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GRAPPLE YARDING IN THE INTERIOR OF BRITISH COLUMBIA

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Abstract

A study was conducted in the Interior of British Columbia to evaluate the productivity and cost of a grapple-yarding system consisting of a Washington 108 swing yarder with grapple, Caterpillar D8 backspar, International TD20 guyline anchor, Timberjack 2520 feller-buncher, and a Denis D3000 telescopic log processor. A system analysis was carried out to determine if the equipment was being fully utilized. The machines were monitored for three months from the late summer to the early winter of 1990. This grapple-yarding system is the first of a series of cable-yarding systems operating in the Interior of British Columbia to be studied by the Forest Engineering Research Institute of Canada (FERIC).

Introduction

With environmental concerns increasing, and new site-disturbance guidelines coming into effect, alternative harvesting methods are being considered by the forest industry in the Interior of British Columbia. Although choker yarders are used occasionally in the Interior to harvest hand-felled wood that is inaccessible to skidders, other yarding technology, e.g. grapple yarding, has not been practical because piece size is usually too small to make the operation economical. Recently an Interior cable yarding contractor, Armitage Contracting Limited, combined a steep-slope feller-buncher, a grapple yarder, and a stroke delimber to overcome the small piece size and terrain limitations. The Forest Engineering Research Institute of Canada (FERIC) evaluated this operation from August to November 1990 with the objective of illustrating cost and productivity associated with using the system.

Study Method

Shift-level and detailed-timing studies were done on both the yarder and the buncher. Only a shift-level study was done on the delimber; however, detailed-timing data about the delimber were available from a previous study (Moshenko 1991). A DSR Servis recorder was installed on each of the three machines to collect shift-level data. Summary reports were generated from each recorder's shift-level data, and included mechanical availability, machine utilization, productivity, and cost. Detailed-timing data were gathered using a hand-held data logger. Detailed timing occurred randomly throughout the shift-level study, and took into consideration variations in site and stand conditions. Log volume was determined from the sawmill weigh-scale records.

After the stems were felled and bunched, FERIC collected data on species, butt diameters, and number of stems per bunch to determine bunch volumes for the yarding phase of the productivity study. Numbers were painted on each bunch for future identification. After the bunches were yarded, individual stem data (ie. species, butt class, and bundle number) were recorded and later combined with information about species, diameters, and average length measurements determined from the decked wood in order to generate volumes for individual stems and bundles. Volume data were collected only for the areas where detailed timing occurred and not for the entire block.

Keywords: Harvesting, Grapple yarding, Cable yarding, Harvesting systems.

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Site and System Descriptions

The study area was located approximately 50 km west of Kelowna, British Columbia. It was a mixed stand of lodgepole pine, Englemann spruce, and subalpine fir growing on an average slope of 20%. The average stem volume was 0.45 m^3, and the timber-cruise summary reported a net volume per hectare of 327 m^3. The large amount of blowdown in the block obstructed the feller-buncher's travel at times; however, a good portion of the blowdown areas was hand-felled and/or hand-bucked. The ground was also very wet in some areas, which made the block too sensitive for ground skidding.

A Timberjack 2520 feller-buncher equipped with a Koehring felling head was used to fell the block (Figure 1). A 1979 model Washington 108 swing yarder rigged with a 2.7-m grapple (Figure 2) did the yarding in conjunction with a Caterpillar D8 mobile backspar and an International TD20 mobile guyline anchor. A three-man crew consisting of the operator, hooktender (spotter), and utility man worked the yarding system. Log processing was done by a Denis D3000 that was mounted on a Komatsu PC220LC carrier (Figure 3). Loading and hauling was done by two self-loading trucks.

The feller-buncher felled the trees in strips perpendicular to the yarding road, and placed bunches parallel to the roadway. The butt ends of the bunches were lined up in a continuous row over which the yarder positioned its rigging. Some areas of blowdown were present throughout the block and these were left for hand-falling (approximately 12% of the total volume).

Because of a delay in moving from the previous block, the grapple yarder moved onto the study block four weeks after the feller-buncher had started work. The yarder and mobile backspar positioned the rigging directly over a row of bunches so that the grapple could secure a bunch near the butts (Figure 4). At first, the operator had some difficulty setting the lines over a row of bunches; therefore, extra yarding time was required to clean up stems and bunches that were out of reach for that setup. Once the operator was able to align the rigging over a row of bunches, yarding productivity improved.

The stems were decked at roadside (Figure 5) to be processed by a Denis D3000 log processor that entered the block five weeks after yarding began. The Denis D3000 was delayed in its move because the operator was being trained while the machine

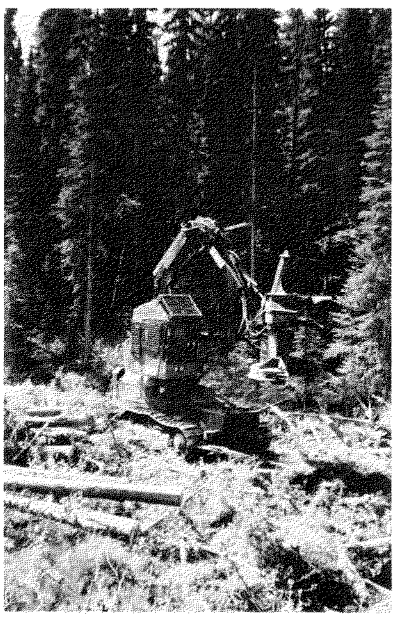

Figure 1. Timberjack 2520 feller-buncher.

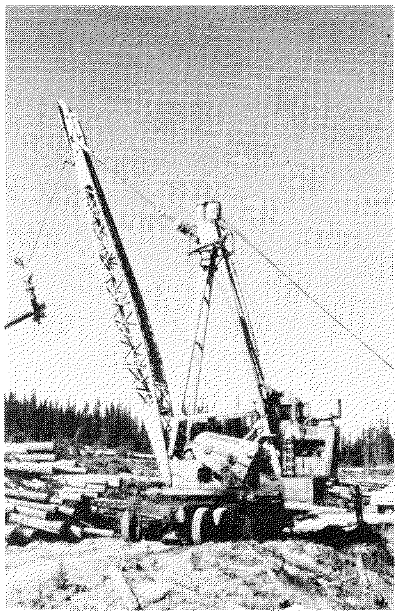

Figure 2. Washington 108 swing yarder.

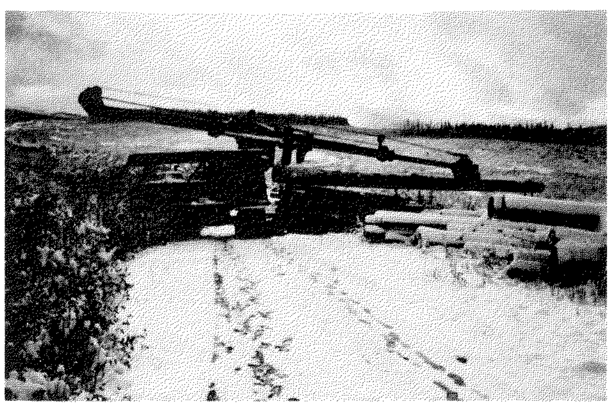

Figure 3. Denis D3000 telescopic log processor.

Figure 4. Grapple securing a bunch of stems.

Figure 5. Stems being decked at roadside.

was operating in the previous block. The processor delimbed, topped, bucked, and placed the stems into processed decks, and self-loading trucks did the loading and hauling.

Results and Discussion

The contractor operated the equipment for one shift per day, five days per week. Additional shifts were worked by the processor to narrow the production gap between the yarding and felling phases. The study period lasted from August 1 to November 9, 1990 during which time 7121 metric tons (10 468 m^3) of logs were weigh-scaled at the sawmill. The conversion factor for this block was higher than normal due to the relatively large amount of blowdown. The ownership and operating costs for the feller-buncher, grapple yarder, and processor were \$114.37/h, \$216.12/h, and \$80.87/h respectively (Appendix II). All costs in this report were derived using FERIC's standard costing formula, and are not the actual costs incurred by the contractor.

Shift-Level Study

Falling. The Timberjack 2520 feller-buncher was monitored for 27 productive shifts from August 1 to September 13, 1990. The average productivity over this time was determined to be 88 stems/h (44.1 m^3/h) with felling costs of \$2.59/m^3 (Table 1). Small areas, containing merchantable wood from blowdown, were left by the feller-buncher and later hand-felled. The volumes in these areas were not included in the feller-buncher analysis.

Utilization of the Timberjack 2520 was calculated to be 76.1% with a machine availability of 84.1%. Two-thirds of its delays were associated with mechanical problems and servicing, while the other one-third were primarily due to operational breaks and delays (Table 2).

Yarding. The Washington 108 grapple yarder worked 32 productive shifts from August 29 to October 15, 1990. The average productivity during this time was 80 stems/h (40.0 m^3/h). Grapple-yarding costs, including those for the mobile backspar and mobile guyline anchor, were \$5.40/m^3 (Table 1). Hand-felling in parts of the block reduced the turn size for the grapple yarder, thus increasing grapple-yarding costs in those areas.

The yarding system was utilized 79.9% of the time, and was mechanically available during 89.5% of the study period. Nonproductive time was evenly distributed between the mechanical and non-mechanical delays; however, mechanical delays occurred more frequently than operational delays, but mechanical delays were of shorter duration.

Processing. The Denis D3000 telescopic log processor was productive for 34 shifts from October 2 to November 9, 1990. The machine was double shifted for four days during this period. Average productivity was 71 stems/h (35.3 m^3/h). Processing costs for the wood in this block were determined to be \$2.29/m^3 (Table 1).

The D3000 had a machine utilization of 81.8% with an availability of 84.2%. The majority of delays were caused by mechanical difficulties and the need for regular servicing. Operational delays were attributed mainly to the operator's need for rest breaks (Table 2).

Detailed-Timing Study

Approximately 11 h of detailed timing were performed on the feller-buncher, and 31 h on the grapple yarder (Table 3). The studies were conducted randomly during the shift-level monitoring period. All productive time and delays less than ten minutes were considered part of the detailed-timing

Table 1. Shift-Level Study: Summary

	Feller buncher	%	Grapple yarder	%	Processor	%
Productive machine hours (PMH) (h)	159.6	76.1	209.0	79.9	242.5	81.8
Nonmechanical delay hours (NDH)						
Operational (h)	15.8	7.5	24.4	9.3	7.3	2.5
Organizational (h)	1.0	0.5	0.7	0.3	0	0
Mechanical delay hours (MDH)						
Wait (h)	2.7	1.3	0	0	7.0	2.3
Repairs (h)	17.4	8.3	12.2	4.6	15.4	5.2
Service (h)	13.3	6.3	15.4	5.9	24.4	8.2
Total machine hours (TMH) (h)	209.8	100.0	261.7	100.0	296.6	100.0
Utilization (PMH/TMH) (%)	76.1		79.9		81.8	
Machine availability [(TMH-MDH)/TMH] (%)	84.1		89.5		84.2	
Total number of stems	18 512		20 930		20 930	
Volume produced (m^3)[a]	9 256		10 468		10 468	
Average volume (m^3/stem)	0.50		0.50		0.50	
Shifts with production (no.)	27		32		34	
Piece production						
Stems/PMH	116		100		86	
Stems/TMH	88.2		80.0		70.6	
Volume production						
m^3/PMH	58.0		50.1		43.2	
m^3/TMH	44.1		40.0		35.3	
Production/8-h shift						
Number of stems	706		640		565	
Volume (m^3)	352.8		320.0		282.4	
Total ownership & operating cost ($/h)	114.37		216.12		80.87	
Total machine cost ($/$m^3$)	2.59		5.40		2.29	

[a] Volume difference between feller-buncher and grapple yarder/processor is due to hand-felling in blowdown.

Table 2. Shift-Level Delays: Summary

Description	Feller-buncher (No. occ.)	(h)	(%)	Grapple yarder (No. occ.)	(h)	(%)	Processor (No. occ.)	(h)	(%)
Nonmechanical delays									
Operational									
Personal	41	12.9	25.7	-	-	-	23	6.6	12.2
Visitors	1	0.4	0.8	1	0.3	0.6	2	0.7	1.3
Weather	-	-	-	1	8.0	15.2	-	-	-
Planning	1	0.3	0.6	1	1.4	2.7	-	-	-
Auxiliary equipment	2	2.2	4.4	5	14.7	27.9	-	-	-
Organizational									
Wait for other phase	-	-	-	1	0.7	1.3	-	-	-
Operator not available	1	1.0	2.0	-	-	-	-	-	-
	46	16.8	33.5	9	25.1	47.7	25	7.3	13.5
Mechanical delays									
Repairs to carrier	10	7.0	13.9	1	0.5	0.9	3	2.3	4.2
Repairs to prime attachment									
Hydraulics	3	1.1	2.2	-	-	-	3	3.6	6.7
Electrical	-	-	-	-	-	-	5	3.6	6.7
Saw implement	2	4.9	9.7	-	-	-	11	5.9	10.9
Rigging	-	-	-	7	11.7	22.2	-	-	-
Structural	1	4.4	8.8	-	-	-	-	-	-
Wait for parts	1	2.7	5.4	-	-	-	2	7.0	12.9
General service	41	13.3	26.5	47	15.4	29.2	64	24.4	45.1
	58	33.4	66.5	55	27.6	52.3	88	46.8	86.5
Total delays	104	50.2	100.0	64	52.7	100.0	113	54.1	100.0

Table 3. Detailed-Timing: Summary

	Feller-buncher		Grapple yarder		Processor [a]	
	min	%	min	%	min	%
Total productive time	586.09	86.9	1 452.64	78.2	1 048.79	82.9
Total unmerchantable cycles time	13.25	2.0	19.89	1.1	53.51	4.2
Total sumtime	35.05	5.2	-	-	114.41	9.1
Total moving time	-	-	306.38	16.5	-	-
Total delays <10 min each	39.84	5.9	77.98	4.2	48.26	3.8
	674.23	100.0	1 856.89	100.0	1 264.97	100.0
Total study time (PMH)	11.24		30.95		21.08	
Total stems (no.)	1313		3724		1780	
Total volume (m^3)	590.85		1 690.66		943.40	
Average volume (m^3/stem)	0.45		0.45		0.53	
Total stems/PMH	117		120		84	
Volume production (m^3/PMH)	52.6		54.6		44.8	

[a] Detailed-timing data for the Denis D3000 telescopic log processor were obtained from a previous FERIC study (Moshenko 1991).

study. Delays greater than ten minutes were accounted for in the shift-level study.

Falling. During the evaluation of the feller-buncher, detailed-timing data were collected for 1 313 stems (or 591 m^3). Analysis of these data revealed a productivity of 52.6 m^3/h (based on productive time) and an operating cost of \$2.86/m^3, based on a machine utilization of 76.1% as derived from the shift-level study.

The feller-buncher's productive time was broken down into separate elements (Table 4). Each felling cycle may have contained all or only some of these elements, occurring in various orders, due to the changing ground and stand conditions in the block. A description of the elements used during the detailed-timing study are found in Appendix I. Because delay times less than ten minutes were included in the detailed-timing study, a list of descriptions and percentage breakdown appears in Table 5.

Yarding. During detailed timing of the grapple yarder, data were collected on 3 724 stems (or 1 691 m^3) (Table 3). Data analysis indicates a yarding productivity of 54.6 m^3/h (based on productive time) and a cost of \$4.95/m^3, if a machine utilization of 79.9% is assumed.

This productive time is also further broken down into separate elements as shown in Table 6. Each grapple-yarding cycle may contain all or only some of these elements, depending on which activities were required to complete each cycle. A description of elements used in the detailed timing are found in Appendix I.

Table 4. Breakdown of Timing Elements for All Feller-Buncher Cycles

Activity	Time (min)[a]	%
Swing empty	122.78	19.6
Cut	124.19	19.8
Swing loaded	144.72	23.1
Move	115.52	18.4
Clean[b]	54.37	8.7
Prepare bunch	12.13	1.9
Travel	14.18	2.3
Delay	39.84	6.2
	627.73	100.0
Sumtime	33.97	
Total	661.70	

[a] Times associated with merchantable stems only.
[b] Clean time includes brushing and the removal of unmerchantable stems.

Table 5. Delay Time for Feller-Buncher: Summary

Description	%
Engine stalled	22.5
Coffee break	21.3
Personal	21.2
Planning	15.1
Unknown	11.1
Machine stuck	8.8
Total	100.0

Delay times less than ten minutes were again included in the detailed timing of the grapple yarder. A list of their descriptions and percentage breakdown appears in Table 7.

Table 6. Breakdown of Timing Elements for All Grapple-Yarder Cycles

Activity	Time (min)[a]	%
Outhaul	497.60	26.8
Hook-up	304.52	16.4
Inhaul	531.89	28.6
Unhook	105.15	5.7
Deck	33.38	1.8
Move yarder	129.26	7.0
Move backspar	177.07	9.5
Delay	78.02	4.2
Total	1 856.89	100.0

[a] Times associated with merchantable stems only.

Table 7. Delay Time for Grapple Yarder: Summary

Description	%
Set-up rigging	20.1
Discussion	13.6
Personal	13.3
Wait for crew	12.4
Repair backspar	11.3
Logs not in reach	10.0
Unknown	9.6
Warm-up backspar	4.4
Logs hung-up	2.8
Cables hung-up	2.5
Total	100.0

Daily production varied during the study period because of differences in piece size, average yarding distance, and amount of total time associated with moves. Table 8 summarizes production figures for the grapple yarder for the seven days in which detailed timing occurred.

Several factors affected productivity of the grapple yarder including the volume per cycle, the number of stems yarded in a cycle, and the yarding distance. Tables 9, 10, and 11 show cost summaries as a function of these factors. Because inhaul and outhaul times were high, yarding distance appears to be the factor having the greatest effect on cycle time. The volume per cycle was not a limiting factor for the yarder; however, the number of stems that the grapple could hold depended on the cross-sectional area of the individual butts. The maximum volume yarded in one cycle was 9.24 m^3, and this contained three logs with butt diameters of 92, 24, and 20 cm. The maximum number of stems yarded in one cycle was 13 with a volume of 5.69 m^3, and this contained logs with butt diameters ranging from 15 to 31 cm.

Processing. Detailed timing of the processor was not done for this study block; however, data collected on this machine in a previous study is summarized in Table 2 (Moshenko 1991). Some operating conditions in the previous study were different: piece size was larger (0.53 m^3/stem), the machine operator was more experienced, and trees were hand felled. The hand-felled wood, after yarding, resulted in many stems being decked top first as opposed to the feller-bunched wood having the majority of its stems decked butt first. Because the D3000 processes stems butt first, processing efficiency is higher when stems are decked butt first. The larger piece size and the more experienced operator helped overcome a potential decrease in productivity

Table 8. Grapple-Yarding Production: Summary

Day	Total time (min)	Yarding time (%)	Moving time (%)	Delay time (%)	Average yarding distance (m)	Total cycles	Average volume/ stem (m^3/stem)	Average stems/cycle (no.)	Average cycle time (min)	m^3/h	Stems/h
1	441.64	81.9	14.4	3.7	85	269	0.84	2.3	1.64	70.1	83
2	215.41	84.8	12.6	2.6	118	109	0.64	2.8	1.98	54.1	84
3	254.42	82.9	10.6	6.5	105	132	0.46	2.7	1.93	39.1	85
4	224.10	65.3	28.7	6.0	70	126	0.25	3.0	1.78	24.9	101
5	97.15	68.0	21.4	10.6	57	63	0.25	3.8	1.54	36.6	149
6	311.52	81.7	16.4	1.9	73	206	0.30	4.9	1.51	58.0	193
7	312.14	80.1	16.8	3.1	82	200	0.43	4.2	1.56	69.3	160
All[a]	1 856.89	79.3	16.5	4.2	85	1105	0.45	3.4	1.68	54.6	120

[a] Calculations include cycles with zero production (i.e. unmerchantable stems, dropped loads) for all detailed-timing data.

Table 9. Average Cycle Times and Costs as a Function of Cycle Volume: Grapple Yarder

Range of vol/cycle (m^3)	No. of cycles	Average volume/stem (m^3/stem)	Average volume/cycle (m^3/cycle)	Average stems/cycle (no.)	Average cycle time (min)	Average yarding distance (m)	Average costs ($/$m^3$) [a]
<0.51	323	0.19	0.25	1.3	1.57	87	28.31
0.51 - 1.00	186	0.25	0.78	3.1	1.52	82	8.79
1.01 - 1.50	123	0.33	1.27	3.8	1.63	85	5.79
1.51 - 2.00	136	0.39	1.75	4.5	1.58	81	4.07
2.01 - 2.50	89	0.51	2.27	4.4	1.77	88	3.52
2.51 - 3.00	60	0.50	2.73	5.4	1.64	87	2.71
3.01 - 4.00	92	0.66	3.52	5.3	1.62	81	2.07
4.01 - 5.00	50	0.80	4.43	5.6	1.92	84	1.95
5.01 - 6.00	21	0.91	5.49	6.0	1.75	89	1.44
>6.00	7	1.36	6.43	4.7	1.57	84	1.10
All[b]	1 087	0.45	1.56	3.4	1.62	85	4.68

[a] Average costs/cycle assume a machine utilization of 79.9%. [b] Calculations do not include nonproductive cycles as in Table 8.

Table 10. Average Cycle Times and Costs as a Function of Number of Stems per Cycle: Grapple Yarder

No. of stems/cycle	No. of cycles	Average volume/stem (m^3/stem)	Average volume/cycle (m^3/cycle)	Average cycle time (min)	Average yarding distance (m)	Average costs ($/$m^3$) [a]
1	328	0.62	0.62	1.57	86	11.42
2	183	0.61	1.22	1.57	84	5.80
3	125	0.51	1.59	1.74	94	4.93
4	126	0.49	1.95	1.64	86	3.79
5	104	0.45	2.24	1.70	86	3.42
6	77	0.39	2.36	1.67	80	3.19
7	62	0.37	2.56	1.52	78	2.68
8	44	0.30	2.42	1.61	77	3.00
9	14	0.37	3.37	1.40	69	1.87
10	12	0.35	3.53	1.44	63	1.84
11	8	0.40	4.35	1.79	74	1.86
12	3	0.34	4.08	1.38	60	1.52
13	1	0.44	5.69	1.24	80	0.98
All[b]	1 087	0.45	1.56	1.62	85	4.68

[a] Average costs assume a machine utilization of 79.9%. [b] Calculations do not include nonproductive cycles as in Table 8.

associated with processing hand-felled wood decked by a yarder. Despite these different operating conditions, processing productivities in the two blocks were very similar.

An observation concerning the height of the roadside log decks was also made during the study. Sections of the study block with maximum yarding distances of 160 m resulted in log decks with heights greater than 4 m; therefore, the processor had to break down the decks in these areas before processing could occur. Hence, when choosing an optimum yarding distance, consideration should be given to building log decks to reasonable heights.

Equipment Interaction

To evaluate the advantages of feller-bunched versus hand-felled wood, productivities and costs were compared. When using a feller-buncher, the felling productivity is 44.1 m^3/TMH at a cost of $2.59/$m^3$. Yarding productivity is 40 m^3/TMH at a cost of $5.40/$m^3$ for a total cost of $7.99/$m^3$. In comparison, it is estimated that a hand-faller in this same stand would have cut 140 m^3/day (based on 6.5 productive hours per day) at a cost of $2.11/$m^3$. An estimated yarding productivity would have been 25 m^3/TMH at a cost of $8.64/$m^3$, resulting in a total cost of $10.75/$m^3$. Therefore, the feller-bunched wood shows a system savings of $2.76/$m^3$. It is assumed that the productivity and cost of the processor does not change between the two methods for the purpose of this costing; however, more stems would likely be yarded top first in hand-felled wood, requiring

Table 11. Average Cycle Times and Costs as a Function of Yarding Distance: Grapple Yarder

Yarding distance (m)	No. of cycles	Average volume/stem (m^3/stem)	Average volume/cycle (m^3/cycle)	Average stems/cycle	Average cycle time (min)	Average costs ($/$m^3$) [a]
20	47	0.38	1.73	4.6	0.80	2.08
30	72	0.39	1.55	4.0	0.97	2.82
40	63	0.49	1.89	3.9	1.09	2.60
50	73	0.43	1.52	3.5	1.22	3.62
60	98	0.51	1.65	3.3	1.32	3.61
70	98	0.41	1.42	3.4	1.39	4.41
80	104	0.45	1.48	3.3	1.54	4.69
90	86	0.41	1.40	3.5	1.69	5.44
100	88	0.44	1.34	3.0	1.79	6.02
110	90	0.52	1.52	2.9	1.82	5.40
120	91	0.47	1.55	3.3	2.10	6.11
130	83	0.48	1.61	3.3	2.21	6.19
140	59	0.51	1.67	3.3	2.23	6.02
150	29	0.48	1.83	3.8	2.49	6.13
160	6	0.62	1.77	2.8	2.82	7.18
All[b]	1 087	0.45	1.56	3.4	1.62	4.68

[a] Average costs include a machine utilization of 79.9%.
[b] Calculations do not include nonproductive cycles as in Table 8.

the processor to turn the stems prior to delimbing and bucking and resulting in higher processing costs.

The cost increase of falling with a feller-buncher instead of by hand is minimal compared to the cost savings resulting from improved grapple-yarding productivity associated with feller-bunched wood. Yarding is the most expensive phase in this operation; therefore, improving yarding productivity and reducing its cost will benefit the system.

Other changes can also be made to the feller-buncher/yarding system to further reduce the total system cost. More time should be spent in the felling phase to prepare bunches. An estimated 10 to 15% more time is required while felling to place an additional stem in each bunch. Improving the bunch formation, and increasing the average number of stems per cycle for yarding from 3.4 to 4.4 increases yarding productivity by at least 25% (Table 12). This 25% increase could theoretically lead to an additional $0.82/$m^3$ savings and further increase the $2.76/$m^3$ system savings mentioned earlier. Processing in this system is efficient, and if changed, may adversely affect the loading phase. For example, processing done in a central sortyard would require off-highway trucks as well as a loader to be in the block.

Conclusions

Overall machine productivity for the feller-buncher, grapple yarder, and processor were 44.1, 40.0, and 35.3 m^3/h respectively. These outputs result in a system cost of $10.28/$m^3$ for the three phases, illustrating that this combination of equipment can be an effective harvesting system for conditions in the Interior of British Columbia when adjustments to scheduling are made to equalize the daily productivities.

The grapple yarder benefits from feller-bunched wood by being able to yard more than one stem per turn, with a short hook-up (grappling) time involved. The processor also benefits because most of the stems in the deck have the butts facing the road, so time is not spent turning the stems before processing. Factors limiting the use of this type of system are: slopes greater than 50% present an unsafe terrain for feller-buncher use, and the risk of site disturbance increases; and yarding distances less than 160 m (if volume per hectare does not increase) are needed to keep the log decks to an appropriate height for the processor.

Advantages of using a feller-buncher rather than hand-fallers include productivity increases in both the felling and yarding phases which reflect in the cost savings for the harvesting system. The system cost can be further reduced by planning carefully to maximize results in each phase; for example, more time spent falling can improve yarding productivity and reduce the system cost.

Table 12. Effects of Feller-Bunching on Productivity

	Feller-Buncher Productivity			Grapple Yarder Productivity		System		
	Case 1	Case 2	Case 3	Case 1	Case 2 & 3	Case 1	Case 2	Case 3
Stems/8-h shift	706	642	614	640	800	-	-	-
m^3/h	44.1	40.1	38.4	40.0	50.0	-	-	-
Cost/m^3 ($)	2.59	2.85	2.98	5.40	4.32	7.99	7.17	7.30

Case 1: Actual productivity and derived costs from the study.
Case 2: 10% decrease in feller-buncher productivity resulting in a 25% increase in yarder productivity.
Case 3: 15% decrease in feller-buncher productivity resulting in a 25% increase in yarder productivity.

References

Moshenko, D.W. 1991. Evaluation of a Denis D3000 telescopic log processor. FERIC Technical Note TN-166. 8 pp.

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Disclaimer

APPENDIX I
Definitions

Feller-Buncher

swing empty - Time from the release of the previous tree into a bundle until the felling head is positioned to cut another tree.

cut - Time taken to cut a tree(s) and secure it in the collector arms of the felling head.

swing loaded - Time taken to place the stem(s) in a bunch after it has been cut.

move - Time taken for machine to move into position to continue felling (tracks are in motion).

prepare bunch - Time required for buncher to arrange the stem into a well-formed bunch.

clean - Time taken to clean the debris from around the working area.

travel - Time required for machine to move longer distances within the block.

delay - Time when the buncher was stopped and not felling trees.

sumtime - Total felling time of a cycle when individual element times were missed.

Grapple Yarder

outhaul - Time taken for grapple to move from roadside until it stops at the target stem(s).

hookup - Time taken for the grapple to be opened, dropped, and secured around the target stem(s).

inhaul - Time required for stem(s) to be moved from the block to the roadside.

unhook - Time taken for stems to be released from the grapple into the deck once they have reached the roadside.

deck - Time associated with the yarder moving a bunch already in the log deck, to straighten or re-pile the deck.

move yarder - Time taken for crew to move the yarder or the mobile guyline into a new position.

move backspar - Time taken for crew to move the backspar into a new position.

APPENDIX II
Costing Summary

	Timberjack 2520 feller-buncher	Washington 108 grapple yarder	Caterpillar D8 mobile backspar[a]	Dresser TD20 mobile guyline[a]	Denis D3000 processor
OWNERSHIP COSTS					
Purchase price = P	$395 000	$800 000	$60 000	$40 000	$318 000
Salvage value (% of P)	20	30	30	30	25
Salvage value = S	$79 000	$240 000	$18 000	$12 000	$79 500
Scheduled h/yr = H	1 700	1 900	1 900	1 900	2 100
Expected life = Y (yr)	6	12	6	6	6
Insurance = Ins (%)	2	2	2	2	2
Interest = I (%)	12	12	12	12	12
Average investment = AVI = (P+S)/2	$237 000	$520 000	$39 000	$26 000	$198 750
Loss in resale = (P-S)/(Y•H)	$30.98/h	$24.56/h	$3.68/h	$2.45/h	$18.93/h
Insurance cost = (Ins/100)•(AVI/H)	$2.79/h	$5.47/h	$0.41/h	$0.27/h	$1.97/h
Interest cost = (I/100)•(AVI/H)	$16.73/h	$32.84/h	$2.46/h	$1.64/h	$11.81/h
Total ownership cost	$50.50/h	$62.87/h	$6.55/h	$4.36/h	$31.45/h
OPERATING COSTS					
Wire rope cost = Wr					
Mainline (335 m of 22 mm) @ $220/30 m	-	$2 457	-	-	-
Opening (335 m of 22 mm) @ $220/30 m	-	$2 457	-	-	-
Haulback (670 m of 19 mm) @ $165/30 m	-	$3 685	-	-	-
Strawline (700 m of 10 mm) @ $90/30 m	-	$2 100	-	-	-
Line life = LL (h)	-	950	-	-	-
Rigging cost = Rc	-	$12 500	-	-	-
Rigging life - Rl (h)	-	5 700	-	-	-
Annual repairs and maintenance (% of total P)	10	10	10	10	10
Annual repairs and maintenance = R	$39 500	$80 000	$6 000	$4 000	$31 800
Fuel consumption = F (L/h)	25	25	2	2	15
Fuel price = f ($/L)	$0.42/L	$0.42/L	$0.42/L	$0.42/L	$0.42/L
Lube & oil (% of F • f)	20	10	10	10	15
Wages = W					
Operator	$20.75/h	$21.12/h	-	-	$20.02/h
Hooktender	-	$20.76/h	-	-	-
Utility man	-	$18.56/h	-	-	-
Wage benefit loading (% of W)	35	35	-	-	35
Line cost = (Total Wr)/LL	-	$11.26/h	-	-	-
Rigging cost = Rc/Rl	-	$2.19/h	-	-	-
Repair and maintenance cost (R/H)	$23.24/h	$42.10/h	$3.16/h	$2.10/h	$15.14/h
Fuel & lube cost	$12.60/h	$11.55/h	$0.92/h	$0.92/h	$7.25/h
Labour cost	$28.03/h	$81.59/h	-	-	$27.03/h
Total operating cost	$63.87/h	$135.24/h	$4.08/h	$3.02/h	$49.42/h
TOTAL OWNERSHIP AND OPERATING COST	$114.37/h	$198.11/h ($216.12/h)[b]	$10.63/h	$7.38/h	$80.87/h
Production/h (m^3)	44.1	40.0	-	-	35.3
Cost/m^3	$2.59/$m^3$	$5.40/$m^3$	-	-	$2.29/$m^3$

[a] Used machine.
[b] Grapple yarder, mobile backspar, and mobile guyline cost.