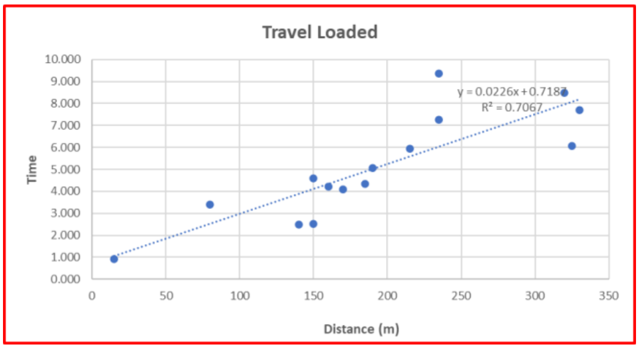
Graph 2: Travel loaded time = .0226 (dist) + .7187



As expected time/distance relationships are strong with the greater variance for travel loaded attributable to varying load weight.

Table 2: Forwarder – basic operation times (@ 200m).

Element	std. time (mins)
Travel unloaded /10m	0.352
Travel loaded /10m	0.524
Position/occ.	1.715
Load/stem	0.352
Unload/stem	0.207

Position occurrence – 50% of cycles (repositioning)

Processed logs/tree – 3.315

Production Work Value

Basic data contained in Tables 1 and 2 were used to construct production levels for each machine, and further to estimate a crew production level.

Table 3a: Extrapolation of basic data to daily production – processor.

Target calculation			mins/stem
Position			0.493
Clear			0.280
Fell live stem			0.579
Fell dead			0.063
Process live stem			1.342
Process dead			0.023
Total Cycle/stem			2.780
+ Allowances 31.8%			3.664
Cycles/day			130.988
m^3/day (.5 m^3/tree)			65.494
m^3/day (.7 m^3/tree)			91.691

Table 3b: Extrapolation of basic data to daily production – forwarder

Target Calculation (200m)			mins/cycle		
			200m	175m	250m
Travel unloaded	.0139*200+.7371		3.517	3.170	4.212
Position			1.715	1.715	1.715
Load			20.387	20.387	20.387
Travel loaded	.0226*200+.718		5.238	4.673	6.368
Unload			12.142	12.142	12.142
Total cycle time			43.000	42.087	44.825
+ Allowances 31.8%			56.674	55.471	59.079
Cycles/day (480 min)			8.470	8.653	8.125
Production @ .125m^3/piece			62.009	63.354	59.485
Production @ .175m^3/piece			86.813	88.695	83.278

Discussion - crew production

In this study it is not intended to quantify optimum crew production as this is dependent on numerous variables including forwarder travel distance, processor access distance, crew allocation of duties to include truck loading, number of trucks loaded per day, variability in tree size etc. Rather, maximum crew production will normally be determined by the controlling cycle that in this case is that of the forwarder, i.e. 62 – 87 m^3/day at 200m lead distance dependent on tree size at 0.5 - 0.7m^3.

Machine costing

Indicative daily crew operating costs of this mechanised production thinning system were estimated using commonly used machine costing methodology. Costing of forestry equipment relies on individual and specific operator preferences and circumstances. Different costing methodologies can produce a range of outcomes. Rather than rely on any one methodology or introduce any perception of bias we have adopted two common forestry equipment costing approaches:

"Business Management for Logging, 3rd edition 2020", Future Forests Research.

This is an updated version of the costing handbook for loggers first produced by the NZ Logging Research Association in 1981 and subsequently reviewed three times by the Blackburne Group, Chartered Accountants.

"Informe Harvesting 2021" and daily rate estimates, based on an independent survey of harvesting equipment, vehicles, labour and overheads, by Forme Consulting Group Limited.

This publication, widely subscribed to by industry participants, is based on a comprehensive costing methodology developed for managing harvesting operations during the last 20 years of the NZ Forest Service.

Here we provide machine costings that provide a daily cost range rather than define and discuss the relative merits of each methodology.

Fig 4: Forwarder loading in the forest.

One significant difference however is the flexibility within the Informe model to differentiate between the number of fixed and variable hours used for machine operation. This is important where variable (operating) hours for a harvesting machine may differ considerably from those fixed hours that require recovery of fixed costs when harvesting systems and scale constrain available working hours. To demonstrate this the roadside stacker and loader is only partially engaged whereas the forwarder and processor are utilised for full day.

Table 4a: Key cost inputs – machinery

	Processor	Forwarder	Loader
Purchase price	$435,000	$600,000	$300,000
Power KW	87	156	122
Standard hours	1400	1400	1400
Variable hours	1400	1400	800
Life hours	8555	15000	9932
Cost set of tyres		$28,800	
Fuel	$1.30	$1.30	$1.30
Interest (debt)	8.00%	8.00%	8.00%
Interest (equity)	3.00%	3.00%	3.00%
Risk	1.50%	1.50%	1.50%

Table 4b: Indicative annual machinery costs – Informe

	Processor	Forwarder	Loader
Depreciation	$56,950	$42,879	$29,482
Interest/risk	$20,121	$28,579	$13,877
Insurance	$13,606	$19,432	$9,392
R & M	$50,377	$34,206	$29,173
Fuel	$18,073	$23,660	$14,368
Oil	$2,050	$3,470	$1,625
Tyres		$13,440	
Overheads	$11,289	$13,003	$12,700
Total/annum	$172,465	$178,670	$110,616
Total/day (235 days)	**$733.89**	**$760.30**	**$470.71**

Table 4c: Indicative annual machinery costs – BMOL

	Processor	Forwarder	Loader
Depreciation	$53,390	$39,312	$31,717
Interest/risk	$20,153	$26,730	$13,268
Insurance	$5,971	$7,920	$3,931
R & M	$34,704	$25,553	$20,616
Fuel	$34,835	$45,427	$35,526
Oil	$5,225	$6,814	$5,329
Tyres		$13,440	
Total/annum	$154,279	$165,196	$110,388
Total/day (235 days)	**$656.51**	**$702.96**	**$469.74**

Note: Individual cost components vary between differing approaches to costing e.g. BMOL Is based on 75% borrowed capital, Informe 70%, differing fuel consumption formulae, no overhead component (BMOL) etc.

Crew costing

To complement machinery costing we have constructed a crew costing that is similar to that observed during on-site studies. The summary below captures the additional cost items upon which we have based our total crew cost.

Table 5: Daily crew cost components

Cost/day		Informe	BMOL
Crew accessories		$79	$79
Powersaw		$50	$50
Vehicles	2 vehicles @ 60km	$180	$180
Processor		$734	$657
Forwarder		$760	$703
Loader		$471	$470
Wages	Owner + 1 hr travel + 1 hr overtime	$553	$553
Wages	Operator + 1 hr travel + 1 hr overtime	$437	$437
Total		**$3,264**	**$3,128**

Note: For non-machinery costs we have adopted common costing methodology based on "*Informe Harvesting 2021*".

Operation indicative costs/tonne

Table 6 provides estimates of the operational costs of production thinning per day, and per tree for the two estimated tree sizes in this operation, using the two costing techniques:

Table 6: Operation indicative cost/tonne (200m forwarder lead)

Indicative costs/tonne	**Informe**	**BMOL**
$/DAY	$3,263.86	$3,128.17
0.5m^3 tree size (62m^3/day)	$52.64	$50.45
0.7m^3 tree size (87m^3/day)	$37.52	$35.96

System balance

As noted earlier we have not attempted to balance the workloads between the processor and forwarder/load cycles as the study outcomes represent the operation as observed in near balance;

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however further system refinement could occur in a number of ways, for example:

- increasing/decreasing forwarder lead distance to discover optimum distance
- re-allocation of truck loading tasks from the forwarder operator to the processor operator thus freeing the forwarder operator to forwarder operation only
- reducing truck load-out by rescheduling to outside normal work- day
- calculating an interference time i.e. in this case where the processor is delayed (as observed on numerous occasions) by forwarder movement within its operational area. This is a theoretical calculation only but possible at optimum forwarder haul distance.

Production thinning options for small growers

Small scale forest growers considering a production thinning operation may need to bear the following in mind:

1. Condition and current state of the stand. This will include age, size, topography, and previous silviculture treatment. Stocking will be a key consideration for accessibility of equipment where small highly manoeuvrable machines that leave little damage to the residual crop are able to access cull stems. Smaller, more powerful and sophisticated felling and extraction equipment are increasingly available.
2. Health of the stand, in this case, production thinning is undertaken predominantly as a *Nectria* control operation. Wind damaged stands, where access for personnel with powersaws is dangerous, could also be considered for production thinning as a tidy-up operation
3. Access to a product market. In this case the Daiken Mataura mill is an outlet for pulp grade material and a strong market for small export material is available through the Port of Bluff.
4. Ready access to the forest stand without the need to construct metal roads and/or dismantle farm infrastructure such as fences/gates/water pipes etc.
5. Lack of local manual thinning-to-waste crews - these crews are becoming harder to find for a variety of health, safety, and wellbeing reasons. Forest stands that have missed a timely thin-to-waste operation become increasingly costly to thin because they need advanced felling skills - in some cases this will preclude manual operations altogether.

Consideration of mechanised thinning to waste

Processor data collection methodology has allowed some further analysis to provide production estimates if log recovery and extraction was not carried out i.e. operation is mechanised thin to waste. This is summarised in Table 7:

Table 7: Mechanised thinning to waste – estimated cost/day.

Processor only fell to waste Cost/day	**Informe**
Crew accessories	$79
Powersaw	$50
Vehicle	$90
Processor	$734
Wages Owner + 1 hr travel	$485
Total	**$1,438**

Estimated No. trees/day = 224
Estimated stems/ha removed = 300
Estimated ha/day = 0.75
Estimated cost/ha = $1917

This assumes felling time will be similar as for a stem recovery operation where additional care to reduce breakage and management of stem placement etc impact felling times.

Conclusion

Production thinning has been a viable option in some New Zealand forests for decades. This is particularly true where forests are large, located within the supply circle of a significant pulpwood market, and have access and topography suited to mechanised operations.

Increasing availability of smaller and highly sophisticated equipment, the shift in tree harvesting from motor manual to mechanised, and a wider variety of market options, are now opening up opportunities for smaller growers to consider production thinning as an alternative to early thin-to-waste stand treatment.

John Fodie's Southland operation is an example where such operations can be viable for both the contractor and forest owner. While perhaps marginally cost-effective for the forest owner in this scenario, our view is that with further system development and refinement such operations can become cost effective.

We note that residual stand damage was minimal, testament to the care and skill of the crew operators and see no reason why similar production thinning operations which are common in other parts of the world and often on much more difficult topography, cannot become normalised practice in our industry.

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Acknowledgements

Support and funding for this project was provided by New Zealand Forest Growers Research Limited and the New Zealand Forest Growers Levy Trust.

We also acknowledge the assistance and co-operation from John Fodie and Roger Hill, and Forest Enterprises Growth Ltd, forest manager for New Forests Southland Estate Ltd where the study was undertaken.

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Appendix: Machine Specifications

1. John Deere forwarder

KEY SPECIFICATIONS - JOHN DEERE 1210E FORWARDER	
ENGINE	
John Deere Power Tech Plus 6068	
Engine displacement	6.8l(415 cu.in.)
Net peak power	140 Kw at 1900 rpm
Net peak torque	780 Nm at 1400 rpm
TRANSMISSON	
Hydrostatic - mechanical, 2 speed gearbox	
Tractive force	175 kN
Travel speed - gear 1	0 - 7.5 km/h
Travel speed - gear 2	0 - 23 km/h
DIMENSIONS	
Wheel base (mm)	5100
Length (mm)	9570
Width (mm)	2746
Fuel tank capacity	167 L
Ground clearance (mm)	755
Gross vehicle weight (kgs)	21,800
WHEELS/TYRES	
Front	26.5 - 20
Rear	26.5 - 20
BRAKES	
Hydraulically actuated, oil immersed, multi-disc	
HYDRAULICS	
Load sensing, power adjustable	
Pump capacity (cm^3)	140
Operating pressure	24 Mpa
Hydraulic tank	161 L
BOOM	
Type	CF7
Maximum reach lengths	7.2/8.5/10m
Gross lifting torque	125 kNm
Slewing torque	32 kNm
Slewing angle	380 deg
CABIN	
Rotating, or rotating and levelling	
Rotating angle	280 deg
Tilt - sideways	10 deg
Tilt - forward and backward	6 deg

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2. Hyundai excavator

KEY SPECIFICATIONS - HYUNDAI ROBEX 14T EXCAVATOR	
ENGINE	
Kirloskar 4R 1040T	
Water cooled, 4 cycle diesel, 4 cylinder in line,direct injection turbo charged	78 kW at 2200 rpm
Max. torque	368 Nm at 1500 rpm
Displacement	4160 cc
DIMENSIONS	
Crawler length (mm)	3750
Overall length (mm)	7850
Overall width (mm)	2600
Cab height (mm)	2860
Operating weight (kg)	13500
KEY SPECIFICATIONS SATCO 214 FELLING HEAD	
Weight	1370 kg
Number of knives	4 moving / 1 fixed
Max. full coverage delimb dbh (cm)	35
Max. roller open (cm)	60
Max. delimb open (cm)	60
Saw type Hultdins supercut	100 - 19cc motor
Max. cut (cm)	64

Note: Standard specifications from product brochures

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