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THE COST OF PRODUCT SORTING DURING HARVESTING

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Abstract

Many companies and their contractors must adapt to the reality of integrating harvesting with the sorting of multiple products. This separation of products can be performed at several stages during harvesting. This Technical Note combines the results of published and unpublished studies to describe the advantages and disadvantages of separating two or more products with the various machines used in full-tree, tree-length and cut-to-length harvesting systems. The cost of separating six products is simulated for three different harvesting systems.

Introduction

As early as 1969, the forestry community was realizing that multiproduct harvesting was becoming increasingly common in the industry and that it would, in all likelihood, become increasingly common in the future (Pickard 1969).

Today, many industrial wood users, and especially their harvesting contractors, must adapt to the reality of integrated harvesting of multiple forest products. This multiproduct harvesting implies the sorting of various products so as to maximize the value and quality of the raw material and to satisfy the requirements of the different users.

Separation of stems into different products in the forest during harvesting operations nonetheless entails a cost for whoever must perform this work. This additional cost arises in part from potential decreases in the productivity of the machines that must now include a product separation phase in their work cycles to create distinct piles that will permit loading and hauling of the separated products. The value added by producing separate products does not generally provide any direct benefits to the person responsible for the sorting. It is thus important to quantify the related costs well so as to equitably reward those who assume this responsibility and to evaluate the economics of the process.

The goals of this report are thus to describe the possible consequences of sorting operations on the work cycle of harvesting machinery and to provide estimates of the magnitude of the costs related to multiproduct harvesting. The data in this report come from published and unpublished studies conducted by FERIC, as well as studies produced by other research organizations. The last part of this report presents a cost simulation that compares the separation of six products using three harvesting systems.

Sorting Options

Depending on the operational context, product separation can be carried out in several places, including at the stump, at roadside or in a satellite mill. Because the latter option has been dealt with by Favreau (1995a, b), the present report will limit itself to a discussion of the first two cases.

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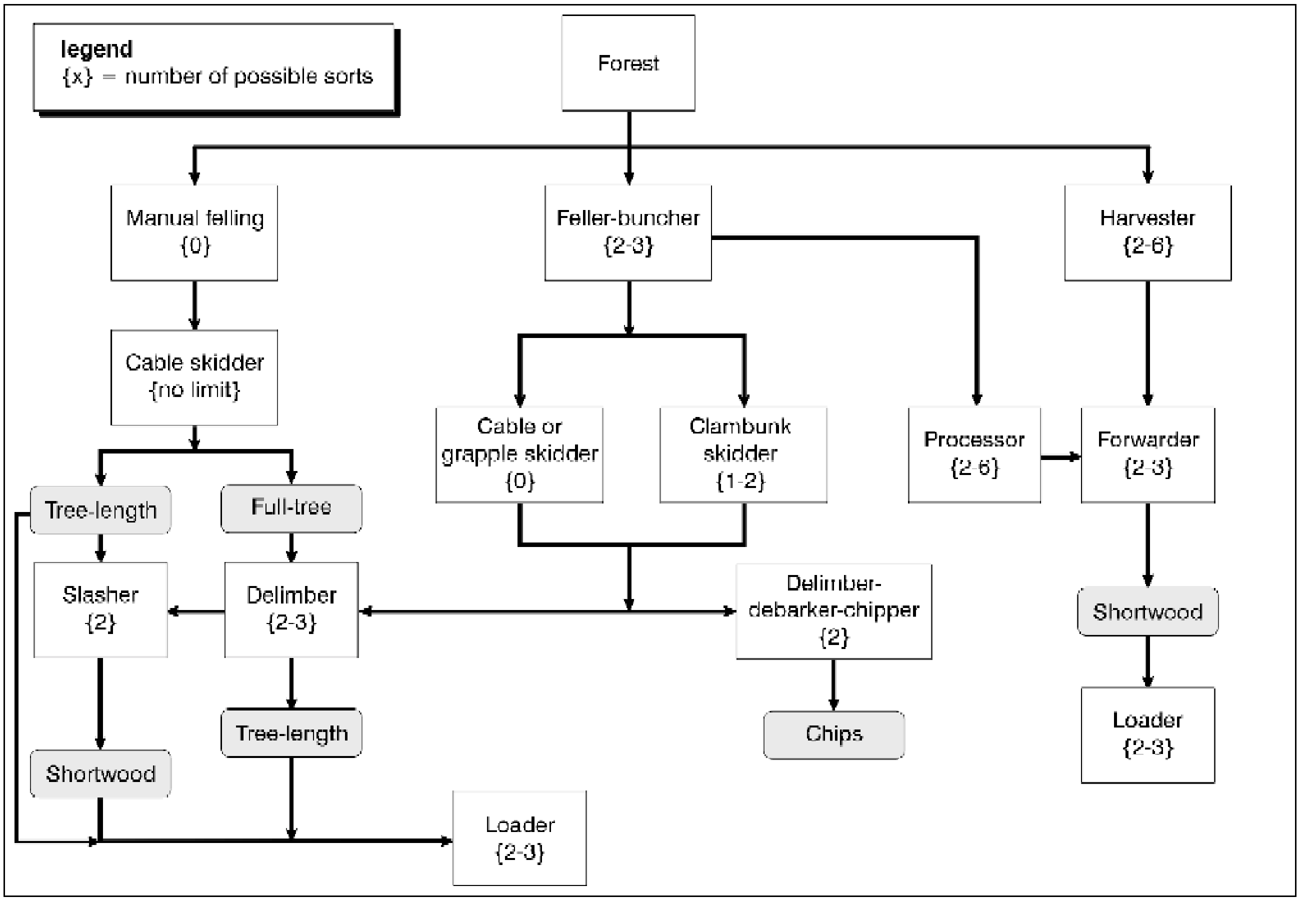

Figure 1. Options for multiproduct sorting using current harvesting systems in eastern Canada.

The separation of stems into two or more products can be done based on several criteria, which depend on the specific requirements of the mills. Stems can be sorted:

- by *species* or species group;
- by *quality* criteria (e.g., form, defect, decay, etc.);
- by *size* criteria (e.g., diameter, length); and
- by *end-product* (e.g., lumber, pulp, veneer, other).

Choosing the best method of carrying out the sort is dictated by (1) the harvesting system used, (2) the configuration of the haul trailers, (3) the structure of the forest, and (4) the number of products to separate. The separation of products can be complex, as in the case of a mixedwood forest in which the number of species and the product specifications required by the many mills involved can vary widely.

Figure 1 illustrates the in-woods sorting possibilities for the most common harvesting systems in eastern Canada. Stuart (1972) presents a similar diagram that displays 11 scenarios for the separation of single or multiple products during cable skidding, both in partial cutting and in clearcutting.

Product Separation Integrated Within Full-tree or Tree-length Systems

The phases in full-tree or tree-length harvesting that lend themselves to sorting are mechanized felling, cable skidding, mechanized delimbing, and loading of the trailers.

Sorting With Feller-bunchers

Feller-bunchers can sort full-trees simply by creating separate bunches. The usual method involves forward or backward carrier travel just before placing a tree in a bunch. Favreau and Franklin (1993) measured no loss in productivity with feller-bunchers separating large and small stems in Nova Scotia and Manitoba. However, since feller-bunchers work rapidly, they cannot be expected to perform anything more than a rough separation of species or sizes (Figure 2).

In October 1995, a feller-buncher was studied by FERIC in cooperation with Abitibi-Price Inc.'s Iroquois Falls (Ontario) division. To simulate a forest composed of two or three different species to separate during felling, randomly selected stems were marked with a ring of paint in the felling corridor in front of the feller-buncher. The operator had to separate the stems into distinct piles, but no specific instructions were provided on how to accomplish this.

Table 1 summarizes the results. The forest was uniform, with typical characteristics for that region: an average density of 1200 stems/ha and an average volume of 100 m³/ha. The site was flat and moist, with relatively thick organic soils (CPPA class 4.1.1).

The proportion of species was simulated at 1/3:2/3 for the separation of two products and at roughly 1/3:1/3:1/3 for three products. Sorting into two or three products decreased productivity (stems/PMH) by 7.5 and 10.6%, respectively, in comparison with the productivity recorded without sorting. The creation of separate bunches increased carrier movement, and this could have had two additional consequences: more rapid wear of the drive components, and more pronounced rutting in soft ground. The latter phenomenon was observed during this study.

Figure 2. Separation of two products with a feller-buncher.

New options such as the Quadco or Gilbert-Tech (Plamondon 1995) full-tilt felling heads facilitate creating piles compared with traditional felling heads. This type of head permits the creation of piles of different products without requiring excessive movement of the carrier by taking advantage of the head's lateral inclination capabilities.

Effect on Skidding

Sorting full-trees at the stump necessarily implies the creation of smaller bunches. This could lead to a significant decrease in the productivity of grapple or cable skidders (Gingras 1988). In contrast, a clambunk skidder would be less affected because of its method of loading, which is better adapted to dealing with small bunches.

In addition, skidding productivity could decrease if there is only a small proportion of one of the products on the cutover. This would lead to more travel on the site to keep only a small volume of secondary products separated from the primary product stream.

Table 1. The effect of separating two or three products on the productivity of a feller-buncher

	One product	Two products	Difference (%)	Three products	Difference (%)
Parameters					
Stems harvested	1175	870	---	254	---
Proportion of marked stems	0	35:65%	---	31:31:38%	---
Proportion of the work cycle spent moving to create piles	2.4%	5.5%	---	9.5%	---
Stems/PMH	254	235	-7.5	227	-10.6

For example, the baseline productivity data provided by Mellgren (1990) for a grapple skidder indicate that the terminal time averages 3 minutes, of which 80% is devoted to loading. For a skidding cycle based on a distance of 200 m in which the bunches of a secondary product are scattered over the cutover, a 50% increase in loading time would increase the total cycle time by about 15%.

Sorting During Skidding

With *mechanized* felling, it is unrealistic to separate products using grapple skidders or cable skidders because of the amount of work involved. Although a clambunk skidder could use its loading boom to separate species, this would be unproductive and thus expensive because few stems would be loaded simultaneously.

With *manual* felling, cable skidders can be used to separate stems by species into distinct piles at roadside, simply by unhooking the chokers holding the stems in front of the appropriate piles (Figure 3). If theand features high density or large stems, product separation could also be done during choking.

Figure 3. Unchoking stems into separate piles by species using a cable skidder.

In an unpublished study conducted in 1989 with Stone-Consolidated Corporation at Portage-du-Fort (Quebec), FERIC observed the unhooking time of eight cable skidders bringing wood to a landing to create six different piles (Table 2).

Table 2. Time associated with unhooking stems in selection harvesting

	Time (min)	% of total
Total cycle time per machine	66.4	100
Average time for activities at the landing	7.7	12
- Unhooking stems	3.1	5
- Travel between the six piles	1.9	3
- Other (scaling, delays, etc.)	2.7	4

During this study, the total cycle time was long (66 minutes) because of the long skidding distances. The need to unload stems at six different piles decreased productivity by at least 3% compared with unloading at a single pile because of the extra travel between piles and the additional time required for getting on and off the machine more often. Several factors can affect the time required to create sorted piles. The most important are the number of piles, the distance separating the piles and the space available for maneuvering around the piles.

Sorting With Stroke Delimbers

Stroke delimbers are often used for separating two, three or even four products. Since the stems are typically handled one at a time, it is relatively easy to lay them in different locations. Roadside processing permits sorting that would more heavily penalize the productivity of multi-stem machines working on the cutover (e.g., a feller-buncher).

The main problem posed by separation of stems into different products using a delimber is the crowding of the landing by the separate piles of tree-lengths. In effect, since the species are randomly distributed in the undelimbed piles of stems, it is difficult to plan the best position of the stems other than those of the primary product, which typically occupies a position perpendicular to the road. Depending on the available space, on the configuration of the road and ditches, and on the number of products, the secondary products can be placed:

- in separate piles, parallel to the primary pile;
- on top of the primary pile, but positioned some distance back from the edge of the pile, overhanging the edge of the pile, or diagonally atop the pile;

- in the ditch, parallel to the road and in front of the primary pile; and
- on the opposite side of the road.

In 1993, FERIC conducted a study at Stone-Consolidated Corporation's Chicoutimi (Quebec) operations to determine the effect of separating two species, jack pine and spruce, on the productivity of a stroke delimber. Similar data were collected at Abitibi-Price Inc.'s Iroquois Falls (Ontario) division in October 1995. In the latter case, the delimber had to separate sawlog-size stems (>20-cm stump diameter) from smaller-diameter pulpwood stems. The results of these two studies are presented in Table 3. In both operations, the less-abundant product to be separated was placed at 45 degrees on top of the main pile and positioned slightly back from its face (Figure 4).

The productivity loss attributable to sorting was calculated in two ways. The first method consisted of standardizing the stem-placement times for all cycles as if all the stems had been placed in a single pile perpendicular to the road. The results indicated that productivity losses ranged between 7.1 and 9.5%. However, this approach does not account for other delays attributable to the instability of the stems placed diagonally on the piles and alignment of the butts.

Figure 4. Sorting of products with a stroke delimber.

The second method used to calculate the effect of sorting on productivity was to conduct an operational trial in which the delimber worked over a short period without separating the species. In this test, the productivity losses attributable to sorting amounted to 8.2 and 14.0%. However, these results could be questioned in light of the short duration of the trials and the possibility of an accelerated pace of work by the operator. With the available results, it appears reasonable to expect that the separation of two products would lead to a productivity decrease of between 5 and 10% for the delimber.

Table 3. Effect of the separation of two products on the productivity of stroke delimbers[a]

	Stone-Consolidated Corporation		Abitibi-Price Inc.
	Machine 1	Machine 2	
Normal operation - two products			
Total number of stems	631	722	405
Proportions of the two products (%)	53:47	67:33	75:25
Average placement time - main product (min)	0.058	0.061	0.040
Average placement time - second product (min)	0.121	0.116	0.140
Stems/PMH - with sorting of two products	172	223	186
Stems/PMH - estimated without sorting (standardized placement time)	190	240	203
Productivity loss due to sorting (%)	9.5	7.1	8.4
Operational trial without sorting			
Nombre total de tiges	211	161	n.a.
Stems/PMH	200	243	n.a.
Productivity loss due to sorting (%)	14.0	8.2	n.a.

The few cycles that were studied in which a third product was separated indicated an additional increase of 15% in the average delimbing cycle time compared with delimbing cycles in which only two products were separated.

Sorting With Slashers

If the delimber doesn't need to separate the stems and hauling will occur in the form of shortwood logs, the separation of logs with similar characteristics can occur during the slashing phase. In effect, the slasher can process each bolt according to particular specifications and can create distinct piles. However, in practice, the limited mobility of the slasher's carrier limits the number of distinct piles that can be created to two or three in practice. In addition, it is often tempting to process several stems simultaneously to increase productivity, but this has the effect of reducing the proportion of high-value products.

Young and Pike (1994) studied the productivity losses with a mobile slasher separating sawlogs from pulpwood in comparison with the productivity for producing pulpwood alone. The machine's productivity decreased by 36%, from 35.1 to 22.6 m³/PMH. Blinn et al. (1986) found that the total harvesting cost increased by 11.3% in moving from a system that produced only pulpwood to an integrated sawlog/pulpwood production system, with separation carried out by a mobile slasher working at roadside. Fortunately, the increased value of the products recovered from this operation exceeded the cost increase due to sorting.

Product Separation Integrated Within Cut-to-length Harvesting Systems

Cut-to-length harvesting systems lend themselves well to product separation, whether at the stump (by the harvester or the processor) or at roadside (with the forwarder or processor).

Sorting With Single-grip Harvesters

As with a delimber, a single-grip harvester can easily separate its products because it usually handles only a single stem at a time. While proc□œÔessing the felled stems, it is easy to move the harvesting head slightly to create two, three or four distinct piles, with no noticeable loss of productivity. This has been demonstrated in several studies in the Nordic countries (Mikkonen 1977; Kuitto 1980; Bjurulf 1992). Table 4, taken from Bjurulf (1992), shows the minimal effect of separating multiple products (up to four) on a harvester's processing time.

Table 4. Effect of sorting on the productivity of a single-grip harvester (Bjurulf 1992)

	Number of products		
	2	3	4
Number of stems harvested	314	331	332
Average stem volume (m³)	0.15	0.14	0.14
Minutes/stem	0.39	0.41	0.40

In a study carried out by FERIC in 1995 at J.D. Irving, Ltd's St-Léonard (New Brunswick) division, no productivity decrease when separating sawlogs and pulpwood was observed for a single-grip harvester performing commercial thinning.

Sorting With a Processor

A processor can operate at roadside, but typically works on the cutover behind a feller-buncher or a manual faller. In eastern Canada, there are two main processor configurations: a single-grip processor whose processing head is mounted at the end of an articulated boom (e.g., Target, KMB, Marquis ET-1), and a two-grip processor whose processing unit is mounted on the carrier (e.g., Rottne).

The ease of separating products with single-grip processors is comparable to that with a single-grip harvester. Meek (1993) observed processing and sorting of four different products at thtump in New Brunswick without any significant effect on productivity. Favreau (1994) observed a similar result in the La Tuque region of Quebec in a study of a Target '92 processor, which produced up to six different products, including tree-length stems and sawlogs of various lengths (Figure 5).

The creation of different piles is more difficult with two-grip processors, since this requires back and forth movements of the machine or rotation of the processing unit. Moreover, the slashed logs fall from relatively high above the ground, and tend to bounce. It is thus more difficult to control the exact position of each log. Bjurulf (1992) measured a very slight productivity loss during the separation of four products with a two-grip machine (Table 5).

Figure 5. Multi-product processing with a single-grip processor.

Table 5. The effect of sorting on the productivity of a two-grip processor[a] (Bjurulf 1992)

	Number of products		
	2	3	4
Number of stems	301	293	310
Stem volume (m³)	0.24	0.23	0.25
Minutes/stem	0.49	0.49	0.50

[a] The machine was actually a two-grip harvester, but its processing cycle is identical to that of a two-grip processor.

Sorting with a forwarder

Thanks to its articulated boom, a forwarder can also be used to carry out some sorting of products. Three scenarios are possible. In order of increasing cost, these are:

- separately transporting products that have been entirely sorted beforehand by the processor or the harvester;
- carrying out an additional separation working from piles already partially sorted by the harvester; or
- conducting product separation entirely at the time of loading or unloading.

Mikkonen (1977) found that the cost of forwarding increased by \$0.20 to \$1.15/m³ (costs adjusted to 1995 values) when a forwarder delivered four products to roadside rather than two. Kuitto (1980) calculated that each product to separate (beyond two) added from \$0.27 to \$0.50/m³ (costs adjusted to 1995 values) to the total forwarding cost.

The results obtained by Bjurulf (1992) and presented here in Table 6 show the increase in loading time caused by product separation after partial sorting by a harvester.

Table 6 demonstrates that the maximum productivity is obtained when the forwarder does not have to perform any sorting (the "2/2" scenario). The lowest productivity was obtained when the forwarder had to separate two or three additional products, primarily because of increased loading and unloading times, but also because of the increased number of trips per trail when the volume of a single product was insufficient to provide a full load.

The feasibility of transporting more than one product in a single trip depends greatly on the operator's skill, as well as on the log length and the distribution (volume and location) of the various products. Several scenarios for product separation are possible. In order of decreasing feasibility:

Table 6. The increase in forwarder cycle time as a result of the transport or separation of several products (Bjurulf 1992)

	Number of products delivered to roadside[a]				
	2/2	2/4	2/5	3/5	4/5
Number of cycles	7	7	8	8	9
Volume/cycle (m³)	16.0	15.8	14.4	15.1	14.6
Loading time (min/m³)	0.82	1.32	1.41	1.20	1.12
Productivity (m³/PMH)	24.8	20.7	20.0	21.5	22.1

[a] Figures represent the number of products separated by the processor/the number of products unloaded at roadside; the difference between the two numbers represents the number of products separated by the forwarder.

- One product can be loaded while the forwarder moves to the back of the block, and the second during the return to roadside. Thus, the products are separated along a horizontal plane in the load bunk during loading.
- One product can be placed to the left of the bunk and another to the right; that is, the products are separated along a vertical plane within the bunk. The forwarder's load bunk can also be modified (e.g., with the addition of pickets) to help keep the products separate.
- For short logs (less than 3 m), one product can be placed at the front of the load bunk and one at the rear.

Product Separation Integrated With an In-woods Chipping System

During in-woods chipping, it is often necessary to separate veneer-quality logs or sawlogs before chipping. The removal of a certain quantity of sawlogs or veneer logs from the chip-production line increases the chipping cost because the average and total volumes of stems to be chipped decrease. Favreau (1995a) discussed the economic impact of increasing the volume extracted as sawlogs on the cost of roadside chipping.

Favreau and Franklin (1993) studied five scenarios in which sawlogs were separated before chipping; two in hardwood forest and three in softwood forest. In the hardwood stands, they found that the best scenario consisted of using a worker to produce the logs manually as a distinct operation before chipping. Depending on the size of the loader used, the production costs of the sawlogs ranged from \$8.08 to \$10.12/m³.

In softwood forest, the best approach was to produce the logs directly on the cutover, using a processor or a single-grip harvester (Favreau and Franklin 1993). This approach gave a cost of \$7.45/m³ of sawlogs and helped the system to maximize sawlog recovery.

Comparative Analysis of Three Sorting Scenarios

This section of the report illustrates the practical application of the results described in the previous sections. It contains a simulation of three different product-separation scenarios that a manager could choose among to supply six products to six different mills. This type of situation is common in eastern Canada.

For the purposes of the simulation, it was assumed that the harvest occurred in a mixedwood forest containing 30% trembling aspen (0.30 m³/stem), 20% jack pine (0.20 m³/stem) and 50% spruce-fir (0.15 m³/stem), at a density of 1000 merchantable stems per hectare. The six products to be separated were:

- 2.5-m aspen logs for waferboard;
- 5.0-m aspen logs for veneer;
- 5.0-m spruce-fir sawlogs;
- 2.5-m spruce-fir pulpwood;
- 5.0-m jack pine sawlogs; and
- 2.5-m jack pine pulpwood.

The three production options included one full-tree system and two cut-to-length systems:

- a feller-buncher and grapple skidder, with a delimber and a slasher;
- a feller-buncher and a two-grip processor with a forwarder; and
- a single-grip harvester with a forwarder.

The results of the simulation appear in Tables 7, 8 and 9 for the three systems. The productivity and hourly cost assumptions appear in the Appendix (Tables A.1 through A.3). **Table A.4 provides a summary of the productivity correction factors for each machine in terms of the number of products to sort.** The costs for each product (\$/m³) reflect the effect of separating the products and of the average volume per species or product.

The net cost at roadside is lowest with the full-tree system. The simulation gave an additional cost of \$1.77/m³ for the separation of six products, which was 14.5% more than the baseline cost of \$12.20/m³ if all the volume had been transformed into pulpwood. The separation into sawlog and pulpwood piles at the time of slashing was the factor that contributed most to this increase.

The cut-to-length system that used a feller-buncher and a processor saw a cost increase of \$1.33/m³ for separating six products, an increase of 8% over the baseline cost without product separation. The use of a single-grip processor, which is less expensive than the two-grip machine in the simulation, would reduce the cost of this system.

For the conditions and systems simulated, the cut-to-length system with a single-grip harvester was the least affected by the product separation, with a cost increase of only \$0.66/m³, which amounts to 4.2% of the baseline cost (without product separation). This result is attributable to tfact that the harvester's productivity is almost unaffected by the creation of distinct product piles during processing.

Table 7. The costs of sorting products in the simulated full-tree harvesting system

	Without sorting	Cost ($/m³) Aspen products	Jack pine products	Spruce-fir products
Feller-buncher, separation of aspen and softwoods (base productivity -5%)	3.97	3.73	4.47	4.47
Grapple skidder[a]	2.68	2.12	2.96	2.96
Delimber, separation of jack pine/spruce-fir (base productivity - 10%)	2.91	2.46	3.27	3.72
Slasher, separation of pulpwood and sawlogs (base productivity - 30%)	2.64	3.45	3.77	3.96
Total cost	12.20	11.74	14.47	15.11
Weighted total cost	---		13.97	
Additional (sorting) cost	---		$1.77 (+14.5%)	

[a] At a 100-m skidding distance.

Table 8. The costs of sorting products in the simulated cut-to-length harvesting system with a feller-buncher and a processor

	Without sorting	Cost ($/m³) Aspen products	Jack pine products	Spruce-fir products
Feller-buncher, separation of aspen and softwoods (base productivity - 5%)	3.97	3.73	4.47	4.47
Processor, separation of softwoods and two aspen products (base productivity - 2%)	7.24	6.13	7.48	8.61
Forwarder, separation of softwood pulpwood and sawlogs (base productivity - 15%)[a]	5.29	5.29	6.22	6.22
Total cost	16.50	15.15	18.17	19.30
Weighted total cost	---		17.83	
Additional (sorting) cost	---		$1.33 (+8.0%)	

[a] At a 150-m forwarding distance.

Table 9. The costs of sorting products in the simulated cut-to-length harvesting system with a single-grip harvester

	Without sorting	Cost ($/m³) Aspen products	Jack pine products	Spruce-fir products
Single-grip harvester, separation of softwood species and two aspen products	10.57	7.79	10.22	12.39
Forwarder, separation of softwood pulpwood and sawlogs (base productivity - 15%)[a]	5.29	5.29	6.22	6.22
Total cost	15.86	13.08	16.44	18.61
Weighted total cost	---		16.52	
Additional (sorting) cost	---		$0.66 (+4.2%)	

[a] At a 150-m forwarding distance.

Conclusions

In this report, the results of several studies were combined to determine the costs and feasibility of various options for sorting products at the stump or at roadside using machinery commonly used in common full-tree and cut-to-length harvesting systems in eastern Canada.

Overall, cut-to-length harvesting systems, particularly those which use single-grip harvesters or single-grip processors, are the best adapted for carrying out multiple-product sorting at the lowest *additional* cost. It is thus not surprising that the popularity of these systems is increasing in the current context of integrated multiproduct harvesting. However, full-tree harvesting systems remain the least expensive and can also be modified to permit the separation of different products, particularly if there are relatively few products to separate. In this case, the feller-buncher or the delimber can be used effectively.

Multiproduct harvesting is now a reality that all forestry operators must adapt to. FERIC will continue to follow the evolution of technologies that permit the separation of products at the lowest possible cost during harvesting.

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Appendix
Cost and Productivity Assumptions Used in the Simulation

Table A.1. Assumptions common to all machines

Working life (years)	4
Number of scheduled machine hours (SMH) per year	4000
Utilization rate (%)	75
Residual value (% of purchase price)	10
Licensing fees ($/year)	1000
Insurance fees (% of purchase price)	5
Interest rate (%)	10
Wages and benefits ($/operator-SMH)	20
Fuel costs ($/L)	0.45

Table A.2. Assumptions and hourly costs for each machine

	Feller-buncher	Grapple skidder	Delimber	Slasher	Single-grip harvester	Processor	Forwarder
Purchase price ($)	420 000	185 000	300 000	300 000	500 000	460 000	300 000
Lifetime repair cost ($)	420 000	185 000	270 000	270 000	625 000	529 000	300 000
Fuel (L/PMH)	25	18	22	22	21	24	17
Oil and lubricants ($/PMH)	1.80	1.30	1.58	1.58	1.51	1.73	1.22
Fixed costs ($/PMH)	48.48	21.54	34.73	34.73	57.65	53.07	34.73
Variable costs ($/PMH)	48.80	25.35	34.64	34.64	63.68	57.33	34.38
Labor costs ($/PMH)	26.67	26.67	26.67	26.67	26.67	26.67	26.67
Total cost ($/PMH)	123.95	73.56	96.04	96.04	148.00	137.07	95.78

Table A.3. Production functions for the various machines (except for slashi are from FERIC's internal logging database)

	Production function[a]
Machine	
Feller-buncher	$P = 50.338 * V^{0.3011}$
Grapple skidder[b]	$P = 573.01 * D^{-0.6803}$
Delimber	$P = 66.83 * V^{0.4454}$
Slasher[c]	$P = 34.6$
Single-grip harvester	$P = 42.46 * V^{0.6683}$
Processor	$P = 41.16 * V^{0.4902}$
Forwarder	$P = 58.61 * D^{-0.2339}$

[a] P = baseline productivity (m^3/PMH), V = volume (m^3/stem), D = extract in distance (m).

[b] For volumes greater than 0.25 m^3/stem, the productivity increases by a factor of 1.4.

[c] Source: Gingras (1994) for a volume of 0.15 m^3/stem; for volumes of 0.2 and 0.3 m^3/stem, the productivity increases by factors of 1.05 and 1.15, respectively.

Table A.4. Productivity correction factors for sorting[a]

	Number of products		
	2	3	4
Machine			
Feller-buncher	-5%	-10%	n.a.
Delimber	-10%	-15%	n.a.
Slasher	-30%	n.a.	n.a.
Single-grip harvester	0%	0%	0%
Processor (two grip)	-2%	-2%	-2%
Forwarder	-15%	-20%	n.a.

[a] n.a. = not available.