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A COMPARISON OF THE LUMBER YIELD FROM CUT-TO-LENGTH AND FULL-TREE HARVESTING SYSTEMS

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Abstract

In November and December 1994, FERIC compared the lumber yield from two roughly 75-m³ furnishes of softwood harvested with two different systems. One furnish was harvested as full-trees using a feller-buncher, a cable skidder, and a stroke delimber. The other was harvested using a cut-to-length system comprising a single-grip harvester and a forwarder. All the wood was scaled and milled separately at Domtar Inc.'s sawmill in Val d'Or, in Quebec's Abitibi region. The results were similar for both furnishes, though the cut-to-length system provided a slight benefit in terms of volume yields and the value recovery per cubic metre. Conversely, the average value of the products produced from full-trees was slightly higher. Losses after drying were nearly identical. However, the operational context may not have been perfectly typical, especially in the case of the full-tree system. Other studies would be necessary to confirm the wider applicability of the results in this report.

Introduction

Full-tree harvesting has dominated all other methods in eastern Canada since 1983 (Gingras and Ryans 1992). However, the recent growth in the popularity of cut-to-length systems has led to questions about the relative advantages of these systems, particularly in terms of lumber yield. FERIC was invited to collaborate with Domtar Inc. and FOR International ltée., a consulting firm, in a comparative trial to determine the quality and value of the lumber produced with the two systems. The trial was carried out under the "Testing, experimenting and technological transfer in forestry" program sponsored by Natural Resources Canada. This report describes the results of trials held in November and December 1994 at Domtar's sawmill in Val d'Or (Quebec). The full-tree system comprised a feller-buncher, a cable skidder, and a stroke delimber at roadside, whereas the cut-to-length system comprised a tracked single-grip harvester and a forwarder. The equivalent of two truckloads of wood for each system were followed from the stump up to the final finished product produced by the sawmill.

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Methodology

In a 70-year-old jack pine and black spruce stand, two comparable blocks were inventoried before randomly assigning them to the two systems.

During harvesting, the operator of the single-grip harvester targeted the production of 3.1-m logs. If the minimum merchantable diameter of 9 cm was reached before yielding a log length of 3.1 m, and the merchantable part of the log was already at least 1 m long, the operator continued processing up to a length of 2.4 m. In the full-tree system, the delimber operator was instructed to top the trees at a diameter of not less than 6 cm. Both systems were thus designed to recover the maximum amount of merchantable fiber from each tree.

All of the volume produced by the two systems was scaled in the mill's yard, and all efforts were made to ensure that the volumes obtained for stems and logs were comparable. The debarking-slashing facility was emptied before treating the two furnishes of wood, and the two furnishes were processed separately. Four ring debarkers were used to debark the full-tree stems (small end first), which were then conveyed to four slashers, which each handled one to five stems at a time. One of these four production lines was subsequently used to debark the logs produced by the cut-to-length system. The logs obtained from each system were automatically sorted into bins (Figure 1) using six classes based on the anticipated cant size (in inches). The results from the Multimeg electronic classification system that was used for this sorting were recorded for each furnish of wood.

Figure 1. Sorting bins
at the debarking-slashing facility.

The sawmill was also emptied before processing the two furnishes of wood, and each furnish was handled separately. The volume of lumber produced was obtained from the sawmill's automated sorting scanners after sawing of each of the six classes of cant. A physical inventory was conducted (Figure 2) to verify the data produced by the automatic sorting system. Dimension lumber (2×3, 2×4, and 2×6) that was more than 7 feet long was dried, then a scaler tallied the number of pieces per quality class and evaluated the losses that would be incurred during the final trimming to size. Readers should note that the dimensions of the sawed lumber are given in inches and feet in this report because these are the units that the sawmilling industry usually uses.

Figure 2. Lumber produced
from the cut-to-length system in the mill's yard.

Results

Stand Inventory

The results of the stand inventory are presented in Table 1. The differences between blocks were not statistically significant.

Table 1. Results of the stand inventory

	Harvesting system	
	Cut-to-length	Full-tree
Density (stems/ha)	1 555	1 675
Species mix (% pine/% spruce)	56/44	64/36
Basal area (m^2/ha)	24.0	26.5
Average DBH (cm)	14.0	14.2

It should be noted that not all stems recorded in the pre-harvest inventory were necessarily harvested; for example, some stems in the 10-cm diameter class may have been judged by the operators to be unmerchantable at the time of harvesting. This has some impact on the average volume of the stems that were har- vested.

Scaling of the Wood

For each furnish, the gross merchantable volume (i.e., up to the minimum utilization diameter of 9 cm) and the total volume harvested were calculated (Table 2).

Table 2 reveals that the gross merchantable volume per stem was 11% higher in the full-tree system, and this difference must be accounted for in subsequent comparisons. However, the proportions of unmerchantable volume were comparable, which suggests that the instructions to maximize the amount of fiber recovered from each tree were followed to a similar extent by the operators in both systems.

Debarking and Slashing

The debarking-slashing facility sorted debarked logs using a Multimeg classifier, and the results are presented in Table 3.

The electronic classifier indicated that the average volume per log was 7% greater in the full-tree system than in the cut-to-length system. However, the difference in the nature of the measurements suggests that it would be inappropriate to attempt overall volumetric comparisons based on these results. The data were, however, used to compare the effect of log size on yield.

The log length distributions obtained with the two systems were not compared. Doing so would have required an additional length measurement of the logs from the full-tree system after the debarking phase, and this would have delayed the trials. However, the results for logs produced by the cut-to-length system could be obtained directly from the scaling, and are presented in Appendix A.

Table 2. Wood volumes before debarking and slashing

	Harvesting system	
	Cut-to-length	Full-tree
Gross merchantable volume (m^3)	72.9	82.0
Total volume (m^3)	76.9	87.2
Proportion of unmerchantable volume (%)	5.2	6.0
Number of stems	721[a]	730
Average gross merchantable volume (m^3)		
per tree	0.101	0.112
per log	0.040	n.a.

[a] Stems were counted by an observer at the time of harvesting.

Table 3. Wood volumes calculated by the Multimeg classifier after debarking or slashing

	Harvesting system	
	Cut-to-length	Full-tree
Volume accepted for sawing (m^3)[a]	75.4	79.6
Number of logs accepted for sawing	1750[b]	1746
Average volume per accepted log (m^3)[a]	0.043	0.046

[a] The volume and number of logs were determined electronically and are not necessarily comparable with the scaling data.
[b] In addition, 68 logs were sent directly to the chipper.

Sawmilling

The main results from the sawmill are presented in Table 4. These are net results, after drying in the case of dimension lumber and based on "green" volumes for boards. The nominal dimensions were used to calculate the board-foot volumes. A complete list of the products obtained (by length) and a price table are presented in Appendix B.

Although the yield and value recovery per cubic metre were slightly higher for the cut-to-length system, the results were very similar. Several factors unrelated to the harvesting system can have a determining influence on the value of the products that were obtained. For example, the considerable difference in revenues between the "stud" and "economy" grades is more often linked to the presence of external factors such as decay. The relative output in the "economy" grade was nonetheless identical for the two furnishes of wood, and thus didn't affect the comparison. This can be confirmed by using "stud" prices to calculate the revenues in all categories and thereby demonstrate that the differences remain comparable.

Figures 3A and 3B present the volume distributions by product and by length. The lengths followed the same distribution for both furnishes of wood. There was a greater proportion of 2×3 lumber with the cut-to-length system, whereas the full-tree system produced more 2×4 lumber. Figure 3C presents the volume distribution in terms of sale price. The most important differences concern products sold at $415 and $315 per 1000 fbm, and these represent the main source of variation in the average price of lumber produced from the two furnishes of wood. These two price classes mainly include 10-foot-long 2×4 and 2×3 studs.

Physical deformations of the wood, splits, and checks that arise during drying necessitate additional trimming. One critique that is often made of full-tree systems is the potential for reduced lumber yields as a result of damage to the fiber or stresses created during harvesting and subsequent handling and which might appear after drying. However, the volume losses during the post-drying trimming to size were comparable, at 3.0% for the cut-to-length system and 2.6% for the full-tree system.

Figure 4 illustrates the gross lumber yield for the two systems in relation to the average volume per log. The shaded areas represent the class of cant that was produced; each area contains two points, one for each of the two systems. The 3-in. and 4-in. cant classes were milled together, since the mill's two saw lines were used simultaneously. These classes represented the majority of the volume for the two furnishes of wood. By plotting the relative volumes per debarked log obtained from the Multimeg system (0.043 and 0.046 m^3) on the graph, a difference of only 0.9% in lumber yield can be seen. This puts the 7% greater volume per log harvested by the full-tree system in better perspective. For simple sawing patterns, the yield decreases when changing from 2×3 lumber to 2×4 lumber. This phenomenon may have had an unfavorable effect on the lumber yield from the full-tree furnish, but its overall effect on annual output would probably be low.

Table 4. Results after sawing

	Harvesting system	
	Cut-to-length	Full-tree
Volume sawed (fbm)	15 111	16 440
Yield		
Gross merchantable volume (m^3)/1000 fbm	4.82	4.99
Ratio fbm/m^3	207.3	200.5
Average volume per piece of lumber (fbm)	4.57	4.62
Average value of the products ($/1000 fbm)	311.51	314.49
Value recovery ($/$m^3$ gross merchantable volume)	64.57	63.06

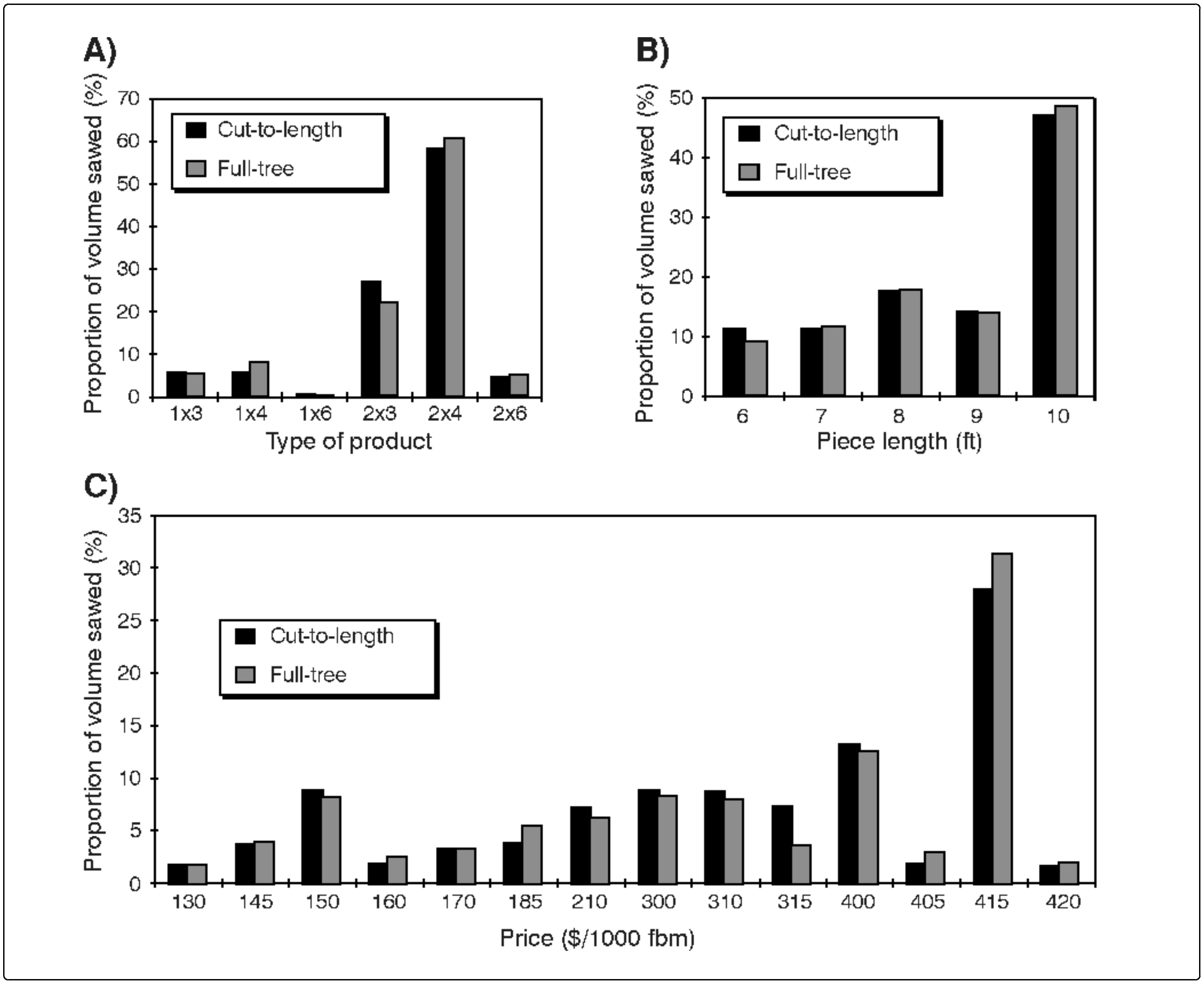

Figure 3. Distribution of volumes by product (A), length (B), and sales price (C).

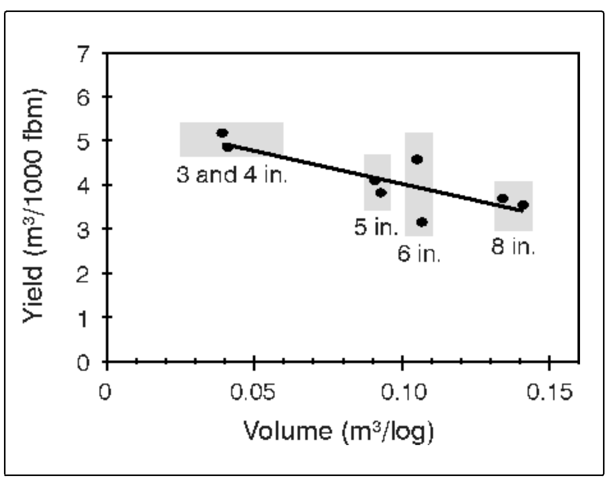

Figure 4. Gross ("green") yield in relation to the average log volumes estimated by the Multimeg system.

Conclusions

The lumber yields from the two systems were similar, though slightly in favor of the cut-to-length system. The value recovery per merchantable cubic metre was 2.4% higher for this system. In contrast, the average sale price for products was 1% higher for the full-tree system, and the difference was largely attributable to the greater proportion of 10-foot-long 2×4 studs produced by this system. However, the full-tree system benefited from working with raw material whose volume per tree averaged 11% greater than in the cut-to-length system. The effect on lumber yield was not of the same magnitude and was difficult to quantify. This shows the importance of comparing identical furnishes of wood. Even though the stands selected for the study were considered homogeneous, natural variation within the stands did not permit the production of identical furnishes under the study conditions.

The similar proportions of unmerchantable volume harvested by the two systems shows that it is possible to obtain comparable fiber recovery if the harvesting objectives are clearly specified. Losses after drying were also nearly identical in both systems.

However, the trial may represent an optimistic scenario for the full-tree system, since the high level of integration of the operations could have limited the amount of breakage during the various harvesting phases. The skidding distance, which was slightly less than the normal maximum in the region (300 m rather than 450 m), and the use of a cable skidder, which is lighter than a grapple skidder, could also have worked in favor of the full-tree system. FERIC has reported on wood breakage in these two systems during harvesting (Favreau 1997).

Many other factors could have led to different results than those observed during the current trial, including less effective slashing at the mill or a less-precise measuring system on the single-grip harvester. In a different context, producing random-length logs, the results might have been more complex, and in the case of the cut-to-length system, might have required better control of the products processed in the forest.

It goes without saying that a complete economic analysis, one that incorporates all harvesting and processing costs as well as revenues (e.g., chips), would require a considerable number of assumptions. The small differences observed in this study would probably be obscured by more important factors relating to the specific context of the company being studied and the cost assumptions that were used.

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Appendix A
Lengths of the Logs Produced by the Cut-to-length System

During cut-to-length harvesting, slashing is performed under less favorable conditions than those encountered at the mill. The distribution of log lengths should thus be monitored often. However, a simple frequency distribution of log lengths does not provide a complete assessment of the situation because an inexact length for a pulp log doesn't have the same impact as it would have for a large sawlog. Table A1 shows clearly how the variability of the results is larger for small-diameter logs than for large-diameter logs. However, the table does not distinguish cases in which logs were deliberately slashed at shorter lengths to avoid defects such as forks or excessive sweep.

Table A1. Distribution of logs by length and diameter class

	Length class (m)					
	1.90	2.20	2.50 (minimum that can be sawed)	2.80	3.10 (target)	3.40
Diameter class at top (cm)						
6	0	0	39	3	0	0
8	1	3	125	3	23	3
10	0	2	15	10	644	0
12	0	1	2	9	388	1
14	0	0	3	0	299	1
16	0	0	2	0	155	1
18	0	1	0	0	51	0
20	0	0	1	0	12	0
22	0	0	0	0	13	0
24	0	0	0	0	1	0

Appendix B
Volumes of the Products that Were Obtained and the Prices Used to Calculate Revenues

Cut-to-length system, lumber output (fbm)

			6'	7'	8'	9'	10'	Total
Green	1×3		125	196	272	2	218	813
	1×4		136	112	253	3	317	821
	1×6		30	0	4	0	0	34
Dry	2×3	studs	597.00	497	516	824	1 050	3 484
	2×3	economy	0	95	260	0	200	555
	2×4	studs	768[a]	546	928	1 074	4 220	7 536
	2×4	economy	0	168	256	0	793	1 217
	2×6	studs	6	49	88	198	240	581
	2×6	economy	0	0	40	0	30	70
Total			1 662	1 663	2 617	2 101	7 068	15 111

Full-tree system, lumber output (fbm)

			6'	7'	8'	9'	10'	Total
Green	1×3		110	180	232	0	305	827
	1×4		198	219	363	3	523	1 306
	1×6		3	0	8	0	0	11
Dry	2×3	studs	459[a]	567	692	675	580	2 973
	2×3	economy	0	112	220	0	265	597
	2×4	studs	684[a]	630	891	1 176	5 160	8 541
	2×4	economy	0	168	421	0	787	1 376
	2×6	studs	12	0	72	405	320	809
	2×6	economy	0	0	0	0	0	0
Total			1 466	1 876	2 899	2 259	7 940	16 440

Sale price ($/1000 fbm)

			6'	7'	8'	9'	10'
Green	1×3		150	150	170	170	170
	1×4		160	160	185	185	185
	1×6		160	160	185	185	185
Dry	2×3	studs	210	210	300	300	315
	2×3	economy	130	130	145	145	150
	2×4	studs	310	310	400	400	415
	2×4	economy	130	130	145	145	150
	2×6	studs	315	315	405	405	420
	2×6	economy	130	130	145	145	150

[a] Includes several "green" pieces that were initially slashed to 6 ft and not subsequently dried.

[b] As of December 1994 (the prices of 2×4 and 2×6 material have been adjusted so as to reflect a typical price structure).