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MECHANISED THINNING WITH A WARATAH GRAPPLE HARVESTER AND TIMBERJACK FORWARDER

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ABSTRACT

A production study was undertaken of a system using a Waratah HTH Model 230 single grip harvester and a Timberjack 230 8 tonne forwarder to production thin a stand of radiata pine on flat country. Using a modified fifth row outrow method, the harvester selected, felled and delimbed approximately 60 trees per productive machine hour (PMH) in a mean merchantable tree size of 0.48m³ (29 m³/PMH). The forwarder extracted log lengths of 5.0 to 6.0 metres (0.17 tonne piece size), in 11.0 tonne loads, a distance of 200 metres to a landing. The extraction productivity of the forwarder was 22.6 m³/PMH. A difference in productivity of around 30% between the two forwarder operators was measured, while a difference of 25% between the two Waratah operators was found.

INTRODUCTION

Mechanised thinning systems have been the focus of several recent research investigations in New Zealand. These systems tend to be comprised of two parts, harvesting (felling, delimbing and cutting to length) and extraction. One harvesting machine evaluated in New Zealand conditions was the Lako harvester in tree length thinning (Raymond et al, 1987).

Extraction by forwarder, while considered the standard overseas, is becoming a feature of some of the more recent mechanised thinning operations in New Zealand. For example, a Volvo 861 forwarder was studied in shortwood thinning (Raymond and Moore, 1989).

The two most important factors affecting the productivity of harvesters, delimbers or processors working in radiata pine is the level of malformation and branch size. These aspects of mechanised harvesting have been examined in several previous studies (Johannsson and Terlesk, 1989, Johannsson, 1990).

This Report describes an operation using a single grip harvester and a forwarder in production thinning of radiata pine in New Zealand.

ACKNOWLEDGEMENTS

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MACHINE DESCRIPTIONS

Waratah HTH Model 230 Single Grip Harvester

Figure 1 - Waratah HTH working in Kaingaroa Forest

The Waratah HTH has a hydraulically driven chainsaw, with a 66cm bar running 0.404 chain for felling trees of up to 55cm at the butt. For delimbing, there is one fixed knife and two movable wrap-around knives. Trees are driven through the knives by three spiked feed rollers. The hydraulic requirement is 270 l/min. at 250bar, and the total weight of the harvester head is 1450kg. In this operation the Waratah was mounted on a Caterpillar E200B base machine which was powered by a Caterpillar 88 kW (118 hp) diesel engine.

Timberjack 230 8 Tonne Forwarder

The forwarder used was a Timberjack 230 8 tonne model powered by a General Motors 353N diesel engine rated at a maximum 70 kW (94 hp). The forwarder was fitted with a Serco 4000 crane

Figure 2 - Timberjack forwarder working in Kaingaroa Forest

which had 360 degree rotation, a 1.5 tonne lift capacity at 3.1 metres and a maximum reach of 5.5 metres. The grapple was a Northland Steel Products LG500 with an open width of 1.8m. Bunk capacity of the Timberjack is rated at 7.3 tonnes and 4.8 metre log length. Operating weight of the unit is 9.3 tonnes.

STUDY AREA

The study area was a seventeen year old radiata pine stand in Kaingaroa Forest. All trees had been pruned and the operation produced 100% pulp material, with no sawlogs. Details of the stand are outlined in Table 1.

Table 1 - Stand details

STAND AGE (years)	17
INITIAL STOCKING (stems/ha)	576
FINAL STOCKING (stems/ha)	236
MEAN MERCH. DBH (cm)	26.6
MEAN MERCH. TREE SIZE (m^3)	0.48

SYSTEM OPERATION

The system had been working for six months prior to the study. Four operators were employed in the operation, two for each machine. Although three of the four operators had some experience in logging, and machine operating generally, experience on harvesters and forwarders was limited to this period. The operators worked in alternating shifts approximately five hours each, without breaks. Limited long term data (20 days) from a more recently logged block showed daily scheduled hours of 10 to 10.5 hours. The off-duty operators trimmed roughly processed logs, and trees unsuitable for the harvester prior to uplift by the forwarder, and also assisted with maintenance.

Waratah HTH

The work method involved the Waratah entering the stand at one end and working at right angles to the access roads and skids. A modified fifth row outrow method was followed (Figure 3). The work method was modified to the extent that efforts were made to avoid removing crop trees. The"outrows" were roughly parallel and spaced at approximately 15 metre intervals.

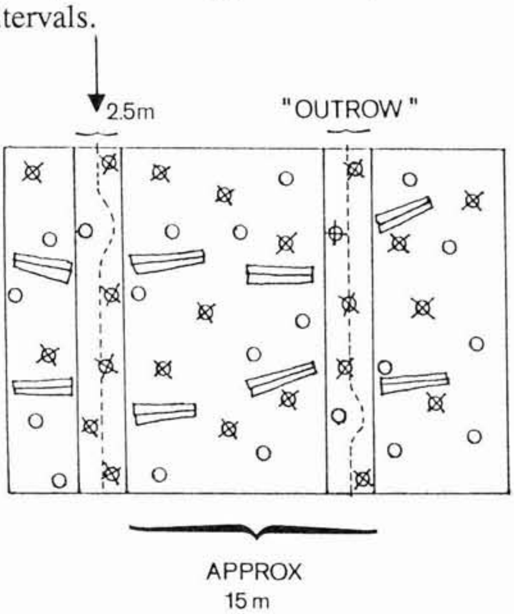

Figure 3 - Layout for extraction by forwarder

The harvester felled and delimbed trees both into and away from the unthinned stand, processing logs, and piling them for the forwarder. Slash was removed from the log piles to aid manual trimming of some partially delimbed logs, while heads were placed in the harvester's path as a slash bed to minimise the impact of machine travel. The processed logs of length 5.0 - 6.0 metres were not bunched to allow the off-duty operators to trim more effectively and to aid the forwarder in grappling a load. Grappling was easier with the logs splayed rather than bunched because the grapple claws overlapped as opposed to abutting each other. The productivity of the harvester was also enhanced through not bunching the processed logs.

Timberjack Forwarder

The forwarder's travel was restricted to the outrows, moving forward as loading progressed. Large logs were loaded individually, with several smaller logs being grappled together to improve loading efficiency. Frequently, logs would be pulled closer to the machine to enable a successful lift and to avoid damage to crop trees.

Once loaded, the forwarder travelled forward out of the stand along the outrow to the access road and on to the skid. In this cold-deck operation, logs were unloaded to a stack, with poorly delimbed logs segregated for manual trimming. Returning to the loading site along the outrow, the forwarder either turned in the stand to extract in the direction it had come, or continued on to extract to the skid on the opposite side of the block, depending on the distance of the skids from the load site.

Most forwarders feature rear-facing dual controls. The Timberjack used these to avoid turning manoeuvres on the skid, where space could be limited. The forwarder also frequently reversed distances up to 50 metres along the road, and at times, for considerable distances into the stand.

STUDY METHOD

Pre-Study Measurement

Prior to timing the work cycle of the harvester, all trees in the machine's path were assessed for DBH, pruned status and form class (Table 2). This data was then linked, on an individual tree basis, to the harvesting times measured during the time study.

Table 2 - Assessment of tree form

FORM CLASS	CRITERIA
1	Straight, small branches (branches < 6 cm.)
2	Straight, slight sweep (some branches > 6 cm.)
3	Malformed,(eg. double leaders, heavy sweep) or many large branches.

Post-Study Measurement

At the conclusion of the study period, more than 200 logs were measured for length and large and small end diameter, in order to calculate mean log volume. The same logs were also assessed for limbing quality before manual tidy-up trimming (Table 3).

Table 3 - Assessment of logs for delimbing quality

LOG QUALITY CLASS	CRITERIA
1	Flush trimmed or stubs less than 1 cm.
2	Largest stub from 1 to 2 cm.
3	Largest stub from 2 to 5 cm.
4	At least one stub greater than 5cm.

To obtain a mean log size in tonnes, a truck payload from weighbridge measurement was divided by the number of pieces loaded on the truck. Six 100m by 6m plots were located at right angles to the outrows to assess residual stocking levels and damage to crop stems.

RESULTS AND DISCUSSION

Waratah 230 HTH Grapple Harvester

Table 4 - Productive work cycle for 445 observations

Element	No. of obs.	Mean per cycle (min)	Mean per obs. (min)	95% Conf. limits
Process (merch. trees)	445	0.77	0.77	0.04
Move	290	0.13	0.22	0.01
Bunch	38	0.05	0.35	0.07
Clear slash	27	0.02	0.30	0.10
Clear stumps	9	0.01	0.35	0.13
Other (incl.fell unmerch. trees)	35	0.02	0.25	0.04
Average time per productive cycle	445	1.00		
Mean no. of logs per tree	3.1 ± 0.1			
Mean tree dia. (DBH cm.)	26.6 ± 0.7			
Mean merch. tree size (m^3)	0.48			
Productivity/PMH (m^3)	28.8			

Total duration of the study was 8.2 hours of which 7.3 productive machine hours (PMH), were recorded. Work cycle and tree measurements were recorded for 356 trees, and additional times were taken for a further 124 trees, a total of 480 trees for the study. Approximately 224 merchantable stems/ha were removed yielding an estimated 108 m^3/ha. The mean DBH of thinned stems was 26.6 cm, with a mean volume per tree of $0.48m^3$.

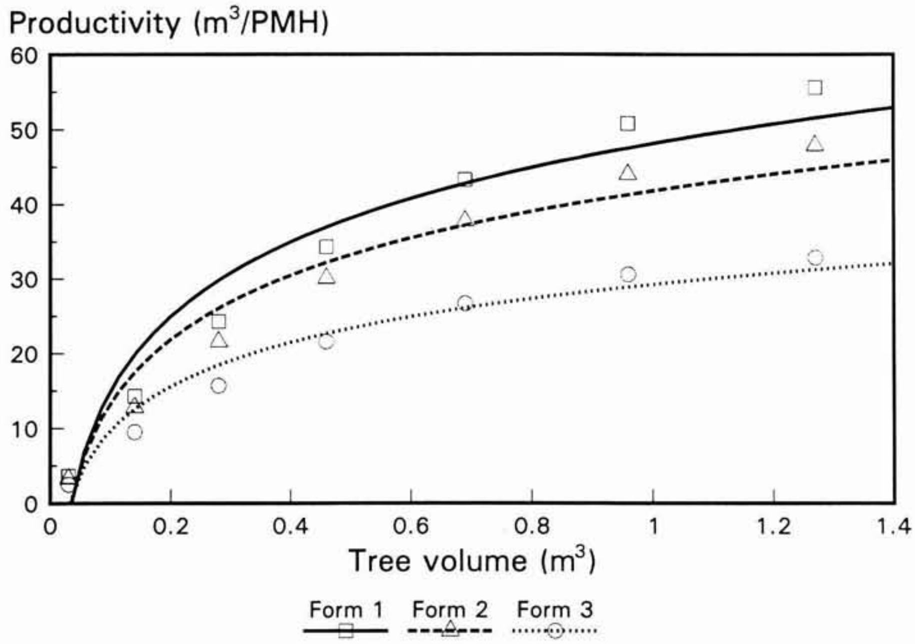

Figure 4 - Harvester productivity for form classes 1, 2 and 3

Two operators were observed. Operator A was observed for 178 cycles and Operator B for 312. Average productivity for the harvester operation was 28.8m^3/PMH, with a production rate of 60 trees per hour, or 1.00 minute per tree. An average 3.1 logs were cut from each tree with an average piece size of 0.16m^3. A count of logs being loaded on truck resulted in an estimated mean piece weight of 0.17 tonnes/piece. Details of the productive work cycle are shown in Table 4. The "process" element is comprised of the sub-elements of "select", "position", "fell" and "delimb" and "cut-to-length". On average, 13% of the productive cycle time was spent moving between tree processing sites.

There were significant differences in the processing time for merchantable trees between Operator A and B, with Operator B being 23% faster processing trees of form class 1 and 27% faster in form class 3 trees. This suggests that as the tree form becomes more demanding, the difference between operators is more pronounced.

Effect of Tree Form on Productivity

Tree form class had a significant effect on processing time, with malformed or large branched trees taking significantly longer to process. Form class 2 trees took 25% longer to process than class 1, and class 3 trees 120% longer than class 1 trees. Figure 4 shows the effect on productivity of processing trees of different form classes. Of the trees processed, 44% were of class 1, 27% of class 2 and 29% of class 3. The following equation was developed to predict process time by DBH and form class. All thinnings had been pruned to heights ranging between 2m and 7m, but pruned height did not appear to affect processing time.

Process Time (minutes) =
(exp (0.0457 x DBH (cm) + F))/1000
$R^2 = 0.63$

where F =

5.08	for form class :	1
5.262	"	2
5.693	"	3

exp = base e raised to the power of the value

Log Lengths and Delimbing Quality

Mean log length measured was 5.17 metres ($\pm$ 8 cm, 95% confidence limits). Minimum length measured was 2.6 metres and maximum was 7.07 metres.

Table 5 - Assessment of logs for delimbing quality (n = 175)

CRITERIA	OCCURRENCE
1. Flush trimmed or stubs less than 1 cm.	26%
2. Largest stub from 1 to 2 cm.	37%
3. Largest stub from 2 to 5 cm.	20%
4. At least one stub greater than 5cm.	17%

Damage to Residual Stems

Post-operation quality control plots indicated that damage levels were low. The total for all categories of damage, (defined as any amount of bark removal from anywhere on the tree, of a minor or major type, incurred during felling or extraction), was 4%, of which one third was attributed to forwarder operations (P. Orme, pers. com). During the time study of the forwarder, no damage to residual stems was observed.

Timberjack 230 8 Tonne Forwarder

Detailed work cycle measurements were recorded for a total of 17 cycles. Two operators were observed (6 and 11 loads respectively) extracting loads averaging 65 logs or 11.0 tonnes. Calculated forwarder productivity for a 200m haul distance (100m on outrow + 100m on access road) was an average 22.6 tonnes/PMH. Details of the work cycle are shown in Table 6.

During the study, travel time for the average 200m haul distance took approximately 12% of the productive cycle time. Some difficulty was experienced turning on to and off the access roads due to narrow road width and steep berms, often the result of "old crop" debris. Travel in the stand was faster on wide, straight and level outrows and payload had little effect on travel speed.

Loading and unloading took up 59% and 25% of the productive cycle time respectively. The consistently higher number of logs grappled by Operator B illustrates the importance of optimising grapple cycles both during loading and unloading and explains much of his higher productivity. Picking up well presented low bunches, that are close to the outrow, clear of crop trees and free of debris is most efficient. The harvester can and should help in this respect as it currently has a higher production capacity.

Analysis of the productivity data indicated a difference in productivity of around 30% between operators in this study. This difference between operators is far more significant than that attributed to changes in payload or travel distance (Figure 5). Such variation must be considered when planning such operations.

The cab layout, crane controls and operator's environment in this machine was sub-optimal. Improvements to these functions may lead to improved productivity.

Table 6 - Timberjack 8 tonne forwarder performance data

	OPERATOR A	OPERATOR B	DATA RANGE
No. of Cycles Measured	6	11	
Average Cycle Time (mins.) *	35.27	25.29	21.20 - 41.85
No. of Logs / Cycle	67.0	62.7	55 - 73
PAYLOAD (tonnes)	11.4	10.7	9.4 - 12.5
PRODUCTIVITY (tonnes/PMH)	19.6	25.6	15.9 - 31.5
LOADING ** - % of Cycle Time	60%	58%	
- Logs / Grapple Load	3.1	3.8	1 - 9
- Time / Log (mins)	0.32	0.23	
- Grapple Loads Required	21.5	16.3	14 - 27
UNLOADING - % of Cycle Time	27%	24%	
-Logs / Grapple Load	4.7	5.7	1 - 9
- Time / Log (mins)	0.14	0.10	
- Grapple Loads Required	14.3	11.0	9 - 16

* 200m average haul distance (100m on outrow + 100m on access road)
** includes moving ahead during the loading cycle (ca. 25m / full load)

Figure 5 - Forwarder productivity

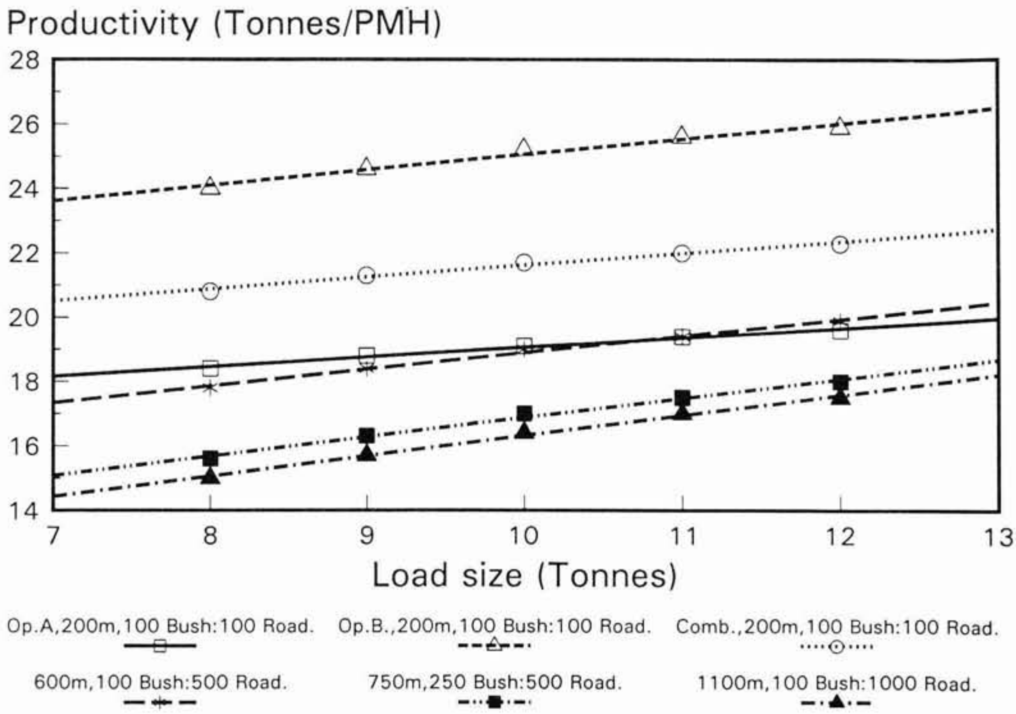

Table 7 - Forwarder travel speeds

		Av. Time to Travel 10m (minutes)	Speed (km / hr)
Travel Empty	- access road	0.047	12.8
	- out row	0.119	5.0
Travel Loaded	- outrow	0.130	4.6
	- access road	0.053	11.3

COST ANALYSIS

Estimates of the daily cost of the operation were established for four operators, working a single shift of ten scheduled hours per day, using the LIRA costing format (Wells, 1981). Machine utilisation estimates for the costing were based on long term data, (70% for the Waratah Harvester and 85% for the forwarder). For the Waratah HTH a capital cost of $410,000 was used and $225,000 for the Timberjack 230 8 tonne forwarder.

Table 8 - Daily cost of the mechanised thinning operation

Item	Cost $/day
Waratah HTH	811
Timberjack 8 tonne forwarder	484
4 Operators	825
3 Saws	75
Vehicle (and mobile workshop)	72
	—
	$2267
Overheads (2.5%)	57
Profit (10%)	227
	—
TOTAL DAILY COST	$2551

CONCLUSIONS

Using a modified fifth row outrow method, the harvester selected, felled and delimbed approximately 60 treees/PMH (29 m^3/PMH). The forwarder extracted log length wood of 5.0 to 6.0 metres in 11.0 tonne loads and had an average extraction productivity of 22.6m^3/PMH. Daily production based on 8.5 PMH per forwarder day is estimated at 192m^3. Using the daily costs in Table 6, unit costs are estimated to be $13.29/$m^3$.

Tree form class, subjectively assessed, had a significant effect on processing time. Slightly swept or kinked trees or with a few large branches, took 25% longer and malformed or large branched trees 120% longer than the time required to process straight, small branched trees. Tree form should be considered when allocating blocks for mechanised production thinning.

Significant differences in productivity were measured between both forwarder and harvester operators (30% and 25% respectively). These differences highlight the difficulty of establishing a benchmark for this activity when assessing a single operator. With respect to forwarder productivity, it was found that the number of logs loaded per grapple load had a major effect on the differing performance between operators.

In summary, the operation was well balanced. The advantages of an "outrow" method were apparent with both machines able to manoeuvre easily and reach trees and logs with a minimum of movement, and hence minimise the risk of damage to residual crop trees. Longer term productivity and utilisation data collection for this mechanised system is continuing.

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The costs stated in this Report have been derived using the procedure shown in the LIRA Costing Handbook for Logging Contractors. They are an indicative estimate and do not necessarily represent the actual costs for this operation.

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