Advantage

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Contents

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Mechanized processing on steep slopes in summer conditions to produce short logs

Abstract

The Forest Engineering Research Institute of Canada (FERIC) studied mechanized processing in cable yarding operations in summer conditions in northern British Columbia. Two danglehead processors were monitored in seven cutblocks to determine processing productivity and costs, the amount and cost of loader support required, and the effects of slope and other factors on productivity.

Keywords

Processing, Roadside, Steep slopes, Cable harvesting, Danglehead, Short-wood system, Productivity, Costs, Northern British Columbia.

Introduction

In response to member interest in mechanized processing with cable yarding, FERIC conducted winter and summer studies of these operations in northern British Columbia. The cooperator, Canadian Forest Products Ltd.'s (Canfor) Mackenzie Operations, used a short-wood harvest system on steep terrain consisting of loaders, processors, and a swing yarder.

After the winter study was completed (Boswell 2004), Canfor asked FERIC to conduct a follow-up study under summer conditions. Canfor was concerned that productivity may be different in the summer because fewer limbs may break off during yarding when the stems are not frozen. They also expected fewer runaway stems on the steep slopes in the summer than in the winter because more limbs would be on the stems, and snow and ice would not be present. Therefore, in the summer of 2004, FERIC monitored the same two danglehead processors and operators that had worked in the winter study, on seven cutblocks.

This report presents productivity and cost information, the amount and cost of loader support required, and the effects of slope and other factors on productivity, and compares these results to those from the winter study.

Objectives

The objectives of this study were to:

- Determine processing productivity in summer conditions.
- Determine the effects of site and stand factors on processing productivity.
- Compare processing productivity in summer and winter.
- Determine the effects of stem size on processor selection.
- Determine the amount and type of assistance that the loaders provided to the processors and compare the processors working with and without loaders.
- Determine the system costs in summer conditions.

Site and stand descriptions

The seven cutblocks were located approximately 60 km northwest of Mackenzie, near the Nation and Manson Rivers. The harvesting prescription in all cases was clearcutting. Table 1 summarizes the site and stand descriptions. All blocks were classified as the Omenica variant of the Engelmann Spruce - Subalpine Fir moist very cold biogeoclimatic subzone (ESSFmv3) (DeLong 2004). Elevations ranged from 1040 to 1280 m. Although the slopes ranged from 10 to 70% and averaged about 35%, decking and processing locations were much flatter than those in the winter blocks (Boswell 2004). The steepest terrain was in Block 7 (Figure 1) while the flattest terrain was in Block 1. Forest cover was dominated by mature subalpine fir (*Abies lasiocarpa*), hybrid white spruce (*Picea glauca* x *engelmannii*), and lodgepole pine (*Pinus contorta*), with minor amounts of trembling aspen (*Populus tremuloides*).

Figure 1. Block 7 had the steepest slopes.

Equipment and system descriptions

A feller-buncher with cab levelling worked on slopes up to 60% and the remaining areas were handfelled. Bunched and single stems were yarded with a swing yarder equipped with a mechanical slackpulling carriage and radio-controlled chokers. A mobile backspar was used with the swing yarder wherever possible.

A Hyundai 210LC carrier equipped with a Waratah HTH620 processing head could

Table 1. Site and stand descriptions

	Block						
	1	2	3	4	5	6	7
Total area (ha)	60.0	17.3	20.6	33.8	26.5	34.6	208.8
Cable yarded area (ha)	8.8	7.2	8.2	23.3	12.8	10.4	25.6
Site characteristics							
Ecological classification	ESSFmv3	ESSFmv3	ESSFmv3	ESSFmv3	ESSFmv3	ESSFmv3	ESSFmv3
Elevation range (m)	1 080–1 140	1 150–1 220	1 090–1 200	1 120–1 240	1 040–1 150	1 170–1 250	1 120–1 280
Slope							
Range (%)	10–40	15–45	20–50	15–40	20–60	25–45	10–70
Average (%)	32	33	41	33	37	31	38
Stand characteristics							
Species composition (%)							
Amabalis fir	11	12	12	11	10	30	20
Spruce	44	10	54	29	42	47	39
Lodgepole pine	45	75	34	60	48	23	41
Aspen	0	3	0	0	0	0	0
Net merchantable volume							
m^3/ha	385	355	356	382	441	374	384
m^3/tree	1.08	0.58	0.59	0.35	0.54	0.69	0.33

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cut a maximum stem diameter of 620 mm while a larger John Deere 892 ELC carrier equipped with a larger Waratah HTH624 processing head could cut a maximum stem diameter of 780 mm. Specifications for the processors and loaders are presented in Appendix I.

All stems were yarded tree length to roadside, then delimbed and cut to length with danglehead processors. The processors also sorted the logs into piles on the road. Heelboom loaders moved the processed logs to suitable decking areas (Figure 2). The processors and loaders worked together, and independently of the yarder, whenever possible. However, when the yarder's productivity was low, the processor had to wait for stems to process and the three machines worked together. Unlike in the winter study, the slopes adjacent to the road were never so steep that a loader was needed to deck the stems for the yarder.

On some occasions, the loaders moved the yarded stems before they were processed. When the yarded decks were high, the loaders pulled the stems down to a location where the processors could reach them. On other occasions, the yarder decked the stems on top of a high bank and the loader moved them to an accessible location for the processor. A loader also needed to move the stems when they were yarded to a location near a creek.

The processors were scheduled to work 12-hour shifts, seven days per week. However, the lack of stems due to low yarder productivity and afternoon shutdowns due to high fire hazards resulted in night shifts and split shifts. During processing the stems were delimbed, manufactured into short logs, and then sorted by top diameter size into four sorts. The target log length was 5 m for most sorts.

Study methods

FERIC collected shift-level data consisting of Servis recorder charts and operators' reports about operating time and delays (greater than 10 min/occurrence) over three months in six study blocks (Blocks 1–6) for two processors and two operators. The

Figure 2. The loader moving processed logs to a suitable decking area.

shift-level hours and Canfor's scale data were used to calculate net processing productivity per productive machine hour (PMH) and per scheduled machine hour (SMH), summarized by block and by machine. Average availability and utilization rates were also calculated from these data.

Detailed timing data were collected on 51 stem decks in the four study blocks (Blocks 3, 4, 5, and 7) for two processors and two operators. Average gross stem volumes and detailed timing data were used to calculate gross processing productivity per productive machine hour for each stem deck and summarized by block by machine as in the winter study. Correlation and regression analyses were performed on the detailed timing data to test the effects of site and stand factors (i.e., ground slope, deck slope, stem size, defects,[1] branchiness,[2] and deck height) on productivity. The detailed timing results were compared to those from the first study (Boswell 2004) to determine if differences in processor productivity could be attributed to the operating season (winter versus summer). Field observations and plotting of trend lines of the detailed timing data were used to evaluate the suitability of each of the two processor sizes and the cost of working with and without the loaders. Work sampling at 2-minute intervals was done frequently throughout the study period to determine the loaders' tasks and time spent assisting the processor.

[1] Defects were measured as a percentage of the total number of stems processed that had fork or rot.

[2] Branchiness was an estimate of the number and size of branches on a stem before processing, and classified according to a five-point scale shown in Appendix IV.

Hourly processor and loader costs were calculated using FERIC's standard costing methods (Appendices II and III) and were applied to the productivity to determine costs per cubic metre. Equipment costs were calculated using a 12-hour shift, with provisions for overtime for time worked over 8 hours. Generic costs were used for the carriers based on the approximate weight classes of the machines used in the study.

Results and discussion

Shift-level processing productivity

Shift-level data were collected for 74 shifts totalling 595 productive machine hours and 810 scheduled machine hours for both processors in six study blocks (Table 2). Three shifts were excluded because one of the processors did not work due to mechanical problems. Shift lengths ranged from 3.0 to 16.2 hours and averaged 10.9 hours, with machine availability from 77 to 93%. The older John Deere 892 ELC/Waratah HTH624 had lower machine availability. Machine utilization ranged from 66 to 78% of scheduled time and the overall utilization was 73%.

The John Deere 892 ELC/Waratah HTH624 processor was 31% more productive than the smaller Hyundai 210LC/ Waratah HTH620 processor, in terms of net m^3/PMH (Table 3).[3] This pattern was very similar to the winter study where the larger machine was 34% more productive (Boswell 2004). However, the weighted average size of trees processed was larger for the John Deere 892 ELC/Waratah HTH624 at 0.78 m^3/tree compared to 0.47 m^3/tree for the Hyundai 210LC/Waratah HTH620.[4]

For each of the two processors, the shift-level data showed very little variation in productivity per productive machine hour for different blocks (Table 2). There was, however, a trend for each machine to have slightly higher productivity in blocks with

[3] Based on net volume loaded out.

[4] The cruise's average tree size was weighted by the estimated total number of trees processed by each processor.

Table 2. Shift-level summary by block [a]

Processor	John Deere 892 ELC/Waratah HTH624		Hyundai 210 LC/Waratah HTH620		Both	Hyundai 210 LC/Waratah HTH620	Both
Block	1	2	3	4	5	6	Overall
Productive shifts (no.)	9	6 [b]	14	17 [c]	16	12 [d]	74
Productive machine hours (PMH) (h)	74.9	60 [e]	105.5	146.4	122.5	85.1	594.4
Mechanical delays (MD) (h) [f,g]	17.1	15 [b]	20.9	14.0	19.3	29.4	115.7
Non-mechanical delays (NMD) (h) [f,h]	1.7	1.7 [b]	17.4	31.4	22.1	9.9	84.2
Unknown delays (UD) (h) [f]	2.5	0.0	2.9	3.1	2.9	4.3	15.7
Total all delays (h) [f]	21.3	16.7 [b]	41.2	48.5	44.3	43.6	215.6
Scheduled machine hours (SMH) (h)	96.2	76.7 [b]	146.7	194.9	166.8	128.7	810.0
Average shift length (h)[i]	10.7	12.8	10.5	11.5	10.4	10.7	10.9
Utilization (PMH/SMH) (%)	78	78	72	75	73	66	73
Availability [(SMH-MD)/SMH] (%)	82	80	86	93	88	77	86
Total volume processed (m^3)	3 036	2 379	3 178	4 369	4 915	2 788	20 665
Productivity							
m^3/PMH	40.5	39.7	30.1	29.8	40.1	32.8	34.8
m^3/SMH	31.6	31.0	21.7	22.4	29.5	21.7	25.5

[a] Block 7 was not completed before the study ended.
[b] Estimate.
[c] Excludes one day with no production because of computer problem.
[d] Excludes two days with no production because of pump problems and cleaning.
[e] Provided by the contractor.
[f] Includes delays ≥10 minutes.
[g] Includes service, fuelling, and yarder and loader mechanical delays that delayed the processor.
[h] Most non-mechanical delay time consisted of waiting for the yarder, waiting for the loader, and moving the machine.
[i] Operators usually did not stop for a lunch break; they ate during their coffee breaks or delays.

Table 3. Shift-level summary by machine

	John Deere 892ELC/ Waratah HTH624 [a]	Hyundai 210LC/ Waratah HTH620 [b,c]
Productive shifts (no.) [d]	15	43
Productive machine hours (PMH) (h)	134.9	337.0
Mechanical delays (MD) (h)	32.1	64.3
Non-mechanical delays (NMD) (h)	3.4	58.7
Unknown delays (UD) (h)	2.5	10.3
Total all delays (h)	38.0	133.3
Scheduled machine hours (SMH) (h)	172.9	470.3
Average shift length (h)	11.5	10.9
Utilization (PMH/SMH) (%)	78	72
Availability [(SMH-MD)/SMH] (%)	81	86
Total volume processed (m^3)	5 415	10 335
Productivity		
m^3/PMH	40.1	30.7
m^3/SMH	31.3	22.0

[a] All Operator 1.
[b] Operator 1 = 22 shifts; Operator 2 = 21 shifts.
[c] Includes John Deere data for 3 shifts that could not be separated.
[d] Excludes data for 16 shifts where the scale data could not be separated by machine.

Table 4. Shift-level time distribution and delays by machine

	Time distribution (%)	
	John Deere 892 ELC/ Waratah HTH624	Hyundai 210 LC/ Waratah HTH620
Productive time [a]	76.7	71.7
Mechanical delays		
Processor	8.5	5.0
Loader	0.6	0.1
Yarder	1.9	1.6
Service and fuel	5.7	6.3
Waiting delays	2.9	4.4
Waiting for loader	0.0	0.2
Waiting for trucks and other equipment	0.0	6.7
Waiting for yarder	1.8	0.7
Moving delays		
Miscellaneous and unknown delays		
Handbucking oversized stems	0.0	0.2
Measuring logs to check accuracy	0.0	0.3
Running loader (loader operator absent)	0.0	0.4
Other miscellaneous and unknown	1.9	2.3

[a] Includes delays ≤10 min.

higher average tree sizes. The productivity for the Hyundai 210LC/Waratah HTH620 in m³/PMH was lowest in Block 4 where the tree size was smallest, and highest in Block 6 where the tree size was largest. Similarly, the productivity for the John Deere 892 ELC/ Waratah HTH624 was lowest in Block 2 and highest in Block 1, again reflecting the differences in tree size. There was no obvious effect of slope apparent in the shift-level analysis.

The John Deere 892 ELC/Waratah HTH624 spent a greater proportion of its scheduled time performing productive activities compared to the Hyundai 210LC/ Waratah HTH620 (Table 4) because the Hyundai 210LC/Waratah HTH620 spent a large portion of scheduled time waiting for other equipment, mainly the yarder. Delays included time when this processor quit early because no wood was available to process.

Detail-timed processing productivity

Productivities were also determined from 75.2 hours of detailed timing (Table 5). Due to operational constraints, the majority of the detailed timing was done on the Hyundai 210LC/Waratah HTH620 processor. Productivities were higher than shift-level study productivities because they were based on a sub-sample of the population, the volumes processed were determined from the gross stem sizes, and average stem sizes were larger.

The productivity of the John Deere 892 ELC/Waratah HTH624 based on detailed timing data was much higher than that based on shift-level data. This is possibly a result of lower stem utilization, a greater difference in stem size, and a smaller sample in the detailed timing study. The John Deere 892 ELC/Waratah HTH624 processor was 67% more productive in terms of gross m³/PMH than the smaller Hyundai 210LC/ Waratah HTH620 processor.[5]

Processing times per stem were very similar at 0.90 min/stem for the Hyundai 210LC/Waratah HTH620 compared to 0.88 min/stem for the John Deere 892 ELC/ Waratah HTH624. However, the average stem sizes were quite different and this resulted in the large difference in productivity between the two machines. The productivity of the Hyundai 210LC/Waratah HTH620 was the lowest in Block 7 where the stem size was the smallest and the processor worked without a loader in six out of ten of the samples, and it was highest in Block 5 where the stem size was largest. The John Deere 892 ELC/ Waratah HTH624 had less variability than the Hyundai 210LC/Waratah HTH620 in both average stem size and average productivity by block. Its individual timing samples showed little variability in processing time per stem regardless of stem size, resulting in a strong relationship between stem size and productivity.

The proportion of time spent processing stems varied by 11% between the two processors (Table 6). This proportion for the Hyundai 210LC/Waratah HTH620's is lower mainly because in Block 7 it worked without a loader and piled its own processed logs, and in Block 3 it spent much time waiting for the loader or the yarder.

Effects of site and stand factors on processing productivity

Detailed timing observations from processing 51 stem decks were used to

[5] Gross productivity is based on gross stem volumes with no deductions for stem defects.

Table 5. Detailed-timing summary for the processors

	Hyundai 210LC/Waratah HTH620					John Deere 892 ELC/Waratah HTH624		
Block [a]	3	4	5	7	all	3	5	all
Sample stem decks timed (no.)	12	8	6	10	36	4	11	15
Productive time (min)	850	594	741	1 484	3 669	365	479	845
Productive machine hours (PMH)	14.2	9.9	12.4	24.7	61.1	6.1	8.0	14.1
Total stems processed (no.)	799	943	729	1588	4059	456	503	959
Total volume processed (m³)	688	364	633	513	2198	382	471	853
Total logs produced (no.)	2 084	2 222	1 994	3 084	9 383	996	1 198	2 194
Average volume (m³/stem)	0.86	0.39	0.87	0.32	0.54	0.84	0.94	0.89
Average time (min/stem)	1.06	0.63	1.02	0.93	0.90	0.80	0.95	0.88
Average logs (no./stem)	2.61	2.36	2.74	1.94	2.31	2.18	2.38	2.29
Productivity								
stems/PMH	56	95	59	64	66	75	63	68
m³/PMH [b]	48.5	36.8	51.0	20.8	36.0	62.6	58.9	60.5

[a] No detailed timing was done on Blocks 1, 2, and 6.

[b] Productivities are based on gross stem volumes with no deductions for stem defects. Actual net productivity based on processed logs loaded out would be lower.

Table 6. Detailed timing: distribution of productive time for the processors

Block [a]	Hyundai 210LC/Waratah HTH620 3	4	5	7	overall	John Deere 892 ELC/Waratah HTH624 3	5	overall
Distribution of cycle time (%)								
Processing stems	63	79	82	60	68	78	80	79
Debris handling	2	4	2	3	2	5	2	3
Decking stems	4	3	2	4	4	2	5	4
Sorting processed logs	5	1	4	2	3	2	2	2
Piling logs	0	0	0	23 [b]	9	0	0	0
Moving the machine	4	1	1	1	2	2	2	3
Waiting for the loader or yarder	17	7	1	2	6	5	0	2
Delays =< 10 minutes [c]	5	5	8	5	6	6	9	7

[a] No detailed timing was done on Blocks 1, 2, and 6.
[b] In Block 7 the processor worked without a loader about 70% of the time and piled its own logs.
[c] Delays ≤10 minutes were removed from the detailed timing data.

investigate the influence of site and stand factors on processing. Only one of three operator-machine combinations provided good data. In the other two combinations, either the factors tested were strongly correlated and thus obscured the influence of some factors, or no significant relationship could be developed.

For the combination John Deere 892 ELC/Waratah HTH624 with Operator 2 (15 decks), statistical analyses proved that productivity was influenced by only stem size and deck slope (R^2 = .79). Productivity increased with stem size and as deck slope increased from negative to positive values. This may be because gravity hinders processing below the road but aids for decks above the road. Also, in the winter study, operators stated that it was harder to see and grab stems that were below grade. The John Deere 892 ELC/Waratah HTH624 rarely had problems pulling large stems uphill for processing, while the smaller Hyundai 210LC/Waratah HTH620 required a loader's assistance for this task (Figure 3). The stem sizes ranged from 0.58 to 1.32 m^3, and the deck slopes ranged from -45 to +40%.

The previous study hypothesized that deck height affected productivity. While there was a trend between processing time and deck height, further analyses showed that the relationship was not significant. However, the statistical analysis was not able to consider how deck height affects the other time elements.

Effects of season on processing productivity

The average productivity in the summer was higher than in the winter for the John Deere 892 ELC/Waratah HTH624 with Operator 2 (62.3 m^3/PMH compared to 50.8 m^3/PMH, based on detailed timing data for both studies) but the stem size was also larger in the summer (0.95 m^3 vs 0.70 m^3). Summer productivity was slightly lower for the Hyundai 210LC/Waratah HTH620 with Operator 1 (34.1 m^3/PMH vs 38.3 m^3/PMH in the winter) but stem size was smaller in the summer (0.50 m^3 vs 0.66 m^3).

Statistical analysis showed no significant difference between winter and summer productivity for the Hyundai 210LC/Waratah HTH620 with Operator 1, even without considering the influence of stem

Figure 3. The loader assisting the processor by pulling a large stem into position for processing.

size. It did show a significant difference between winter and summer productivity for the John Deere 892 ELC/Waratah HTH624 with Operator 2. However, when the results were adjusted to account for differences in stem size, the difference was not significant.

Availability (86%) and utilization (72%) for the Hyundai 210LC/Waratah HTH620 were both lower in the summer than in the winter (94% and 78%, respectively).[6]

Canfor had hypothesized that productivity might be higher in the winter because frozen limbs may break off during yarding. FERIC rated the amount of limbs on each stem processed during detailed timing according to categories defined in Appendix IV. The results showed that over 90% of all stems fell in Category 1 (negligible) for both seasons (Table 7). Slightly more stems were present in Categories 3 and 4 (moderate and high) in the summer. Overall, the average ratings for branchiness were the same in the summer and winter (1.1). The previous statistical analysis indicated that branchiness does not affect productivity. Even though frozen limbs may be broken off during yarding, the breaks may not be clean and the processor may need to remove the stubs. Also, in order to buck a stem into logs the processor must still pass the entire stem through its head. It was observed that the delimbing was highly efficient most of the time. Only the largest limbs (Categories 3 and 4) slowed the processing but they didn't affect the John Deere 892 ELC/Waratah HTH624 processor as much as the smaller Hyundai 210LC/Waratah HTH620. As there was a very low proportion of stems in the higher categories, these stems had no substantial effect on the overall productivity in these timber types. Results may differ in other stand types.

In the winter, stems sometimes slid off the deck during processing and had to be retrieved by a loader. This did not occur during the summer, but the time and cost to retrieve these logs were not determined in the winter study.

Table 7. Comparision of branchiness in summer and winter

Rating [a]	No. of stems		% of stems	
	winter	summer	winter	summer
1	4 373	4 942	94	92
2	247	244	5	5
3	34	136	1	3
4	17	46	0	1
Total	4 671 [b]	5 368 [b]	100	100

[a] Rating definitions are provided in Appendix IV.
[b] These values are greater than the total stems in Table 5 and Boswell (2004) because this table includes unmerchantable stems and samples with too few stems to analyze the productivity data that were deleted from Table 5 and Boswell (2004).

Effects of stem size on processor selection

Processing time (grab and process only) per stem was consistently faster with the John Deere 892 ELC/Waratah HTH624 compared to the Hyundai 210LC/Waratah HTH620 over the range of stem sizes observed. However, the total productive time (i.e., processing, move, sort, deck, pile, debris, and delays less than 10 min) per stem was faster with the Hyundai 210LC/Waratah HTH620 for stems smaller than about 0.7 m^3.

The productivity in m^3/PMH was influenced by some of the same factors that influenced the processing time per stem, but it was not as sensitive to these factors. When the size of the piece processed is considered, it is estimated that productivity in m^3/PMH is higher for the John Deere 892 ELC/Waratah HTH624 than the Hyundai 210LC/Waratah HTH620 for stems larger than about 0.6 m^3. However, because the John Deere 892 ELC/Waratah HTH624 is a larger machine, it is more expensive to own and operate so this must be considered in determining the lowest overall cost.

Costs per cubic metre for comparable conditions (i.e., equal piece sizes, loader assisting, and no yarder) were more similar for the two machines than the average costs would indicate because of the varying

[6] Availability and utilization were not measured for the John Deere 892ELC/Waratah HTH624 for the winter study.

conditions, piece sizes, and utilization factors for the samples. Further analysis indicates that the Hyundai 210LC/Waratah HTH620's cost in $/m^3$ is lower than the John Deere's when the piece size is smaller than 0.83 m^3/stem, while the John Deere 892 ELC/Waratah HTH624's cost is lower for larger pieces (Figure 4).

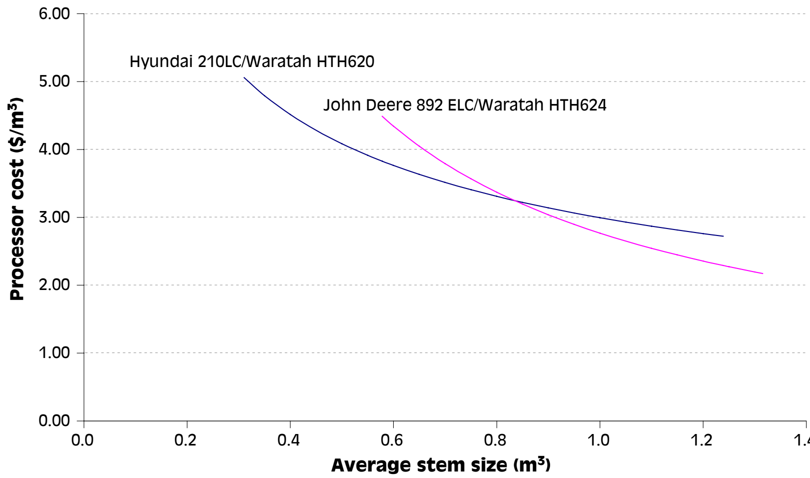

Figure 4. Relationship between predicted processor cost and average stem size for the two processors.

This breakeven point changed to a stem size of about 1 m^3 when the same machine utilization factor (0.78) was used for both machines. However, when considering the system cost (processor plus loader assisting), the breakeven point drops to a stem size of 0.8 m^3, using the same size loader for both processors. These results are based on the equipment costs shown in Appendices II and III, and may vary as fuel or other operating costs change.

The contractor did a good job of matching the machines to the stem size during the study. During detailed timing, the average stem processed by the Hyundai 210LC/Waratah HTH620 was 0.54 m^3 while the average stem processed by the John Deere 892 ELC/Waratah HTH624 was 0.89 m^3. Because the John Deere 892 ELC/Waratah HTH624 mainly worked with larger stems, its overall cost was lower. If both machines had worked with the same size of stems and the stems were smaller than 0.8 m^3, the Hyundai 210LC/Waratah HTH620 would have been the most cost-effective.

Loader support

Work sampling was performed on the loaders for 58.5 hours over 19 days. The results for the loaders assisting the processors are shown in Figure 5 and include data for three loaders. Another loader was usually dedicated to loading trucks, but on three days the loader supporting the processor and yarder also loaded trucks. On two days, there were two loaders on-site assisting the yarder and processor. The loaders' activities consisted of the following:

- piling processed logs
- travelling—moving back and forth between the processor and the log decks
- repositioning unprocessed stems—breaking the pile apart, straightening and untangling the stems, and pulling the stems up closer to the road
- site maintenance—building up areas to place the processed logs and clearing debris

The ground slopes were less than in the winter study and the loaders spent much less time building mats (part of site maintenance) in the summer (0.2%) than in the winter study (2%). The loaders spent less time piling logs in the summer and more time loading trucks, assisting the yarder, and maintaining the site. In the summer study, only 62% of the loaders' time was spent assisting the processor compared to 72% in the

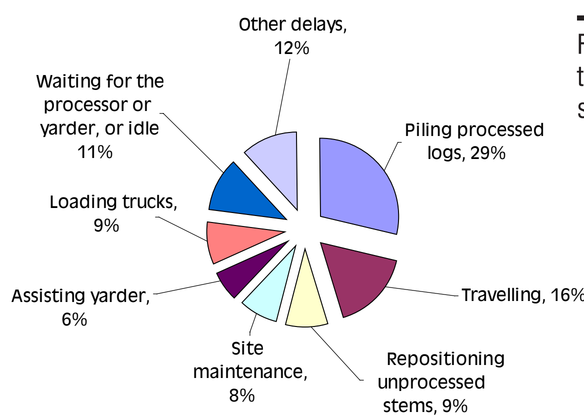

Figure 5. Loader time, work sampling results.

winter. The delay or idle time was similar in both seasons at 23% in the summer and 20% in the winter.

The loaders usually had no trouble finding a location to pile the logs. The average travel distance to pile the logs was about the same in the summer (26 m) as in the winter (25 m), and the proportion of time spent travelling was the same in both seasons. The distance the loaders had to carry the logs was influenced by when the loading took place. If trucks were loaded concurrently with processing, more space was available for piling logs. In Block 5, some right-of-way wood was not removed before the block wood was processed, resulting in less decking space and a longer average travel distance (33 m).

Comparison of processing costs with and without loader support

On fairly flat ground where it is physically possible for the processor to work alone, it may be more economical to work without a loader. During detailed timing, there were seven samples where the Hyundai 210LC/Waratah HTH620 processor worked without a loader due to mechanical problems. Here, the processor sorted and piled its own logs, which provided an opportunity to compare the cost of working with and without a loader. Note that it is not possible for the processor to deck its own logs when the ground slope is very steep. While the maximum sideslope where the processor could work alone was not determined, the ground slope for these seven samples ranged from 18 to 30%.

Non-processing time (i.e., waiting, moving, sorting, decking, and minor delays) averaged 28% of PMH overall but increased to 50% when no loader was present (with or without a yarder). Non-processing time increased from an average of 0.21 min/cycle when the processor was working with a loader but no yarder, to 0.59 min/cycle when working alone. Non-processing time also increased to 0.29 min/cycle when working with a yarder and with a loader. Working with a yarder but no loader increased the non-processing time to 0.72 min/cycle or 58% of PMH.

In order to remove the effects of stem size in the analysis, productivity and costs were plotted against stem size for the samples. Overall productivity increased when working with a loader. For example, for a 0.5 m^3 stem size, productivity increased from about 25 m^3/PMH without a loader to about 50 m^3/PMH with a loader. Correspondingly, processing costs rose from about \$4/m^3 with a loader to \$7/m^3 without (Figure 6 and Table 8). If the loader cost was \$3/m^3 or less, it would be neutral or cost-effective to work with a loader. In this study, the loader cost ranged from \$4.33 to 5.35/m^3. The amount available to cover the cost of a loader varied with stem size and ranged from about \$2/m^3 for stems of 1.2 m^3 to almost \$4/m^3 for stems of 0.3 m^3. It appears that using a loader will increase processor productivity but will increase the overall costs, although with very small stem

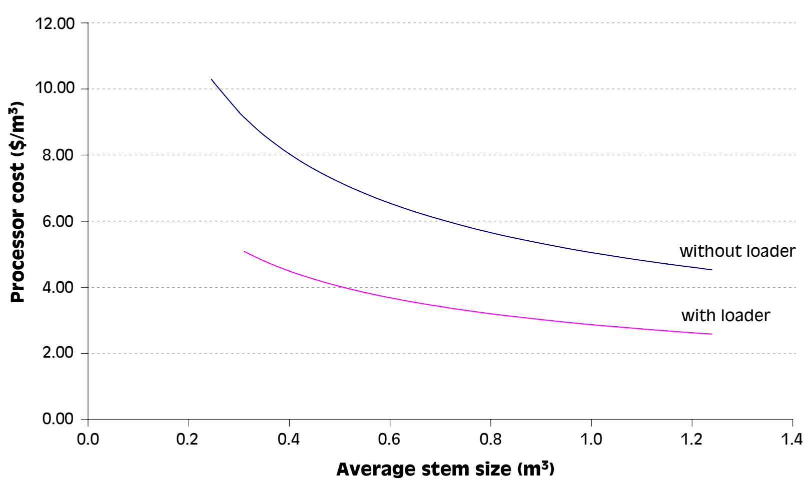

Figure 6. Relationship between predicted Hyundai 210LC/ Waratah HTH620 processor cost and average stem size working with and without a loader.

Table 8. Costs and productivity [a]

Processor	Hyundai 210LC/Waratah HTH620				John Deere 892 ELC/Waratah HTH624		
Loader	Hyundai 290LC	Hitachi EX220	Hyundai 210LC	All loaders	Hyundai 290LC [b]	Hyundai 290LC [b]	Hyundai 290LC [b]
Block[c,d]	3	4	6	overall	1	2	overall
Productivity (m^3/PMH) [e]	30.1	29.8	32.8	30.7	40.5	39.7	40.1
Utilization (%) [e]	72	75	66	72	78	78	78
Productivity (m^3/SMH) [e]	21.7	22.4	21.7	22.0	31.6	31.0	31.3
Hourly machine cost ($/SMH) [f]							
Processor	116.93	116.93	116.93	116.93	140.99	140.99	140.99
Loader	116.20	96.89	96.89	103.33 [g]	116.20	116.20	116.20
Cost ($/m)							.
Processor	5.39	5.22	5.39	5.32	4.46	4.55	4.50
Loader assisting	5.35	4.33	4.46	4.70	3.68	3.75	3.71
Total	10.74	9.55	9.85	10.02	8.14	8.30	8.21

[a] Productivities and costs are based on net volumes loaded out and shift-level timing.
[b] Assumed, loader used for these blocks not known.
[c] Stems in Block 5 were processed by both machines and scale data could not be separated by machine.
[d] Block 7 was not complete when the study ended.
[e] From Table 2.
[f] From Appendix III.
[g] Average loader cost.

sizes there may be a cost benefit. If, however, higher productivity is required or the ground slope is steep, a loader will be needed.

Overall productivity and system costs[7]

The individual utilization rates by block were applied to the processors' shift-level productivity, resulting in overall productivities of 22 m^3/SMH for the Hyundai 210LC/Waratah HTH620 processor and 31 m^3/SMH for the John Deere 892 ELC/Waratah HTH624 processor (Table 8). The John Deere 892 ELC/Waratah HTH624 was 43% more productive than the Hyundai 210LC/Waratah HTH620 in terms of m^3/SMH, partly because of its higher utilization rate. Processing costs ranged from $4.46/$m^3$ to $5.39/$m^3$. The average cost for the John Deere 892 ELC/Waratah HTH624 was 15% less than the Hyundai 210LC/Waratah HTH620, at $4.50/$m^3$ and $5.32/$m^3$, respectively.

The higher productivity of the John Deere 892 ELC/Waratah HTH624 offset its higher hourly machine cost. The cost of a loader working full-time with a processor added an additional $3.68/$m^3$ to $5.35/$m^3$. This cost was less when a loader worked with the John Deere 892 ELC/Waratah HTH624 processor because of this processor's higher productivity. The combined system cost for the processor and loader averaged $8.21/$m^3$ for the John Deere 892 ELC/Waratah HTH624 and $10.02/$m^3$ for the Hyundai 210LC/Waratah HTH620.

Other factors

The processors' boom location on the right of the machines hindered the operators' visibility, so the processors would always swing the stems to the left when processing and drop the logs on the road to the left of the machine (Figure 7). As a result, when a loader was working with a processor to clear and pile the logs, it could only deck the logs in areas to the left of the processor. Processing and decking operations ran the smoothest when the processors were able to work continuously from left to right (as the processor faced the stem deck) and where

[7] Note that these productivities and costs are not directly comparable to those from the winter study, because the winter study was based on gross volumes whereas these figures are based on net volumes. See the detailed timing results to make comparisons.

Figure 7. The processor always processed and placed the logs on the left side of the machine due to visibility.

Figure 8. The loader pulling down stems in a high yarder deck for the processor in Block 4.

Figure 9. The loader moving the stems to roadside before processing due to a creek in Block 5.

there was adequate decking space to the left of the processor.

Processing productivity was low sometimes because the yarder's productivity was low and wood was not available to keep the processor busy. The contractor would have preferred to operate the yarder two shifts per day as in the winter study which would have helped the yarder to stay ahead of the processor. However, difficulties obtaining crew prevented this. Hot weather in summer resulted in fire closures during the day which also prevented running two shifts on the yarder. As well, delays in completion of in-block roads reduced the wood available for yarding.

In several blocks, the terrain and layout affected processing negatively. In Block 4, a large area was yarded to one location, resulting in a very large deck of stems (Figure 8). This slowed processing as the pile had to be pulled down first. Yarding a large amount of stems to one spot also made it more difficult to find adequate space for the processed logs and processing debris.

In Block 5, the road was located below a creek. Many stems were yarded to the creek and then loader-forwarded to the road for processing (Figure 9). The processor experienced delays as these stems were moved to roadside.

In a steep area of Block 5, the yarder landed stems on a high bank above the road. The processor could not reach them so the loader had to move them to the low side of the road before processing.

Summary and conclusions

The John Deere 892 ELC/Waratah HTH624 processor was 31% more productive than the smaller Hyundai 210LC/Waratah HTH620 processor, in terms of m^3/PMH. This result is similar to the winter study where it was 34% more productive. In terms of m^3/SMH, the John Deere 892 ELC/Waratah HTH624 was 43% more productive than the Hyundai 210LC/Waratah HTH620, partly because of its higher utilization.

Analysis of the influence of site and stand conditions on productivity proved that most variables are not significant. Only stem deck slope and stem size had a significant effect on productivity. In both studies, productivity was affected by stem size. The summer study determined that deck slope was also an influence sometimes.

There was no statistically significant difference between winter and summer productivity after the effect of stem size was taken into account.

The analysis indicated that the John Deere 892 ELC/Waratah HTH624 processor is more cost-effective for processing the stems larger than 1 m^3, whereas the Hyundai 210LC/Waratah HTH620 is more cost-effective processing the smaller stems. When the cost of the processor plus loader assisting is considered, the breakeven stem size drops to 0.8 m^3.

Loaders spent 63% of their time assisting the processors. Most of this time involved piling processed logs and moving back and forth between the processor and the log decks. The combined system cost for a processor and a loader averaged \$8.21/m^3 for the John Deere 892 ELC/Waratah HTH624 and \$10.02/m^3 for the Hyundai 210LC/Waratah HTH620. Working with a loader increases the processor's productivity, but when a processor works on fairly flat ground where assistance is not required, then working alone is more economical.

The average net cost of processing was \$4.50/m^3 for the John Deere 892 ELC/Waratah HTH624 and \$5.32/m^3 for the Hyundai 210LC/Waratah HTH620. Operations were most productive when a processor worked with a loader.

Several logistical issues affected processing productivity during this study. Double-shifting the yarder would have been advantageous. However, in-block roads were not completed so volume was not available, the contractor could not get enough crew to run two shifts per day on the yarder, and fire shutdowns reduced the operating time available. As well, in some areas yarding productivity was low because of the terrain and block layout. The processor's productivity was often tied directly to that of the yarder.

Implementation

In addition to the recommendations in the report on the winter study (Boswell 2004), the following should improve the efficiency and productivity of processing operations on steep cable-harvested slopes:

- Ensure yarder productivity is adequate to keep the processor busy or that stems are ready for processing before the processor is brought on-site.
- Where space for decking is limited, process and load right-of-way wood before yarding and processing the in-block stems.
- In locations where a loader must prepare the stem deck for the processor, complete this preparation before the processor arrives to reduce delays for the processor.
- Lay out the block so that the yarder's landing areas are distributed along the road instead of yarding many stems to one location. This will reduce stem deck heights and roadside machine congestion, and improve processing productivity.
- Wherever possible, separate the processing phase from the yarding phase to reduce machine conflicts and to provide adequate volume for the processor.

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Appendix I

Equipment specifications

Processors			
Carrier	Hyundai 210LC	John Deere 892 ELC	
Engine	Cummins B5.9-C	John Deere 6076A	
Power (kW)	112	164	
Maximum boom reach (m)	9.9	11.1	
Lift capacity at 6-m reach (kg)	6 060 [a]	10 422 [b]	
Undercarriage dimensions			
Width (m)	3.40	3.40	
Length (m)	4.44	4.90	
Travel speed (km/h)	up to 5.3	up to 5.5	
Mass (kg)	23 700	30 595	
Processing head	Waratah HTH620	Waratah HTH624	
Maximum delimbing diameter (mm)	560	640	
Maximum diameter saw cut (mm)	620	780	
Mass (kg)	2 210	3 414	
Measuring and control system	LogRrite	LogRite	
Loaders			
Carrier	Hitachi EX 220LC	Hyundai 210LC	Hyundai 290LC
Engine	Cummins H07C-TD	Cummins B5.9-C	Cummins QSB5.9-C
Power (kW)	118	112	159
Maximum boom reach (m)	10.3	9.9	10.8
Lift capacity at 6-m reach (kg)	6 620 [c]	6 060 [a]	9 550 [d]
Undercarriage dimensions (m)			
Width (m)	2.99	3.40	3.40
Length (m)	4.27	4.44	4.95
Travel speed (km/h)	up to 5.5	up to 5.3	up to 5.2
Mass (kg)	23 800	23 700	33 310
Grapple size (mm)	1 270	1 270	1 524

[a] For an arm length of 2.92 m and a 0 m load height.
[b] For an arm length of 3.20 m and a 0 m load height.
[c] For an arm length of 2.96 m and a 0 m load height.
[d] For an arm length of 3.05 m and a 0 m load height.

Appendix II

Machine costs [a]

	Carrier [b] (20–25 tonne class)	Carrier [b] (30–35 tonne class)	Harvesting head [c] (508-mm capacity)	Harvesting head [d] (610-mm capacity)	Log loading grapple [e] (up to 1 524-mm capacity)
Ownership Costs					
Total purchase price (P) $	305 000	410 000	185 000	225 000	22 000
Expected life (Y) y	5	5	5	5	5
Expected life (H) h	15 000	15 000	15 000	15 000	15 000
Scheduled hours/year (h)=(H/Y) h	3 000	3 000	3 000	3 000	3 000
Salvage value as % of P (s) %	25	25	25	25	25
Interest rate (Int) %	6.0	6.0	6.0	6.0	6.0
Insurance rate (Ins) %	3.0	3.0	3.0	3.0	3.0
Salvage value (S)=((P•s/100) $	76 250	102 500	46 250	56 250	5 500
Average investment (AVI)=((P+S)/2) $	190 625	256 250	115 625	140 625	13 750
Loss in resale value ((P-S)/H) $/h	15.25	20.50	9.25	11.25	1.10
Interest ((Int•AVI)/h) $/h	3.81	5.13	2.31	2.81	0.28
Insurance ((Ins•AVI)/h) $/h	1.91	2.56	1.16	1.41	0.14
Total ownership costs (OW) $/h	20.97	28.19	12.72	15.47	1.51
Operating Costs					
Fuel consumption (F) L/h	20.0	30.0	0.0	0.0	0.0
Fuel (fc) [f] $/L	0.55	0.55	0.00	0.00	0.00
Lube & oil as % of fuel (fp) %	10	10	0	0	0
Track & undercarriage replacement [g] (Tc) $	16 000	20 000	0	0	0
Track & undercarriage life (Th) h	5 400	5 400	0	0	0
Annual repair & maintenance (Rp) $	49 000	66 000	30 000	36 000	3 500
Shift length (sl) h	12.0	12.0	0.0	0.0	0.0
Operator wages [h] $/h	25.99	25.99	0.00	0.00	0.00
Wage benefit loading (WBL) %	38	38	38	38	38
Fuel (F•fc) $/h	11.00	16.50	0.00	0.00	0.00
Lube & oil ((fp/100)•(F•fc)) $/h	1.10	1.65	0.00	0.00	0.00
Track & undercarriage (Tc/H) $/h	1.48	1.85	0.00	0.00	0.00
Repair & maintenance (Rp/h) $/h	16.33	22.00	10.00	12.00	1.17
Wages & benefits (W•(1+WBL/100)) $/h	35.87	35.87	0.00	0.00	0.00
Prorated overtime ((((1.5•W-W)•(11-8)•(1+WBL/100))/sl)+ (((2.0•W-W)•(sl-11)•(1+WBL/100))/sl)) ($/h) [i]	7.46	7.46	0.00	0.00	0.00
Total operating costs (OP) $/h	73.24	85.33	10.00	12.00	1.17
Total Ownership and Operating Costs (OW+OP) $/h	94.21	113.52	22.72	27.47	2.68

[a] These costs are estimated using FERIC's standard costing methodology for determining machine ownership and operating costs for new machines. The costs shown here do not include supervision, travel time, profit or overhead and are not the actual costs for the contractor.
[b] Costs for carriers were calculated using generic machines for each class size.
[c] Based on quote from Waratah Distribution for a HTH 622B harvesting head. The HTH 620 harvesting head is no longer manufactured.
[d] Based on a quote from Waratah Distribution for a HTH 624 Super harvesting head.
[e] Based on quote from IMAC Attachments.
[f] Diesel fuel unit price as per a quote from The National Industrial Transport Log for June 2004.
[g] Although the loaders spent a substantial amount of time travelling back and forth between the processor and the log decks, and therefore undercarriage wear would be higher than in stationary applications, this was not accounted for in the costing.
[h] Wage rates are as per 2004 rates outlined in the IWA Southern Interior Master Agreement.
[i] Prorated overtime rates are as per 2004 rates in the IWA Southern Interior Master Agreement and reflect time and one-half for all shift hours in excess of 8 hours but not exceeding 11 hours. Double time was allotted for all shift hours worked in excess of 11 hours.

Appendix III

Equipment carrier and implement combinations and costs

Equipment	Carrier ($/h)	Implement ($/h)	Total ($/h)
Hyundai 210LC carrier with Waratah HTH620 processing head [a]	94.21	22.72	116.93
John Deere 892 ELC carrier with Waratah HTH624 processing head [b]	113.52	27.47	140.99
Hyundai 210LC carrier with 1 270-mm grapple [c]	94.21	2.68	96.89
Hitachi EX220LC loader with 1 270-mm grapple [c]	94.21	2.68	96.89
Hyundai 290LC loader with 1 524-mm grapple [d]	113.52	2.68	116.20

[a] Costs are based on a 20–25 tonne class generic carrier and a 508 mm capacity generic harvesting head.
[b] Costs are based on a 30–35 tonne class generic carrier and a 610 mm capacity generic harvesting head.
[c] Costs are based on a 20–25 tonne class generic carrier with a generic log loading grapple.
[d] Costs are based on a 30–35 tonne class generic carrier with a generic log loading grapple.

Appendix IV

Branchiness rating

Branchiness rating	Description
1 = negligible	no branches or very few at the top
2 = light	branches <4 cm diameter
3 = moderate	some branches >4 cm diameter over 1/3 of the stem
4 = high	many branches >4 cm diameter over 2/3 of the stem
5 = very high	very limby tolerant hardwoods