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Contents

Cost of the first entry phase in a shelterwood cut implemented using the 1-2-3 method

Abstract

The 1-2-3 shelterwood cut system developed by FPInnovations–Feric Division is increasingly being used as part of new ecosystem management approaches in eastern Canada. Feric evaluated the direct harvesting costs for the first entry phase in a shelterwood system implemented using the 1-2-3 method, which is also called shelterwood cutting with close selection. We compared the results of the partial cutting operation with those of harvesting with the protection of regeneration and soils (HPRS). The harvesting costs in the shelterwood approach can be up to \$1.87/m³ more than in the HPRS treatment. However, the increased mean stem volume that is harvested as a result of the stem selection guidelines can mitigate this adverse impact in stands with large trees.

Authors

Vincent Roy
and
Philippe Meek

Eastern Region

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Productivity, Harvesting costs, Shelterwood cut, Single-grip harvesters, Cut-to-length, Full-tree.

Introduction

Harvesting in the softwood forests of eastern Canada has been performed for many years using clearcuts, including both harvesting with the protection of regeneration and soils (HPRS) and other techniques. The evolution that has occurred in management objectives during the past decade has created a need to develop partial cutting methods suitable for boreal softwood stands and that can be implemented using the fleet of available equipment. Shelterwood cutting in two stand-entry phases by means of the 1-2-3 selection method (Meek and Cormier 2004) is now used as a practical silvicultural approach suitable for the challenges raised by ecosystem management in old-growth forests. The first phase of this system aims to promote the establishment of regeneration (Figure 1), and the second and final

Figure 1. Example of a stand treated using a shelterwood cut.

phases represent harvesting of the residual stand with the protection of regeneration. The shelterwood cut's primary objective is to permit the establishment of regeneration in stands with inadequate natural regeneration at the time of harvesting. The selection of large stems during the first entry phase decreases the harvesting costs. However, these costs are higher during the second entry phase because smaller wood is harvested. This system compares favorably with the costs of HPRS followed by site preparation and planting (Meek and Cormier 2004).

To help members improve their expertise in the management of this form of harvesting, this report summarizes the treatment costs during the first entry phase of the shelterwood cut in relation to the mean stem volume that is harvested. This analysis relies on the results of studies of full-tree and cut-to-length harvesting operations that were performed during the development of the method as well as during its implementation between 2004 and 2008.

Methods

We used the same approach (observations of paired plots) that was used during the development of this technique (Meek, 2006; Meek and Cormier 2004). The blocks pairs were used to study clearcutting and shelterwood cutting by the same operator, using the same machine, in similar stands. The same guidelines were provided for stem selection in all partial cut blocks. In the clearcut, the operators harvested all merchantable stems (DBH > 9 cm), whereas in the shelterwood cut, they harvested stems in the extraction trail and removed some trees in the zones adjacent to the trail. In addition to eight pairs of observations obtained before 2008, Feric studied five new operations in Quebec in 2008, providing 10 additional pairs of observations (Appendix 1) for an overall total of 18 pairs of operations that could be used in our analysis. Four of these 2008 operations used the cut-to-length harvesting system: Boisaco's operations in the Haute-Côte-Nord region, Tembec's operations at La Sarre, and Produits Forestiers Saguenay's operations in the Saguenay and Charlevoix regions. The fifth was AbitibiBowater's Mauricie operations, which used full-tree harvesting. The cooperators in this study had acquired sufficient experience with shelterwood cutting that the results of the study should be broadly applicable. The operating methods used in the shelterwood cut are described in Sidebar 1.

Comparative study of HPRS and shelterwood cutting

Detailed time studies, combined with scaling of a sample of the logs produced by the operations, were performed to estimate the productivity of the harvesting equipment. Our observations lasted from 4 to 6 productive machine hours (PMH) for each machine. For the extraction phase, the productivity estimates were based on the volumes extracted by approximately 10 forwarder cycles in the cut-to-length system and 10 to 20 grapple skidder cycles in the full-tree system. We used the productivity equations in Feric's FPInterface software to estimate the productivity of the delimbing phase. The direct production costs for each harvesting phase were calculated by dividing the hourly cost for each type of machine by the observed productivity.

The stand characteristics were measured using temporary sample plots. We used two approaches to describe the effect of the shelterwood cut on the residual stand. First, temporary variable-radius plots were established in the treated stands; second, a high-density network of temporary 100-m² rectangular plots (each 5x20 m) was established in the partially harvested zone on each side of the trails. Figure 3 of Sidebar 2 illustrates the layout of these plots. These plots provided an overview of the treatment quality and facilitated supervision of the harvesting team's work.

Table 1 presents the mean characteristics of the stands before and after treatment in the 18 shelterwood cuts studied.

Table 1. Mean characteristics of the 18 shelterwood cuts studied

	Mean
Extraction trails	
Width (m)	5.1
Trail spacing (center to center) (m)	20.6
Area covered by trails (%)	25
Standing volume	
Before (m³/ha)	157
After (m³/ha)	78
% removal	50
Volume harvested (m³/ha)	79
Mean stem volume	
Before (m³/stem)	0.168
After (m³/stem)	0.134
Difference (%)	(20)
Harvested (m³/stem)	0.193

Sidebar 1

Implementation overview of the shelterwood cut using the 1-2-3 method

Objectives: Establishment of regeneration of the desired species and removal of around 50% of the volume.

Target stands: Mature softwood and mixedwoods stands (dominated by softwoods) with average to good vigor.

Treatment: A 5-m-wide strip is clearcut and serves as the extraction trail. The portal-tree technique (residual stems left standing at the edges of the trails) can be used to keep the trails narrow (Figure 2). The goal is to maintain a width of 5 m to provide partial shading for the regeneration while avoiding excessive wounding of the residual trees.

Selection guideline: On each side of the trail, the selection guidelines are applied within a 5-m zone. The operator must identify groups of three merchantable trees, then harvest the largest of the three while distributing the removal uniformly. This guideline can be adjusted based on various additional goals (species selection, value, tree vigor). If no stem is larger than 12 cm in DBH, no removal occurs. It is generally not necessary to manage for vigor or wounding during the first entry phase because the final harvest will occur soon after the first entry (<15 years).

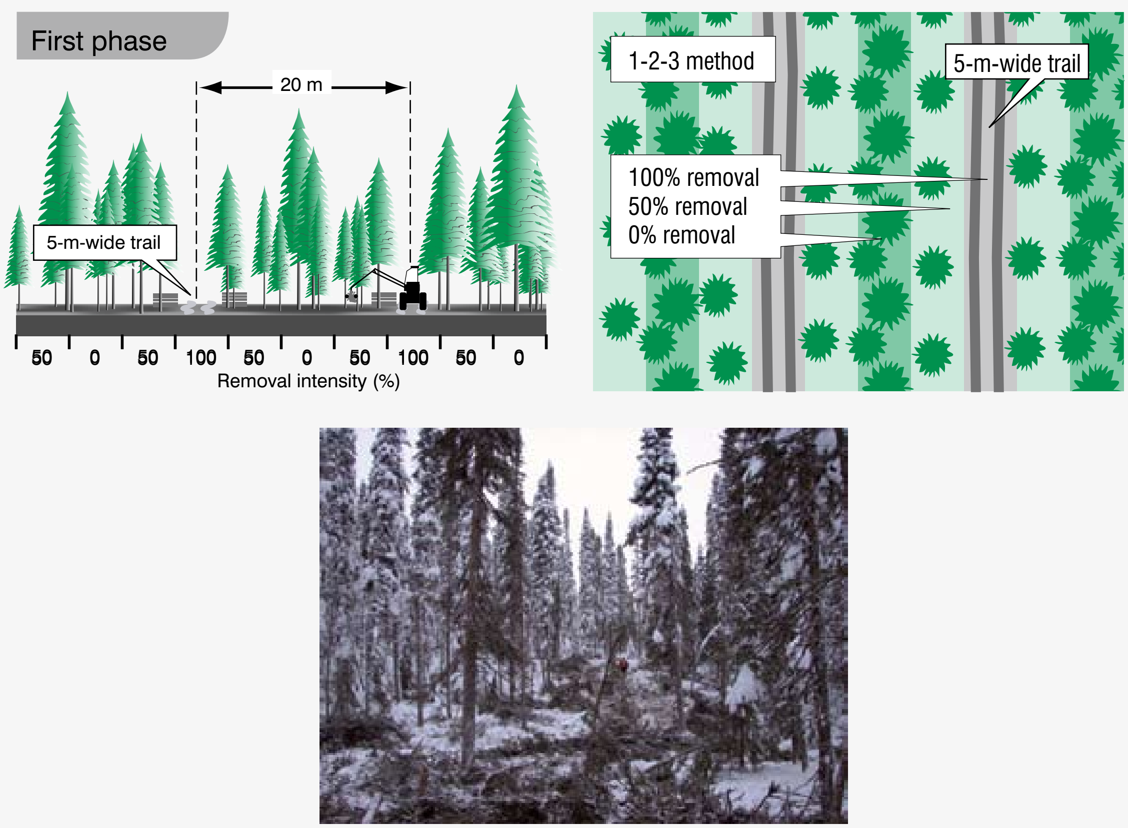

Figure 2. Example of the trails and the removal patterns in the 1-2-3 shelterwood cut method (*note portal trees at trail edges in right-hand figure*).

Sidebar 2

Sample plots used to control the work quality

This inexpensive control system permits rapid evaluation of the treatment quality so that corrections can be made during operations, if necessary.

- Systematically arrange the rectangular 100-m^2 plots to cover the zone of selection cutting after the treatment.
- Measure the trail width (a) and spacing (b).
- Measure the DBH or diameter at stump height (DSH) of standing trees as well as the DSH of harvested stems (depending on which parameter is used in the local volume tables).
- Perform a visual evaluation of the distribution of stumps and of harvesting wounds (to detect any excessive wounding).
- Compile the data (trail spacing and width, removal intensity) and ensure that the work in each plot complies with the operator guidelines.
- Summary stand descriptions can be prepared before and after the treatment based on the results obtained in these plots.

These criteria and indicators can be used informally to permit rapid correction of any problems during operations. Visual estimates are sufficient to judge compliance with the instructions given to the machine operators.

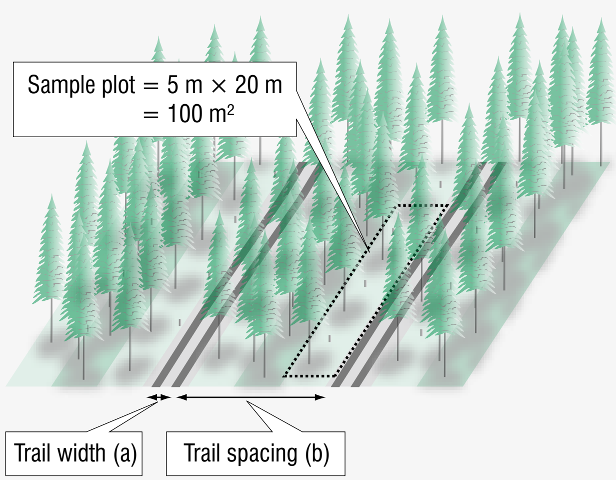

Figure 3. Implementation of the control plots.

Results

Felling and processing versus felling and bunching

Based on the 18 paired observations, the primary factors that affected the work of single-grip harvesters in shelterwood cutting were the increased travel time and increased handling of stems to protect the residual trees. For the feller-bunchers, the travel time and the time required for bunching the harvested stems while protecting the residual stems did not differ greatly between partial cutting and clearcutting. Our analysis of costs as a function of the mean harvested stem volume defined two distinctly different relationships in the two treatments, irrespective of which harvesting system was used.

Extraction

Cut-to-length

During the extraction phase in the shelterwood cut, the forwarder operator had to be more vigilant to limit the wounds to residual stems. In general, the productivity of the forwarders decreased by 5 to 20% in the partial cut. There are several explanations for this decrease:

- The piles of logs were farther apart and had lower volumes. Each grapple load contained fewer logs, on average, than in HPRS. The loading time was thus longer.
- Travel speeds were lower because of the narrow trails
- Travel during loading took longer because the forwarder was forced to move farther to obtain a full load.
- In the partial cuts, incomplete loads within a trail were more frequent.

Full-tree

For the full-tree system, the decrease in skidder productivity ranged from 20 to 40%. This was attributable to the lower bunch volumes. Often, it was necessary to load two bunches to provide a full load, and this increased the distance the skidder traveled, as well as the time required for maneuvering and loading. Although it's possible to minimize this impact by maximizing the size of the piles created by the feller-buncher, this would be offset by decreased feller-buncher productivity.

Direct harvesting costs

In the shelterwood cuts, the selection guidelines required operators to count three adjacent stems and cut the largest one. As a result, the mean harvested stem volume was considerably higher compared with what would have been obtained in a clearcut. Figure 4 illustrates this effect. For the 18 operations, the relationship between the mean standing volume and the mean harvested volume showed an increase of 11 to 19% in the partial cut. This approach thus directly affected the harvesting costs, since the mean stem volume is the variable that most strongly affects the productivity of felling equipment. This relationship can be expected to hold true in any stands that resemble those studied.

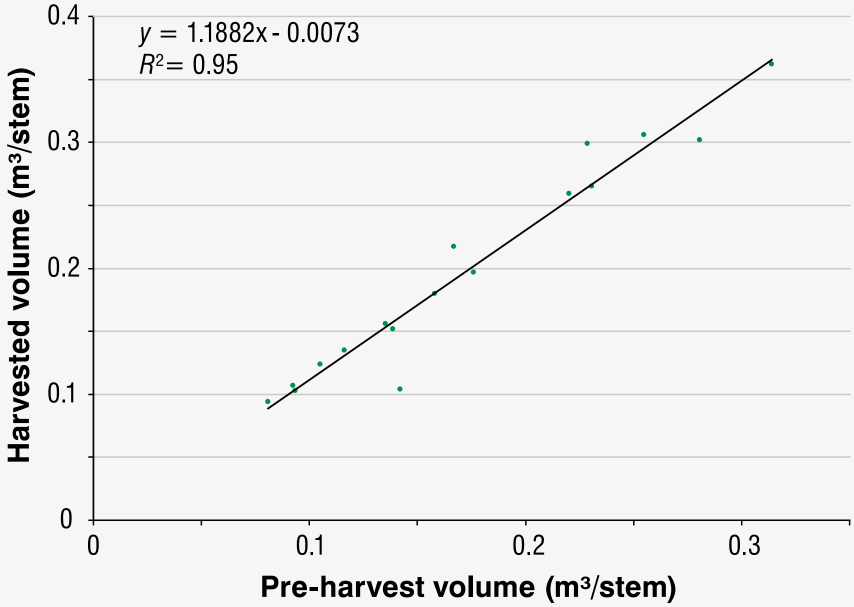

Figure 4. Relationship between the mean volume of the standing merchantable stems before the treatment (Vb) and the mean stem volume harvested (Vh): Vh = 1.1882 Vb – 0.0073, R2 = 0.95.

Figure 5 presents the harvesting costs at roadside as a function of the mean stem volume that was harvested. The indirect costs, estimated at 10%, are included in the calculations. The 18 paired observations were analyzed by means of linear regression to produce the two significantly different cost curves. For the same mean stem volume, the cost of HPRS was from $1.07/m³ to $1.87/m³ lower than the shelterwood cuts. However, in some of the operations, the harvesting costs in the shelterwood cut were less than those in HPRS because the positive effect of the larger mean volume that was harvested outweighed the negative effect of working in a partial cut. It's possible that in certain forest types, the increase in the mean stem volume that is harvested will be very large because of the high proportion large stems.

To accurately estimate the cost of the harvesting operations in the shelterwood cuts based on the 1-2-3 method, it's necessary to consider the effect of the increased stem volume that is harvested

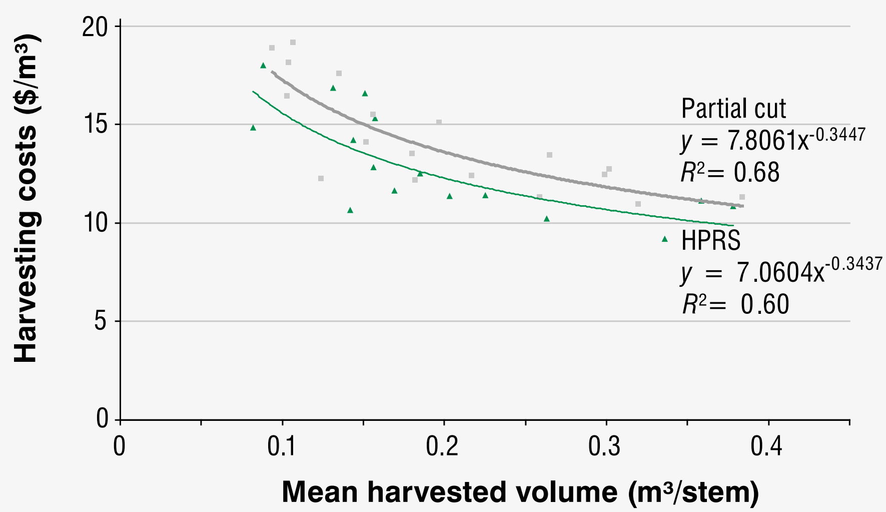

Figure 5. Harvesting costs at roadside for the shelterwood cut (Cpc) and the HPRS (CHPRS) as a function of the stem volume (Vh). (Cpc = 7.8061 Vh–0.3447, R2 = 0.68; CHPRS = 7.0604 Vh–0.3437, R2 = 0.60).

during the first entry phase. Table 2A compares the direct harvesting costs for a stand harvested using the cut-to-length system in HPRS and in a shelterwood cut. The effect of the larger mean stem volume that is harvested (Figure 4) in the shelterwood cut decreases the gap between the felling costs, but this is outweighed by the increased extraction costs, leading to an increase of about 6% ($0.95/m³) in the total harvesting costs.

Table 2B compares the direct harvesting costs for a stand harvested by the full-tree system using the same assumptions used for the cut-to-length system. For a stand with a mean stem volume of 0.115 m³/stem, a mean

Table 2A. Comparison of the costs of HPRS with those of a shelterwood cut (Csh) using the cut-to-length system

	HPRS	Csh
Mean stem volume before harvesting (m³)	0.115	0.115
Mean stem volume harvested (m³)	0.115	0.129
Felling and processing cost ($162/PMH)[a]	9.59	9.43
Extraction cost ($145/PMH)[a]	5.26	6.37
Total harvesting cost ($/m³)	14.85	15.80
Difference ($/m³)	-	0.95
Relative cost (%)	100	106

[a] Typical hourly cost of machines in this category.

Table 2B. Comparison of the costs of HPRS with those of a shelterwood cut (Csh) using the full-tree system

	HPRS	Csh
Mean stem volume before harvesting (m³)	0.115	0.115
Mean stem volume harvested (m³)	0.115	0.129
Felling cost ($181/PMH)[a]	4.95	4.17
Extraction cost ($150/PMH)[a]	3.76	5.68
Delimbing cost ($145/PMH)[a]	6.24	5.95
Total harvesting cost ($/m³)	14.85	15.80
Difference ($/m³)	-	0.95
Relative cost (%)	100	106

[a] Typical hourly cost of machines in this category.

volume of 0.129 m^3/stem was harvested in the shelterwood cut. The felling and bunching costs and the delimbing costs decrease in the shelterwood cut because mean stem volume is the variable that most strongly influences the productivity during these stages. However, despite this, the increase in extraction costs leads to an increase in total harvesting costs in the order of 6% (\$0.95/m^3). As seen in Figure 5, an increase in the mean stem volume that is harvested helps to offset the cost difference between the two treatments. However, during the second entry phase, harvesting of smaller-volume trees will increase the harvesting costs (Meek and Cormier 2004).

Implementation

Implementation of the 1-2-3 shelterwood cut method is relatively simple, but particular care is required whenever any new operation begins. It's helpful to train certain work teams as specialists to rapidly increase their level of expertise and performance.

During the implementation of this method, flagging of the trails helps to guide the machine operators and ensures a uniform trail network. However, this operation can be quite expensive. The use of a GPS navigation system is a less expensive solution.

The cut-to-length and full-tree systems can both be used in shelterwood cuts. However, for large equipment, particular attention must be paid to monitoring the quality of the operation. Using portal trees is strongly recommended (Meek 2006). Machines with the smallest possible upperstructure overhang beyond the tracks will make it easier to meet the trail width guidelines.

Managers can compare the productivity of their operations with those in this report or can use the present results to predict their costs under new operating conditions. However, the results obtained under specific stand conditions can clearly differ from those in the present report.

The structure of the stands to be treated will affect the treatment costs because of the effect of mean harvested stem volume on productivity. Understanding the characteristics of the stands that will be treated will allow managers to predict the magnitude of this volume increase, for example by referring to Figure 4.

The selection guidelines (counting three stems and harvesting the largest one) is a simple rule for machine operators to implement. This guideline can be adapted to meet particular objectives related to stem vigor or species selection. However, care must be taken to avoid unduly complicating the selection guidelines, since the costs would increase beyond those presented in this report.

Acknowledgments

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Appendix 1
Description of the five 2008 shelterwood cutting operations that were studied

Cooperators	Boisaco			AbitibiBowater (Charlevoix)	Produits Forestiers Saguenay		Tembec (La Sarre)		AbitibiBowater (Mauricie)	
Harvesting system	Cut-to-length			Cut-to-length	Cut-to-length		Cut-to-length		Full-tree	
Felling equipment	Tigercat 845			Timbco 415 B	Tigercat 860C		Tigercat 855C		Tigercat 822	
Extraction equipment	Ponsse Buffalo			Valmet 860	Timberjack 1710		n.a.		John Deere 648	
Block	B1	B2	B3	B1	B1	B2	B1	B2	B1	B2
Trail width (m)	4.7	4.7	4.8	4.3	5.3	5.1	5.9	6.0	5.8	5.7
Trail spacing (m)	20.8	21.3	18.9	16.9	19.8	19.6	25.9	25.9	23.5	24.0
Mean stem volume harvested (m^3)	0.302	0.299	0.265	0.124	0.094	0.135	0.103	0.18	0.306	0.362
Harvesting cost, HPRS ($/$m^3$)	12.52[a]	12.52[a]	12.52[a]	10.65	16.86	14.22	9.19	10.21	11.15	10.87
Harvesting cost, shelterwood ($/$m^3$)	12.70	12.45	13.42	12.24	18.89	17.56	16.45	13.49	10.92	11.30

[a] The same HPRS observation was used to generate the three pairs in the Boisaco operation.

FPInnovations – Feric

Eastern Region
580 boul. St-Jean
Pointe-Claire, QC, H9R 3J9
☎ (514) 694–1140
(514) 694–4351
admin@mtl.feric.ca

Western Region
2601 East Mall
Vancouver, BC, V6T 1Z4
☎ (604) 228–1555
(604) 228–0999
admin@vcr.feric.ca

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