Advantage

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Contents

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Studies of the first entry phase in a shelterwood harvesting system

Abstract

The shelterwood system is often perceived as a silvicultural technique with a high implementation cost. FERIC thus developed a relatively inexpensive method for the first entry of a shelterwood system, the seeding cut, based on the selection of dominant trees: the 1-2-3 method. This method helps compensate for the productivity decrease experienced by harvesting equipment as a result of the reduced removal level. The present report summarizes various examples of the use of the 1-2-3 method, and provides guidelines to facilitate its implementation.

Keywords:

Shelterwood harvesting, Natural regeneration, Harvesting, Site preparation, Boreal forest, Productivity, Costs.

Introduction

When the stocking of advance regeneration of desirable species is low, the results of harvesting with the protection of regeneration are often disappointing. However, shelterwood regeneration systems can promote effective regeneration of shade-tolerant species while controlling invasion of the site by competing shade-intolerant species. Frequent reports of desirable regeneration developing after a partial cut (Figure 1) suggest that the extraction trails should be part of the treatment. Shelterwood harvesting also permits extending the harvest rotation, which can (in certain cases) have a positive effect on the annual allowable cut.

Shelterwood harvesting remains a poorly understood silvicultural system in eastern Canada. Current methods, which may be ill-adapted to the operating conditions, often lead to high implementation costs. However, there are many situations where shelterwood harvesting may be an attractive option. For example, in the context of dispersed cut blocks, certain stands must be left standing. These generally show

Figure 1. After the first partial cut, heavy softwood regeneration often develops in the extraction trails.

inadequate regeneration, which could be compensated for by the use of a shelterwood system. The additional wood extracted from the residual stands treated by means of shelterwood harvesting would also help amortize the sums invested in road construction and maintenance.

Simple forms of shelterwood harvesting involve two entries: the first, a seeding cut, permits controlled opening of the canopy and stimulates regeneration; the second, a final cut, removes the remaining cover. This second entry takes the form of harvesting with the protection of regeneration and soils (known as HARP, or CLAAG in some areas), and thus meets the objective of the shelterwood system: to establish abundant regeneration over a 10- to 15-year period.

For the first entry, FERIC has proposed an inexpensive seeding shelterwood method based on the selection of dominants, called the “1-2-3 method”. The method is named based on the process of stem selection: the biggest of every three stems is felled. The high mean stem volume that is removed mitigates the productivity decrease typically experienced by harvesting equipment as a result of reduced removal intensity, unproductive travel, and interference from the residual stand.

FERIC tested the 1-2-3 method in mature softwood and mixedwood forests with five Quebec cooperators (Abitibi-Consolidated Inc., Abitibi Division; Tembec Inc., Témiscamingue Division; Kruger Inc., Scierie Parent Division; Coopérative Forestière Petit Paris; and Matériaux Blanchet Ltée, Amos Division), and one Nova Scotia cooperator (StoraEnso Port Hawkesbury Ltd., Cape Breton). Harvesting equipment of various sizes was used to perform the shortwood and full-tree harvesting operations, and these are described in Appendix 1.

Some species, such as black spruce, have specific requirements for the establishment of regeneration in a shelterwood cut. For this reason, we conducted a parallel study of techniques for seedbed preparation under forest cover (Appendix 2).

This Advantage report summarizes the information gathered on the first entry of the harvesting operation, namely the seeding cut, and on the seedbed preparation that is often required for the establishment of moderately shade-tolerant species in eastern Canada.

Work methods

Partial cutting

Stands targeted for the proposed work method comprised trees of dimensions typically harvested by clearcutting. Figure 2 illustrates the trail layout used and the tree-removal pattern for the main variant of the 1-2-3 method that we studied, which is based on the selection of dominant stems.

Harvesting is carried out along 5-m-wide trails, spaced 20 m apart. Selective harvesting of 50% of the volume is performed in a 5-m-wide strip on both sides of the trail. The 5-m trail width permits efficient maneuvers by the felling equipment and reasonable travel speeds by the forwarder. An effective boom reach of 7.5 m for the

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harvesters is sufficient to perform the partial cut within the 5-m strips. The 5-m-wide untreated strip that lies between the extraction trails will become the access corridor for the final entry. No effort is made to encourage regeneration in this strip, which contains around 25% of the stems in the original stand. As such, the overall

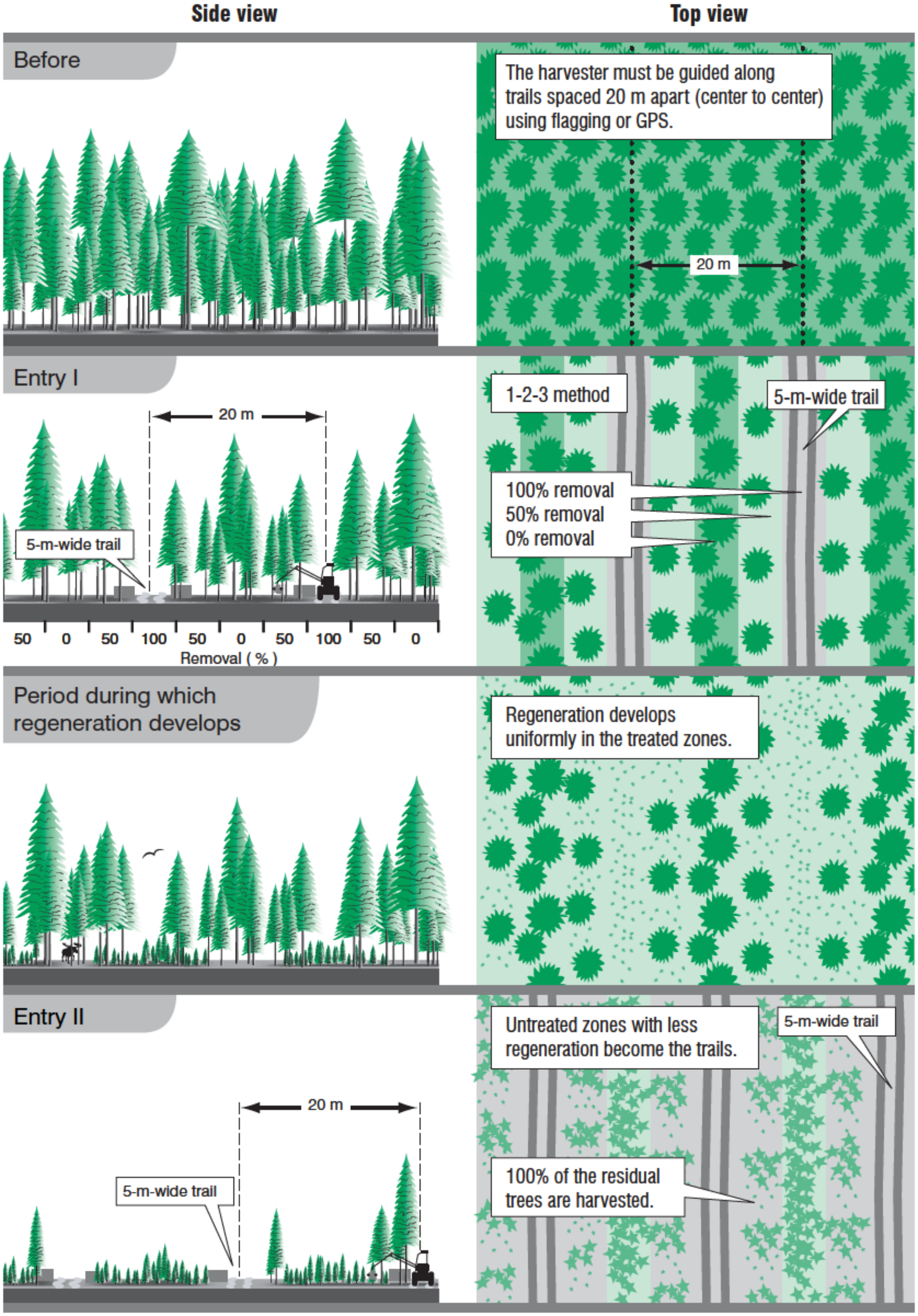

Figure 2. A shelterwood system based on the 1-2-3 method. *During the first entry, the overall removal intensity is 50%. Extraction trails (5 m wide) are spaced every 20 m, and sustain a removal intensity of 100%. Selective harvesting (50% removal), based on the 1-2-3 method, is applied on each side of the trail to a distance of 5 m. This facilitates the development of uniform regeneration under forest cover. The 5-m-wide untreated strip, in which no removal occurs, will serve as an access corridor during the second (final) entry.*

stand-level removal intensity is 50% during the first entry (partial cutting) and 50% during the second entry (the final cut).

Selecting which stems to fell is easy for the harvester operator, since simple guidelines have been designed to sustain high felling productivity. In a shortwood operation, the operator of the single-grip harvester fells all stems in the 5-m-wide extraction trail and creates piles on each side of the trail. Next, the operator must identify groups of three trees within 5-m-deep strips on each side of the trail, starting at the edge of the trail and moving deeper into the stand. The largest of each group of three trees is felled, unless one of the other stems is defective (dead, dying, or leaning). In a full-tree operation, the operator must first identify where to pile the stems alongside the trail or must create such a space during felling before harvesting the trees within the trail and the selected trees (Figure 3).

Figure 3. Arrangement of full-tree piles along an extraction trail in the openings created by selective felling.

Site preparation

The 1-2-3 method that we have proposed for harvesting during the first entry of the shelterwood cut facilitates the preparation of seedbed under the forest cover. The partial-cut zone is relatively narrow, and thus remains accessible from the trail by excavators of average size (with a boom reach of around 8 m from the center of the trail), which are used to create scarified patches. These machines are very adaptable, and have even been used in snow deeper than 1 m.

As in the harvesting phase, a version of the 1-2-3 method can be applied. In this approach, the excavator travels around 3 m, then stops to create a patch a bit larger than 2 m^2 in size (ca. 1 m wide by 2 m long) on each side of the trail, as well as a third patch within the trail. To avoid excessive root damage, the patches should be created at least 1 m from residual trees.

Trials of the 1-2-3 shelterwood method

Partial cutting

The 1-2-3 shelterwood method was the subject of a series of trials designed to help develop an efficient technique for the first entry of the shelterwood cut, to determine the costs of this first intervention, and to determine its flexibility over a wide range of conditions. In addition, the trials let us confirm that the harvesting pattern posed no problems for subsequent scarification; furthermore, it allowed us to demonstrate its biological suitability by letting cooperators monitor the biological response of the stand, and to demonstrate the simplicity and ease of implementation of the method.

Appendix 1 summarizes the seven trials which encompassed 11 harvest blocks, and which treated a range of forests: mixedwood stands dominated by poplar or birch, black spruce stands with jack pine or fir components, and pure fir or black spruce stands. All stands were mature and had inadequate stocking of advanced regeneration. The removal intensity in these operations was always close to 50%. These removal levels were attained in all of the 11 partial-cutting blocks without flagging the trees to be harvested, which clearly demonstrates the ease of implementation of the 1-2-3 method.

Evaluations of harvesting productivity were performed by comparing the equipment's work in clearcutting with that in partial cuts, based on the 1-2-3 method. Each evaluation compared the productivity of the same operator, using the same felling machine and under similar operating conditions.

In the cut-to-length operations of Abitibi-Consolidated, Kruger, and Coopérative Forestière Petit-Paris, single-grip harvesters equipped with a 10-m reach telescoping boom were used (Figure 4). This let us compare two variations of the 1-2-3 method: one in which the operator used the full boom reach and another in which the selective felling was confined to the zone nearest the trail by limiting the use of the full boom extension. With this specialized equipment, typically observed in commercial thinning (Meek 2001), the trail width could be maintained at around 4 m and the trail spacing was increased by 5 m, for a total spacing of 25 m.

We also conducted productivity comparisons in two full-tree operations. The strip in which selective felling was carried out was quite narrow, since the effective reach of the feller-bunchers was limited to 7 or 8 m. In these two operations, the trail width exceeded the prescribed 5 m.

Figure 5 summarizes the results of our detailed productivity studies of the single-grip harvesters in the cut-to-length operations. Each productivity measurement for the shelterwood cut was compared with the corresponding measurement in clearcutting. These productivity comparisons and the typical productivity curve for clearcutting in eastern Canada, provided by FERIC's *ProVue* database, let us develop the curves in Figure 5. The two productivity curves for single-grip harvesters in shelterwood cuts are juxtaposed with the curve for clearcutting in eastern Canada, and illustrate the expected productivity decreases for selective felling in the shelterwood cut: 12 and 21%, respectively, when using a shortened boom reach and when using the full boom reach.

We performed the same analysis for the full-tree operations, and discovered an average productivity decrease of 33% for the feller-buncher in the shelterwood system compared with its productivity in clearcutting. During our visit to the Matériaux Blanchet operation, we also compared the productivity of the grapple skidder in both operations, and found only modest productivity decreases (11%) in the shelterwood cut.

Figure 4. A single-grip harvester based on a Samsung 150 carrier, equipped with a DT boom and a Pan 841 head, working in a mixed jack pine–black spruce stand.

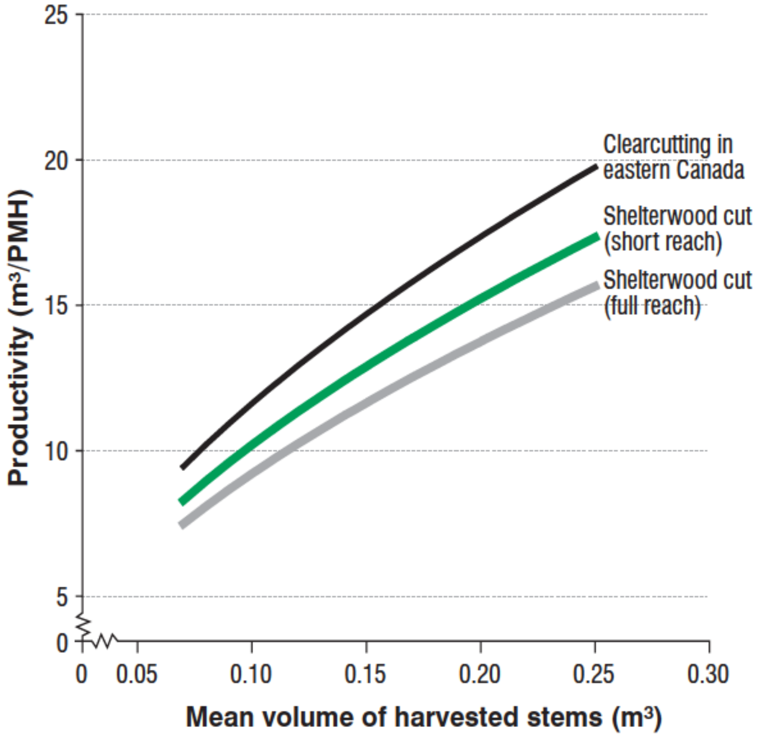

Figure 5. Productivity of the single-grip harvesters as a function of the mean volume of the harvested stem in clearcutting (Productivity = 44.016 * Volume per tree$^{0.5783}$), and in shelterwood cuts using only the short boom reach (Productivity = 38.626 * Volume per tree$^{0.5783}$) and using the full boom reach (Productivity = 34.881 * Volume per tree$^{0.5783}$).

Site preparation

We conducted site-preparation trials in three of the seven harvesting operations (Appendix 2). These trials used two scarification techniques to create scarified patches: a motor-manual technique using brush saw scarifiers and a mechanized technique using excavators.

Motor-manual scarification created two types of scarified patches, depending on whether or not the operator cleared a wide ring around 30-cm-diameter microsites. This cleared space was intended to decrease the risk of rapid invasion by the surrounding competing vegetation. Treatment of the microsite consisted of exposing mineral soil in part of the patch, with the surrounding cleared area (if present) receiving only a surface treatment. Compared with the treatment performed by the excavator, the microsites produced by motor-manual scarifiers were much smaller and consisted essentially of a small “hole” on sites with deep humus. The addition of a cleared area around the microsites decreased the “hole effect”, but the microsite took longer to produce.

Excavators of average size (8 to 12 tonnes) were used for the production of the scarified patches. Because the work monitored was performed in the winter, the machines were equipped with a bucket rather than a rake to facilitate removal of the snow (Figure 6). The work was performed in operations with different harvesting-corridor widths, thus with different dimensions and densities of scarified patches. To facilitate the machine’s travel and decrease the risk of damage to residual trees, the excavator remained entirely within the trails. The width of the treated corridors was thus limited by the excavator’s reach (around 8 m) from the center of the trail.

Figure 6. The Komatsu PC120 excavator used for site preparation in the Abitibi-Consolidated operation.

In operations with 5-m-wide trails, the thinned strips should thus be limited to 6 m width to ensure a complete treatment.

This work demonstrated that it was most efficient to use excavators and limit motor-manual scarification to locations where access to the site by the machines posed problems. With an excavator, it is more efficient to clear scarified patches at least 2 m^2 in size than smaller scarified patches, since the larger patches could each offer the equivalent of two suitable microsites. The main factor that affects the scarification cost when doing patch scarification is the target density of microsites per hectare (Figure 7). Operating costs should be around $300/ha for a density of 1000 microsites/ha, when doing excavator scarification.

Performing the scarification during the winter lets managers extend the treatment season and/or have access to sensitive sites (wet zones or riparian zones). However, the treatment quality is more difficult to control under these conditions. Follow-up is being conducted by the Canadian Forest Service to monitor natural regeneration in the scarified patches produced by the excavator and the motor-manual scarifier.

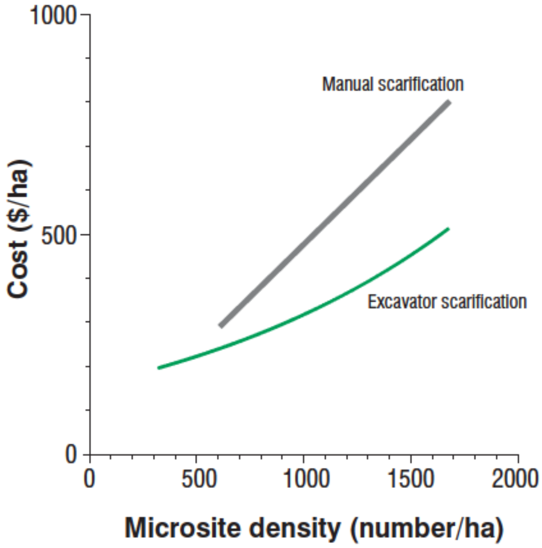

Figure 7. Cost curves for manual scarification of scarified patches with a cleared ring ($Y = 0.477 * \text{density of microsites}$) and for excavator scarification ($Y = 156.2 * e^{0.0007\,\text{density of microsites}}$) as a function of the density of microsites produced.

Implementation costs

The costs of using the proposed shelterwood system are summarized in Table 1 and are compared with the costs of clearcutting trees with the *same mean volume*. The first entry of the shelterwood cut would cost an additional $474/ha (full-tree) and $533/ha (cut-to-length) compared with clearcutting. However, additional costs for whole-scale or infill planting must sometimes be added to the clearcutting scenarios.

A second analysis, presented in Table 2, thus compares a shelterwood scenario with a scenario based on clearcutting and

Table 1. Example of the direct costs for the first entry of a shelterwood cut with a harvest of 90 m³/ha

		Clearcut		Shelterwood cut	
Cut-to-length system	**Hourly rate**	**Productivity (m³/PMH)**	**Cost ($/m³)**	**Productivity (m³/PMH)**	**Cost ($/m³)**
Felling plus processing (0.120 m³/stem)	$148/PMH	12.9	11.47	11.3	13.10
Extraction (dist. 300 m)	$110/PMH	17.8	6.18	14.7a	7.48
Site preparation (1000 microsites/ha)	$105/PMH	n.a.	n.a.	390 microsites/PMH	2.99
Total ($/m³)			17.65		23.57
Cost difference - ($/m³)				5.92	
- ($/ha)				533	

		Clearcut		Shelterwood cut	
Full-tree system	**Hourly rate**	**Productivity (m³/PMH)**	**Cost ($/m³)**	**Productivity (m³/PMH)**	**Cost ($/m³)**
Felling and bunching (0.120 m³/stem)	$124/PMH	33.5	3.70	22.5	5.51
Extraction (dist. 300 m)	$89/PMH	24.0	3.71	21.3	4.18
Delimbing	$110/PMH	20.0	5.50	20.0	5.50
Site preparation (1000 microsites/ha)	$105/PMH	n.a.	n.a.	390 microsites/PMH	2.99
Total ($/m³)			12.91		18.18
Cost difference - ($/m³)				5.27	
- ($/ha)				474	

Table 2. Comparison of the shelterwood and clearcutting systems in cut-to-length harvesting of a poorly regenerated stand with a mean stem volume of 0.120 m^3

	Rate	Productivity (m^3/PMH)	Cost ($/$m^3$)
Shelterwood system			
1st Entry 90 m^3/ha			
Felling plus processing (0.138 m^3/stem)	$148/PMH	12.3	12.03
Extraction (dist. 300 m)	$110/PMH	14.7	7.48
Site preparation (1000 microsites/ha)	$105/PMH	390 microsites/PMH	2.99
Total ($/$m^3$)			22.50
2nd Entry 90 m^3/ha			
Felling plus processing (0.102 m^3/stem)	$148/PMH	11.6	12.76
Extraction (dist. 300 m)	$110/PMH	14.7	7.48
Total ($/$m^3$)			20.24
Mean cost for two entries			21.37
Clearcutting + planting system (180 m^3/ha)			
Felling plus processing (0.120 m^3/stem)	$148/PMH	12.9	11.47
Extraction (dist. 300 m)	$110/PMH	17.8	6.18
Planting (production of plants. site preparation, planting)	$1000/ha		5.56
Total			23.21
Difference - ($/$m^3$)			1.84
- ($/ha)			331.20

planting for a stand that has inadequate advanced regeneration. If the proposed shelterwood system based on the selection of dominant trees is used during the initial intervention, costs are less than those presented in Table 1 because the larger trees are harvested (assumption: an increase of 15% in the mean volume harvested during the first entry and a negligible growth of residual stems until the second entry). However, the smaller residual trees increase the cost of the second entry compared with clearcutting of the original stand. Nonetheless, the shelterwood system based on the 1-2-3 selection method is less expensive (by $331/ha) than the clearcutting system (cut-to-length) once planting costs are included.

Implementation

Since the priority in the shelterwood system is to create conditions suitable for regeneration, it's feasible to avoid expensive efforts to protect the residual stand or perform sophisticated stem selection during felling, unlike in a commercial thinning operation. The quality criteria for the 1-2-3 method offer a simpler option: they focus on confirming that the target distances and removal intensity are met.

The 1-2-3 seeding cut takes advantage of wide extraction trails and can thus be adapted to permit the use of large equipment. This equipment is available in all operations in eastern Canada, thereby permitting rapid implementation of this approach.

The proposed method can be modified to meet the specific ecological requirements of each target species and of the expected competing species. The overall removal intensity can vary between 30 and 60%. The trails themselves represent openings whose width can be increased or decreased to permit the use of specialized equipment. If the shelterwood system requires a three-entry harvest, the first phase can be repeated twice, and the spacing of the trails and removal intensity are modified accordingly.

Most equipment operators demonstrated an ability to select stems so as to maintain their felling productivity. The mean volume of the standing stems decreased in the treated stands, demonstrating that selection based on the 1-2-3 method produced the desired result.

In light of the results of these trials, FERIC has singled out the following elements as important in the implementation of the 1-2-3 method:

- FERIC recommends the use of a seeding cut based on selection of dominants (the 1-2-3 method, with trails spaced at 20 m, center to center) for the shelterwood system. Removal intensity and the timing of the second entry of harvesting should be adjusted to accommodate the local ecological characteristics.
- If a trail spacing of 25 m can be justified biologically, the use of specialized equipment (with a 10-m boom reach) would be required, leading to additional felling plus processing costs that are proportional to the productivity decrease illustrated in Figure 5.
- Harvesting of dominant stems should be favored where the residual stand will have sufficient seed trees remaining after harvesting to ensure adequate regeneration.
- To implement the system with 5-m-wide strips (Figure 2), navigation aids must be provided to guide the operator of the harvester. The use of GPS or flagging of the trails (spaced 20 or 25 m apart) would ensure a uniform distribution of the treatment.
- The use of an excavator for site preparation after the partial cut in the first intervention offers considerable flexibility, and the treatment window can even be extended into the winter when the snow depth is not excessive (less than 1 m). Trails spaced 20 m apart let the machines travel exclusively within the trails, which facilitates the operations and decreases the risk of damaging residual trees.
- The costs related to the use of this shelterwood system are summarized in Tables 1 and 2, respectively, for scenarios with clearcutting wood of the same mean volume and with a complete two-entry shelterwood cut compared with clearcutting plus planting.

Acknowledgments

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Appendix 1 - Description of the shelterwood operations studied by FERIC

Cooperators	Abitibi-Consolidated (Abitibi div.)			Kruger (Scierie Parent)		Tembec (Temis. div.)	Coopérative Forestière Petit Paris		Stora Enso Port Hawkesbury	Tembec (Temis. div.)	Matériaux Blanchet (Amos)
Type of stand	Black spruce and jack pine			Black spruce		Spruce and white birch	Jack pine and black spruce		Balsam fir	Trembling aspen and spruce	Black spruce
Initial merchantable vol. (m^3/ha)	230			n. m.		167	124		248	152	171
% removal	51			50 %[p]		48 %	46 %		47 %	60 %	44 %
Change in mean stem volume as a result of first intervention (%)	–6			n. m.		–28	–13		–14	–45	+21
Harvesting system	Cut-to-length			Cut-to-length		Cut-to-length	Cut-to-length		Cut-to-length	Full-tree	Full-tree
Equipment used	Single-grip harvester Samsung 130/ Pan 828			Single-grip harvester Samsung 150/ Pan 841		Single-grip harvester Valmet 921	Single-grip harvester Samsung 150/ Pan 841		Single-grip harvester Enviro	Feller-buncher Case 1187C	Feller-buncher Prentice 630
Block	**B1**	**B2**	**B3**	**B1**	**B2**	**B1**	**B3**	**B4**	**B1**	**B1**	**B1**
Trail width (m)	4.4	4.0	4.3	5[p]	5[p]	5.5	3.6	3.9	4.8	7.1	5.7
Trail spacing (m)	16[p]	23.7	24[p]	18[p]	26[p]	20.5	17.4	23.6	18.7	19.7	19.2
Mean volume per harvested stem (m^3)	0.152	0.202	0.120	0.142	0.111	0.214	0.156	0.144	0.107	0.217	0.104
Productivity (m^3/PMH)	17.5[a]	18.0[a]	14.2[a]	12.1[a]	11.7[a]	12.1[a]	14.9[a]	12.5[a]	10.1[a]	44.5[b]	32.5[b]

[a] felling plus processing, [b] felling plus bunching, [p] according to the prescription, n. m. = not measured

Appendix 2 - Description of the patch scarification operations studied by FERIC following shelterwood harvesting

Cooperators	Abitibi-Consolidated (Abitibi div.)			Coopérative Forestière Petit Paris		Matériaux Blanchet (Amos)	
Equipment used	Komatsu PC-120 excavator			Kobelco 905 LC-II excavator		La Taupe scarifier/ 65 cc brush saw	
Reach of the machine (m)	8.2			8.6		n.a.	
Snow depth (m)	1.6			1.0		0	
Scarification technique	Trails 16 m/ Short scarified patches	Trails 24 m/ Short scarified patches	Trails 24 m/ Long scarified patches	Trails 16 m/ Long scarified patches	Trails 24 m/ Long scarified patches	Scarification without cleared rings	Scarification with cleared rings
Density (scarified patches/ha)	607	587	372	254	219	1640	797
Size of scarified patches (m^2)	1.3	1.3	2.6	2.4	2.7	0.1	0.8
Productivity (scarified patches/PMH)	304	335	206	107	99	1640	797
Cost ($/1000 microsites)	345	313	255	491	530	151	477