Cable extraction of pulp:
Effect of minimum extracted piece size on productivity

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***Figure 1** – A drag comprising butt and top pieces*

Summary

Researchers from Liro studied the effect of three minimum piece size specifications on the productivity of a cable logging operation. These specifications were:

- >10 cm SED, 3.7m length (**Treatment 1**)
- >20cm SED, 3.7m length (**Treatment 2**)
- >30cm LED, 3.7m length, containing sawlog material (**Treatment 3**)

The major findings were:

- Productivity increased by 9% and 26% by applying Treatments 2 and 3, respectively (Table 1). Increased productivity was achieved through larger average drag volumes
- Treatment 3 resulted in 14 m^3/ha of waste, compared to the 4 to 7 m^3 for Treatments 1 and 2
- Potential net savings to the forest owner (including opportunity costs) by increasing minimum specification above >10cm SED (Treatment 1) were estimated as follows:
  - \$1,134/ha for Treatment 2
  - \$3,136 to \$3,311/ha for Treatment 3.
- Margin on pulp values needed to exceed \$468/m^3 and \$162/m^3 before Treatment 1 and Treatment 2, respectively were more cost-effective than Treatment 3.

***Table 1** - Estimated effect on production (average values). PMH = productive machine hours*

Treatment	Minimum specification (3.7m length)	Volume extracted (m^3/PMH)	Productivity increase relative to Trt 1 (%)
1	>10cm SED	52.5	-
2	>20cm SED	57.7	9
3	>30cm LED (sawlog)	66.6	26

McMahon, Shane; Evanson, Tony; Hall, Peter; Baillie, Brenda: Cable extraction of pulp: Effect of minimum extracted piece size on productivity.

Introduction

Cable logging operations have high daily costs. Correspondingly, unit logging costs ($/m^3) are also high. Therefore, cable logging productivity and subsequent unit costs are sensitive to minimum extracted piece size specifications.

For example:

> Consider a cable logging operation costed at $4,200/day, with an average day comprising 7.5 PMH. This equates to a cost of approximately $0.15/productive second.
>
> A typical minimum extracted pulp log is greater than (>) 10cm SED, 3.7m length. Depending on transport costs and mill door prices, the profit on such a log may range from approximately $0.60 to $1.20.
>
> It follows that, if extraction of this log delays the cable operation for more than four to eight seconds, the extraction cost outweighs the value of the log to the forest owner.

The effect of piece size on hauler productivity has been investigated in the past. Larsen (1985) found productivity could be increased by 5% if the minimum length was increased from 2.4m to 3.7m. If this was further increased to 5.7m, a productivity gain of 23% could be achieved. Given the current market pressures, it is timely to reassess minimum piece size specifications.

This report details the findings of a study to determine the effect of three minimum extracted piece size specifications on the productivity and cost of a cable logging operation.

Study method

The study was carried out on a cable logging operation in Kaingaroa Forest. The extraction machine was a Madill 171 operating the Northbend system. The setting comprised a deep gully with concave sides, devoid of any terrain features that constrained payloads. Two breakerouts were used during the study.

The processing site was separated from the hauler landing by approximately 200m, requiring two-staging of stems with a grapple skidder.

Three minimum extracted piece size specifications were applied across the setting, with a minimum of three extraction corridors per treatment area. These specifications were as follows:

- >10 cm SED, 3.7m length (**Treatment 1**)
- >20cm SED, 3.7m length (**Treatment 2**)
- >30cm LED, 3.7m length, containing sawlog material (**Treatment 3**)

The operation was time-studied over a period of seven days, and data collected on drag volumes and composition. Extracted material was classified as follows:

Butt piece	- stem with butt log attached
Sawlog top piece	- broken stem containing sawlog >30cm LED, 3.7m length
Pulp top piece	- broken stem containing pulp only

The volumes of the butt pieces were calculated using a regression equation derived from the scale measurement of 125 stems extracted during the study. The volumes of the sawlog and pulp top pieces were calculated using a three-dimensional log volume formula (Ellis, 1982). Activity sampling of the processing site was also carried out.

After the operation was completed, the cutover was 100% assessed to determine the volume and size of residual merchantable material. Walk and planting hindrances were also assessed.

Potential net savings ($/ha) to the forest owner through changing the minimum specification were estimated by subtracting opportunity costs from the potential decrease in harvesting costs;

Net saving =

[(%prod. inc. x rate) x rec. vol/ha)] – (waste vol/ha x margin)
Assumptions were as follows:

- The percentage increase in productivity equalled the percentage decrease in unit logging costs
- Average merchantable waste volumes were 7m^3/ha for Treatments 1 and 2, and 14 m^3/ha for Treatment 3
- Recoverable volume = 600m^3/ha
- Logging rate = \$21/m^3 at >10cm SED, 3.7m length specification.

Potential net savings (\$/ha) were calculated over a range of margin on pulp values. The margin on pulp is the profit to the forest owner upon delivering the pulp to the customer.

Results

Drag volume and composition

The average drag volume and composition changed as the minimum specification was increased.

Mean drag volumes increased by 12% between Treatments 1 and 2, and 37% between Treatments 1 and 3 (Table 2). These changes coincided with changes in the drag composition. The proportion of butt pieces increased with increasing specification, whereas the proportion of pulp top pieces decreased. The change in drag composition also resulted in a successive increase in mean extracted piece size; 1.94m^3, 2.08m^3, and 2.58m^3.

The presence of pulp top pieces in Treatment 3 relates to pieces which the breakerouts thought may have produced sawlog, but actually did not. The smaller proportion of sawlog top pieces in Treatment 3, relative to the other treatments, reflects a difference in breakage. The reason for this difference was unable to be identified.

In volume terms, butt pieces contributed between 89% and 98% of the mean drag volume across the three specifications. Mean butt piece volumes for each treatment area were not significantly different ($p<0.05$).

Cycle times

A total of 426 extraction cycles were observed over the seven days. Productive time only was analysed to determine average cycle times.

Underlying differences between cycle times for each treatment were analysed by excluding inhaul and outhaul variation which was predominantly due to haul distance. Standardised inhaul and outhaul times, based on an average haul distance of 200m, were then substituted to give “complete” production cycle time values.

Mean cycle times increased with increasing specification (Table 3). The two main factors contributing to this were increased hook on and breakout times. These trends probably reflect the proportionally greater time required to locate and hook-on extra butt pieces, and slower breakout times for the heavier drags.

Table 3 *– Mean cycle times based on an average haul distance of 200m. Mean values followed by the same letter were not significantly different (p<0.05).*

Treatment	Specification (all 3.7m length)	No. of cycles	Mean cycle time (min)
1	>10cm SED	168	6.60 a
2	>20cm SED	184	6.71 b
3	>30cm LED (sawlog)	74	7.12 b

Table 2 *– Mean drag volume and composition. Mean values followed by the same letter were not significantly different (p<0.05).*

Treatment	Specification (all 3.7m length)	Mean drag volume (m^3)	Drag composition (% of total pieces)		
			Butt pieces	Sawlog top pieces	Pulp top pieces
1	>10cm SED	5.79 a	54	34	12
2	>20cm SED	6.49 a	55	31	14

3	>30cm LED (sawlog)	7.93 b	83	11	6

Table 4 *– Summarised productivity data for the three specifications*

Treatment	Specification (all 3.7m length)	Drags per PMH	Extracted vol/PMH	Productivity increase (%) relative to Trt 1
1	>10cm SED	9.1	52.5	-
2	>20cm SED	8.9	57.7	9
3	>30cm LED (sawlog)	8.4	66.6	26

Hauler productivity

For a given haul distance, productivity is a function of drag volume and cycle time.

Productivity increased with increasing specification (Table 4). Increasing the specification from Treatment 1 to Treatment 2 resulted in a 9% increase in productivity. Increasing the specification from Treatment 1 to Treatment 3 increased hauler productivity by 26%.

Cutover assessment

The cutover within each treatment area was 100% assessed to determine the volume of merchantable waste >10cm SED and 3.7m length. Summarised results are shown in Table 5.

The cutover assessment showed that the volume of merchantable waste was substantially greater in Treatment 3 compared to Treatments 1 and 2. One of the merchantable pieces in Treatment 1 was a small, but complete, stem that had not been extracted. This stem comprised 0.75 m³, or 11%, of the merchantable volume.

Table 5 *– Cutover waste assessment summary based on 100% assessment*

Treatment	Specification (all 3.7m length)	No. of merchantable pieces	Waste >10cmSED, 3.7m length (m^3/ha)
1	>10cm SED	43	7
2	>20cm SED	40	4
3	>30cm LED (sawlog)	92	15

Walk and plant hindrances were assessed. There was no clear relationship between treatment and walk hindrance, suggesting that minor topographic features had a greater effect on slash concentration than did the treatments. The planting hindrance within Treatment 3 was slightly greater than Treatment 1 and 2. This is likely to contribute to slightly slower planting times within Treatment 3.

Calculation of net savings

Table 6 shows the potential net savings to the forest owner through increasing the minimum specification from >10cm to >20cm SED for a range of percentage productivity increases. In this case, changing the minimum specification did not result in a change in merchantable waste, and hence opportunity cost. Therefore, savings to the forest owner reflect the increased productivity alone.

Table 6 *– Potential net saving ($/ha) to the forest owner through increasing minimum specification from >10cm to >20cm SED. A 9% increase in productivity was recorded in this study.*

Productivity increase (%) relative to Treatment 1	Potential net saving to forest owners
3	$378
5	$630
7	$882
9	**$1,134**
11	$1,386

When the minimum specification was increased from >10cm SED to >30cm LED (sawlog), there was a 7m^3/ha increase in merchantable waste. This meant that the potential net saving to the forest owner would vary with the margin on pulp value (Table 7).

Table 7 *– Estimated potential net saving ($/ha) to the forest owner by increasing the minimum specification from >10cm SED to >30cm LED (sawlog only), 3.7m length. A 26% increase in productivity was recorded in this study.*

% productivity increase	**Margin on pulp ($)**				
	20	**10**	**5**	**0**	**-5**
5	$490	$560	$595	$630	$665
10	$1,120	$1,190	$1,225	$1,260	$1,295
15	$1,750	$1,820	$1,855	$1,890	$1,925
20	$2,380	$2,450	$2,485	$2,520	$2,555
26	**$3,136**	**$3,206**	**$3,241**	**$3,276**	**$3,311**

Based on a 26% increase in productivity, increasing the minimum specification from >10cm SED to >30cm LED (sawlog) resulted in a potential net saving ranging from $3,136/ha to $3,311/ha.

An alternative way of viewing these potential net savings is to determine the margin on pulp ($) required before extraction of pulp top pieces becomes economic. Based on the productivity increase mentioned above, the margin on pulp needed to exceed $468/m^3 before Treatment 1, and $162/m^3 before Treatment 2 became more cost-effective than Treatment 3. Thus, in some cases, the margin on pulp may have to increase from 6 to 20 times above present values before extraction of pulp top pieces becomes economic.

Note, that the potential net savings calculated here do not include any added costs associated with slightly increased planting hindrance, and costs associated with changing demands on the processing and uplifting of logs.

Processing activities

The main results from the activity sampling of the processing landing were:

- the skidder was subjected to fewer delays on the landing when Treatment 3 was applied
- the excavator and rubber-tyred front-end loader spent less time sorting and stacking when Treatment 3 was applied
- the skid workers spent more time trimming for Treatment 1, than for the other two treatments
- all of the system components in the activity sampling study had idle time present during all treatments, suggesting that even with the increase in productivity, the system was not necessarily limited by the processing operations.

Discussion

This study demonstrated the potential for increasing cable logging productivity by increasing the minimum extracted piece size specification. The levels of productivity increases found in this study reflect the setting and stand characteristics and the level of breakage. In situations where the terrain is more limiting on payloads, the potential for increased productivity gains is likely to be less. Stand characteristics and breakage determine the volume of pulp pieces available for extraction and total recoverable pulp volumes.

The potential for increased productivity can be gauged by having the hauler operator monitor the drag composition (i.e., number of butt and top pieces). In particular, drags comprising only pulp reduce potential hauler productivity. To a lesser extent, mixed drags (containing butt and pulp pieces) would also reduce productivity.

In some cases, potential gains by increasing the minimum piece size specification may be limited because of a requirement to extract the pulp pieces. For instance, riparian management policies may require the extraction of material smaller than the minimum pulp specification from some sections of the extraction corridor.

The net affect of changing the specification, was the increase in extracted piece size. This could also be achieved by relaxing the cutover waste standard. For example, a current standard of $5m^3$/ha merchantable waste could be relaxed to for example, $15m^3$/ha. The relative difference in butt and pulp top piece volumes and values would ensure that butt pieces were extracted in preference to pulp top pieces. As a means of reducing costs, the adoption of an increased piece size specification has the advantage of providing a clearer guideline for breakerouts.

Acknowledgements

Liro acknowledges the support provided by Fletcher Challenge Forest Limited and Carroll Skyline Logging. This project was funded by the Logging Industry Research Association (LIRA) Inc.

References

Ellis, J.C., (1982) – A three-dimensional formula for coniferous log volumes in New Zealand. FRI Bulletin No. 20. Forest Research Institute, New Zealand Forest Service.

Larsen, A.B., (1985) – A preliminary investigation of cable logging and the influence of piece size on cost and productivity. B.For.Sci. Dissertation, School of Forestry, University of Canterbury.