Technical Note **TN-242** March 1996

EFFECTIVENESS OF CUT-TO-LENGTH HARVESTING AT PROTECTING ADVANCE REGENERATION

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Abstract

Cut-to-length systems based on a single-grip harvester and a forwarder are generally well suited to the protection of advance regeneration. However, regeneration levels may still sometimes fall below what is desired. In the first part of this study, FERIC investigated the factors that affect the survival of fir seedlings. Seedlings beneath piled wood sustained approximately twice as much damage as those located in the felling zone, whereas all seedlings located in extraction trails or under slash piles were deemed to be of unsatisfactory quality. In the second part of this study, FERIC proposed two variations on the usual work methods and studied the results in terms of protection of regeneration. The method that concentrated slash and wood piles increased the level of protection afforded to the regeneration, without any major effect on harvesting costs. Dispersal of slash over the cutover did not provide satisfactory protection of regeneration, but might nonetheless improve a site's plantability.

Introduction

The cut-to-length system is increasing in popularity in eastern Canada. In the managed stands of the Nordic countries of Europe, where these harvesting systems originated, silvicultural scenarios do not necessarily rely on advance regeneration, and slash loads generally do not pose a problem. However, given the higher slash loads inherent to natural stands in eastern Canada, many forest companies are asking whether problems can arise during the reforestation of a site harvested using a cut-to-length system. Figure 1 illustrates the problem well. The area occupied by extraction trails, piles of processed wood and heaps of slash left on the cutover leaves little room for the growth of young advance regeneration.

Figure 1. An extreme example of occupation of the site by "sidewalks" of piled wood and heaps of slash.

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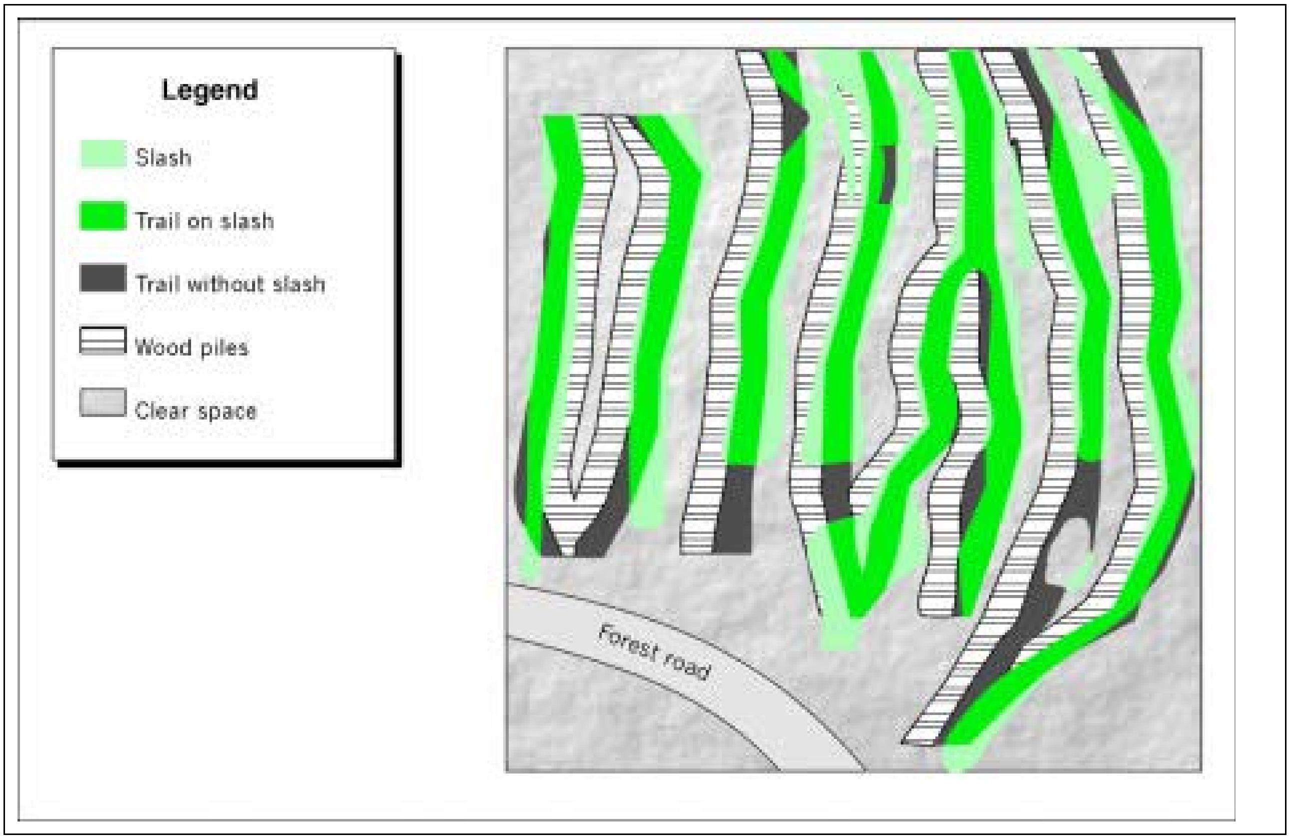

Figure 2. A cutover in which cut-to-length harvesting was conducted (in the Ashuapmushuan Wildlife Reserve in Quebec, 1993).

The diagram in Figure 2, which was produced during a 1993 FERIC study, indicates that about 40% of the area was clear. On this cutover, the stocking of softwood regeneration decreased from 64% before harvesting to 26% afterwards. Factors that could explain this decrease include heaps of slash that extended outside the extraction trails, the low heights of the log piles, and the high proportion of the site occupied by extraction trails, which arises from incomplete utilization of the full reach of the harvester's boom.

Moreover, the presence of slash on the cutover can reduce the quality of site preparation when this treatment is required. In 1994, surveys conducted by FERIC indicated that the slash from cut-to-length harvesting was responsible for a decrease of 10 to 20% in the number of available microsites after site preparation done 2 years after harvesting.

The present Technical Note is divided into two parts. In the first, the impact of a cut-to-length system on regeneration was studied in June 1994 near Lac Castagnier in the Abitibi region of Quebec on the operations of Matériaux Blanchet Inc. Damage to regeneration was measured, taking into account the seedling's position in the felling corridor, the causes of seedling losses, seedling condition and regeneration density. In the second part of this report, FERIC proposed modifications to the usual harvesting method and tested these modifications on the operations of Donohue St-Félicien Inc. in the Lac St-Jean region of Quebec. Three harvesting methods were studied in detail in terms of equipment productivity and silvicultural impacts in the context of a harvest with protection of advance regeneration.

Part A: Impact on Advance Regeneration

Site Description

The study block was located at approximately half the maximum extraction distance in a dense stand (1500 stems/ha) comprising 70% black spruce and 30% jack pine. An opening in the forest cover not far from the study block had led to the establishment of around 15 800 seedlings/ha of fir regeneration, with an average height of 75 cm and a stocking of 100%. The weather was dry during harvesting and the site was flat and firm (CPPA class 2.1.1; Mellgren 1986).

The harvesting system comprised a six-wheel-drive Rottne Rapid forwarder with a 14-tonne capacity and a Rottne Rapid EGS single-grip harvester that produced 3.10-m sawlogs.

Study Methods

The position and height of 395 randomly selected seedlings were surveyed in an 18 × 18 m square plot, divided into reference points along a 2-m internal grid. The plot was positioned along the path of the harvester so as to include at least one entire felling corridor. Once extraction was complete, the condition of the control seedlings and the apparent reason for their condition were recorded. The presence of a control seedling on the extraction trail or beneath a slash pile was easy to establish after extraction of the wood. The identification of seedlings covered by piles created by the harvester was carried out using vertical photographs (Figure 3) and photogrammetric calculations. Each reference point was also used as the center of a 4-m² sample plot used to calculate stocking.

Results

The stocking of regeneration decreased from 100% before harvesting to 65% afterwards. Table 1 presents the condition of the control seedlings for each type of surface cover class. The quality indices in the table were adapted from those described by Ruel et al. (1992). Quality 1 represents an undamaged stem. Seedlings in the Quality 2 class displayed one of the following two defects: a slight inclination (less than 30° from the vertical), or less than one-quarter of the stem circumference with missing bark. Seedlings that had been cut, buried, crushed, uprooted, or severely wounded, as well as those that had an inclination of more than 30° or two light wounds, were classed as Quality 3.

Figure 3. Vertical photograph of a reference point next to a log pile.

The relative areas were corrected so as to represent a typical harvesting corridor (16 m wide). To eliminate overlapping of areas, only those parts of the trails that were free of slash are classed as "trails" in Table 1. The proportion of the actual area occupied by trails, with or without slash, was 27% for the harvesting corridor that passed through the study block. This result complies with current Quebec regulations, which limit the area occupied by trails on a mechanically harvested site to 33% of the total area.

No significant relationship could be established between the presence of damage and seedling height. Trees in the five height classes that contained sufficient stems for purposes of analysis ranged from 5 cm to 2 m in height.

Discussion

The presence of slash or of a trail explained most cases in which regeneration was absent in a sample plot. The regeneration had been destroyed in only three plots outside these zones. However, these three plots contained only one or two seedlings before harvesting. The decrease in stocking thus corresponds almost directly to the relative area occupied by harvesting slash and by trails. Among the plots located in the felling and piling zones, all plots that contained four or more seedlings before harvesting (corresponding to a

Table 1. Summary of seedling quality in each class of surface cover

	Relative area (%)	Proportion of control seedlings (%) in each quality class		
		Quality 1	Quality 2	Quality 3
Surface cover class				
Slash accumulation	16	0	0	100
Trail (without slash)	14	0	0	100
Log pile	17	23	7	70
Felling zone	53	45	17	38
All cover types	100	28	10	62

density of at least 10 000 seedlings/ha) re- tained at least one seedling after harvesting.

As expected, all the control seedlings located in zones of slash accumulation were classified as unsatisfactory (Quality 3). As well, no seedling with satisfactory quality was found on the trail, not even in the central portion, where the ground clearance of the machinery had been expected to spare some seedlings. The fragility of fir regeneration is largely responsible for these results. More than half of the damaged control seedlings in the felling zone had been damaged during positioning of the felling head or as a result of sweeping by branches during processing of the stem. The condition of control seedlings covered by log piles was intermediate between that of seedlings in the felling zone and that of seedlings in zones of slash accumulation. This result suggested that it is desirable to concentrate log piles on the cutover. As a result, an approach based on concentration was evaluated, and the results are described in Part B of this report.

Part B: Modified Harvesting Methods to Improve the Protection of Regeneration

Site Description

In August 1994, FERIC studied the productivity and efficiency of three cut-to-length harvesting methods on Donohue St-Félicien's St-Thomas (Quebec) operations: the method that was normally used (henceforth called the "usual" method), a method with concentration of slash, and a method with dispersal of slash. These methods were compared in three adjacent blocks of softwood forest. The main characteristics of the black spruce stands in the study are presented in Table 2. The site conditions were favorable for harvesting (CPPA class 2.1.1; Mellgren 1986).

Table 2. Average characteristics of the stands in the study blocks

	Method		
	Usual	Concentration of slash	Dispersal of slash
Density (stems/ha)	760	990	1150
Average stem volume (m^3)	0.231	0.170	0.171
Merchantable volume (m^3/ha)	176	168	197

Description of Harvesting Techniques

Figure 4a illustrates the harvester's operational technique in the "usual" method. This operational approach was the one ordinarily used by the operators and as such, was considered to be the most productive. During these trials, the instructions for operating in the first block were to continue using the usual method, in which no particular effort was made to concentrate slash or logs. Where the harvester encountered high stand densities, this method created "sidewalks" (i.e., continuous piles) of wood. The operator nonetheless attempted to maximize the width of the cut strip.

The second method was intended to concentrate slash in the extraction trail, and to pile wood as high as feasible, so as to cover the minimum possible area (Figure 4b). The hypothesis to be tested was that this method would either improve the protection of regeneration or would permit an improvement in the quality of site preparation, since the site preparation implement would only have to avoid the heaps of slash. Without additional travel by the carrier, a larger portion of the felling was conducted with the boom at full extension. When tops were longer than the width of the trail, the operator was required to rotate the tops so that they lined up with the trail or to slash them into two or more sections.

The third method, illustrated in Figure 4c, could prove useful if site preparation was inevitable because of insufficient advance regeneration, as in the case of jack pine stands or overly dense softwoods. Slash dispersal primarily involved moving the tops and branches away from the trail, particularly during the movement of the felling head towards the next tree to be felled.

Study Methods

A Timberjack 1210 forwarder and a harvester comprised of a Keto 150 harvesting head mounted on a Caterpillar 320 chassis were used in this trial (Figure 5).

The productivity of the equipment was determined by time studies conducted in each of the three blocks. A sample of the 5-m logs was scaled to calculate the average log volume. By applying this average volume to the number of logs handled per productive machine hour (PMH), machine productivity in m^3/PMH was calculated.

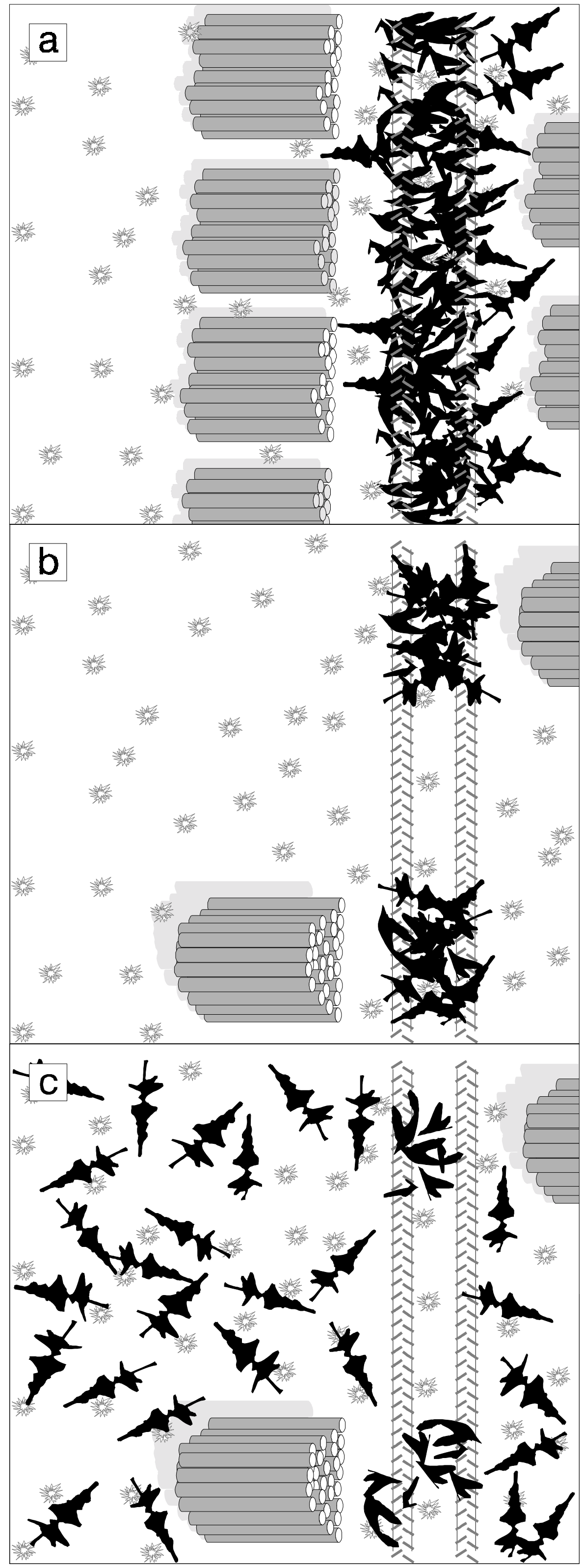

Figure 4. Diagram of the distribution of slash and wood in (a) the usual method, (b) the method with slash concentration, and (c) the method with dispersal of slash.

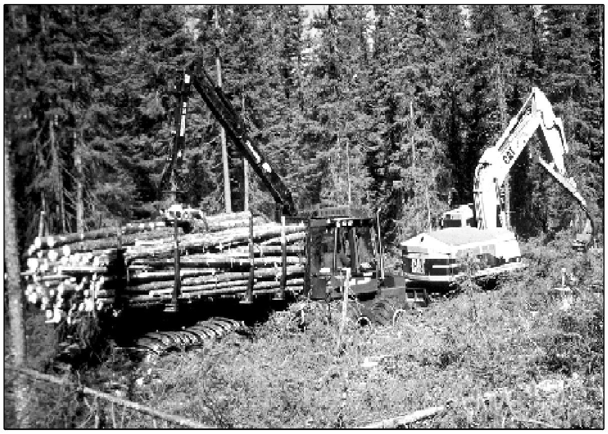

Figure 5. A Timberjack 1210 forwarder and a Caterpillar 320 harvester equipped with a Keto 150 harvesting head were used in the trials.

A network of 4-m² sample plots was installed systematically after harvesting to measure soil disturbance, coverage by slash and the extent of protection of the regeneration. The soil disturbance classes that were used are presented in Appendix I. The slash coverage was considered to be significant when the accumulation of slash was such that it became impossible to see the ground. In these situations, a seed would have difficulty reaching the ground, or snow covering the slash would crush any trees beneath the slash. Where slash covered 100% of the area of a sample plot, the plot was considered unsuitable for regeneration.

Surveys conducted using a global positioning system (GPS) unit provided an estimate of the total coverage of the site by slash, the length of the trails and the total area of the study blocks. The total area covered by the trails was calculated by multiplying the total length of the trails by their average width.

Results

Cost and Productivity

Productivities measured in the three study blocks are reported in Table 3. The high average volume per harvested stem in the study blocks led to high productivity levels for each of the three methods. The harvester's productivity was 14% lower in the method with concentration of slash and wood than in the usual method. This difference was caused by the additional handling of slash. For the method with slash dispersal, the 24% productivity decrease can be explained by the additional time required for handling slash and by a lower average stem volume.

The direct harvesting costs were established by dividing the machine's hourly cost by its productivity; hourly costs were determined using FERIC's standard methodology ($111/PMH for the harvester and $85/PMH for the forwarder; see Appendix II). These costs are estimates, and do not represent the contractor's actual costs.

Table 3. Summary of observations on harvester productivity

	Method		
	Usual	Concentration of slash	Dispersal of slash
Volume per harvested stem (m³)	0.286	0.290	0.210
Proportion of cycles with handling of slash (%)	0	57	61
Productivity (stems/PMH)	105	90	109
Productivity (m³/PMH)	30.1	26.0 (-14%)[a]	22.9 (-24%)[a]
Harvesting cost ($/m³)	3.69	4.27	4.84

[a] Reduction with respect to the usual method.

The detailed time study of the harvester's work cycle presented in Table 4 reveals the time elements that were most affected by the modifications to the usual work method. The time required for handling slash was clearly greater in the method with slash concentration, and to a lesser extent, in the method with slash dispersal. In the latter case, the observed time differences could also have been a consequence of the lower average stem volume and probably of the higher stand density.

Table 5 summarizes the observations on the forwarder in the blocks treated using the usual method and the method with concentration of slash. The purpose of this comparison was to assess the effect of concentrating the logs on the forwarding costs. Particular attention was paid to the number of piles required to fully load the forwa▯œ£rder. For a similar volume per load, 6.3 piles were required to fully load the forwarder in the method with concentrated wood piles, versus 12.8 piles in the usual method. The forwarder's productivity was 15% higher in the method with concentration of wood. When the harvesting and extraction costs are combined, the total cost of the two harvesting methods becomes similar. By concentrating slash and logs in a smaller number of piles, it is possible to avoid cost increases while gaining more and better-distributed area available for regeneration.

Impact of Harvesting

Table 4. Results of the detailed time study on the harvester

	Time (min)		
	Usual method	Concentration of slash	Dispersal of slash
Cycle time element			
Moving	0.06	0.05	0.02
Brushing	0.02	0.02	0.02
Positioning of head	0.12	0.13	0.12
Felling, delimbing and slashing	0.32	0.32	0.27
Operational delays	0.05	0.08	0.06
Handling slash	0.00	0.07	0.06
Total time/stem	0.57	0.67	0.55

Table 5. Summary of observations on the forwarder for the blocks treated using the usual and the slash-concentration methods

	Method	
	Usual	Concentration of slash
Number of piles per cycle	12.8	6.3
Volume per cycle (m^3)	16.7	15.7
Productivity (m^3/PMH)	26.5	30.4
Extraction cost ($/$m^3$)	3.21	2.80
Harvesting cost ($/$m^3$; from Table 3)	3.69	4.27
Total system cost ($/$m^3$)	6.90	7.07

A large portion of the regeneration was protected during harvesting in the blocks treated using the usual method and the method with concentration of slash (Table 6). A difference of 4% in the decrease in stocking between the two methods (decreases of 31 and 27%, respectively) was observed. The decrease in density was also greater when there was no concentration of slash. Dispersal of slash clearly did not offer a comparable level of protection of regeneration.

A description of the soil conditions in each block is presented in Table 7. There was generally little soil disturbance apart from disturbance of the humus layer. The proportion of soil that was free of disturbance and free from deposits of slash was highest in the block with concentration of slash. Slash covered 13ore area in the usual method than in the method with concentration of slash; conversely, the method with dispersal of slash produced 15.2% greater slash coverage than in the usual method.

Table 6. Comparison of stocking and regeneration density before and after harvesting

	Method		
	Usual	Concentration of slash	Dispersal of slash
Stocking (%)			
- Before harvesting	95	94	84
- After harvesting	64	67	40
- Difference (%)	-31	-27	-44
Density (stems/ha)			
- Before harvesting	22 800	16 100	14 400
- After harvesting	7 280	6 820	4 221
- Difference (%)	-68	-58	-71

Table 7. Description of soil conditions after harvesting (results in %)

	Method		
	Usual	Concentration of slash	Dispersal of slash
Disturbance class			
1. Undisturbed soil	44.4	55.0	29.6
2. Covered by slash	43.5	30.5	58.7
3. Disturbed humus	9.6	13.5	10.5
4. Mineral soil deposits	0.4	0.1	0.3
5. Shallow mineral soil exposure (<10 cm)	1.4	0.2	0.5
6. Mix of mineral soil and organic matter	0.0	0.0	0.0
7. Deep mineral soil exposure (>10 cm)	0.3	0.1	0.0
8. Mud	0.0	0.0	0.0
9. Erosion	0.0	0.0	0.0
10. Stump, boulder	0.4	0.6	0.4
	100.0	100.0	100.0

The results in Table 8 indicate that harvesting disturbed the soil in the three study blocks only slightly. The percentage of plots unsuitable for regeneration was lowest in the method with concentration of slash. This suggests that concentrating slash favors the establishment of a greater number of natural or planted seedlings.

The soil disturbance survey indicated a relatively low level of potential soil compaction. The area that showed at least one passage by machines was comparable in all three methods, which indicates good use of the boom's extension on either side of the harvester.

The distribution of slash measured using the GPS system is presented in Table 9 and in Figure 6. These results confirm what was measured in the sample plots in terms of the areas covered by trails and slash. Trails were almost entirely located on the area covered with slash, and the proportion of the total area covered by trails was 22% in all three blocks.

Table 8. Summary of the soil-disturbance survey

	Method		
	Usual	Concentration of slash	Dispersal of slash
Soil disturbance (% of the surface area)			
- light (classes 1, 3 and 10)[a]	96.3	99.4	98.1
- moderate (classes 4, 5 and 6)[a]	3.2	0.5	1.9
- severe (classes 7, 8 and 9)[a]	0.5	0.1	0.0
Total area	100.0	100.0	100.0
Compaction (% of cutover area)	20	23	20
Proportion (%) of plots unsuitable for regeneration[b]	16	11	18

[a] Classes from Table 7; data were only compiled for those areas free of slash.

[b] When 100% of the 4-m² sample plot is covered with slash.

Table 9. Main results of the area analysis conducted using GPS

	Method		
	Usual	Concentration of slash	Dispersal of slash
Proportion of total area (%)			
- Trails	22	22	22
- Slash	41	27	70

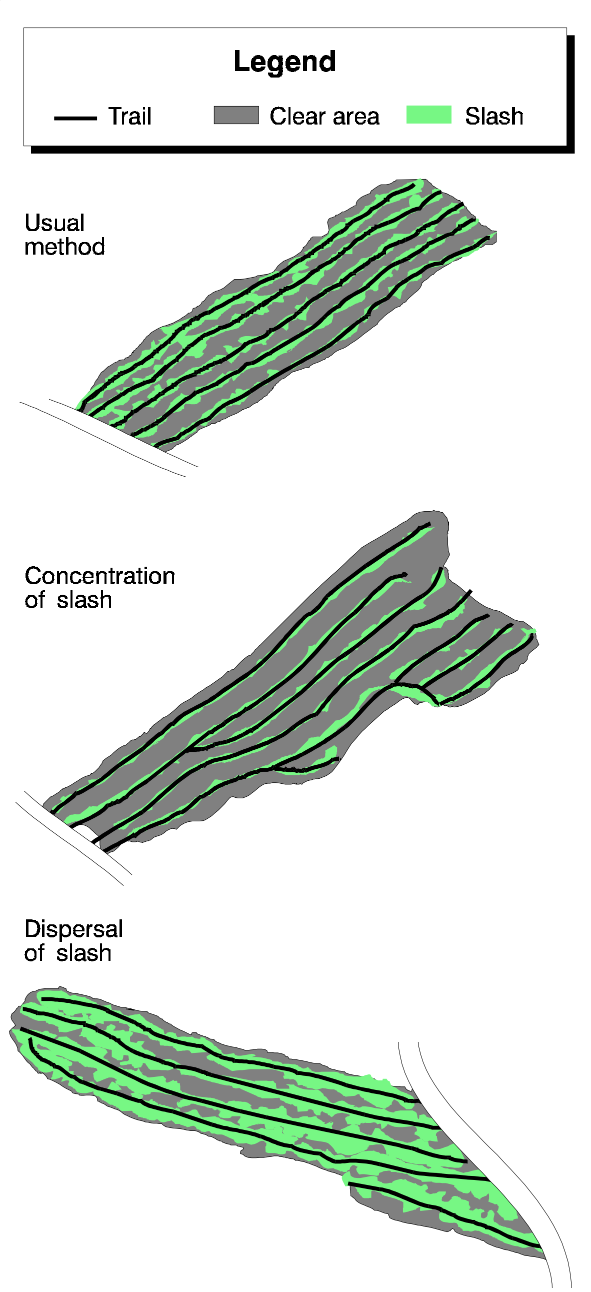

Figure 6. Slash distribution in the three harvesting methods.

Discussion

This comparative study demonstrated that concentrating log and slash piles reduces both the decrease in stocking of advance regeneration and the loss of microsites without significantly increasing costs, at least under the study conditions. The harvester's work was slightly slowed, whereas the forwarder's productivity improved as a result of the improved distribution of logs.

The protection afforded to regeneration in the block with concentration of slash was 4% greater than that in the block harvested using the usual method, and the number of slash-free or partially slash-free plots was 5% higher. These results appear modest at first glance, but the costs to achieve similar results through in-fill planting would be considerable.

The potential gains in plantability with the slash-concentration and slash-dispersal methods were evaluated in the summer of 1995 during scarification trials on the treated areas. These gains will be described in a subsequent report. Should advantages also be evident during site preparation, one can foresee the development of a pre-harvest silvicultural prescription that will define the methods of harvesting and reforestation as a function of the advance regeneration, the slash volume that will be generated by the operation, and the probability of successfully protecting the regeneration.

Conclusions

It is clear that the increased level of protection of regeneration achieved using more efficient harvesting methods could have a positive effect on the allowable cut. The most important thing for natural regeneration of softwood forests is to ensure the survival of advance regeneration, and when the number of free-to-grow seedlings increases, the yields will approach those of a plantation. When a cutover has been naturally regenerated, the growth models generally used in eastern Canada often consider the new stand's growth rate to be equal to that of the former stand, irrespective of the actual density of free-to-grow seedlings. The development of yield tables that account for this density would help to justify the use of more appropriate methods for noticeably increasing the number of growing trees. Improving the results of harvesting with protection of advance regeneration is an economical means of rapidly improving an area's allowable cut to guarantee future supply to mills.

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Disclaimer

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Appendix I

Soil Disturbance Classes

Undisturbed soil:
No apparent modification of the soil surface, or light disturbance of the vegetation, or light movement of the litter without damaging the humus.

Humus disturbed:
All physical modification to the humus layer, including compression of the LFH layers, exposure of the H and F layers, removal of the LFH and/or of the moss, with or without inverting the layer, and excluding all mineral soil exposure.

Mineral soil deposits:
Includes deposits at the edges of ruts or following wheel slippage.

Shallow mineral soil exposure:
Exposure of the upper mineral soil horizon, in which 90% of the roots of the trees that form the stand are found (for black spruce, 10 to 15 cm, depending on the site).

Mix of mineral soil and organic matter:
Deposit of mixed material (mineral, humus or litter) in which the structure is loose or unstable.

Deep mineral soil exposure:
Exposure of mineral soil beneath the rooting zone.

Mud:
Mixture of mineral soil or organic matter with water, caused by the passage of a machine; evaluated in the dry or wet state.

Signs of erosion:
Creation of erosion channels, leaching or sedimentation.

Not capable of disturbance:
Stumps, stones or boulders.

No evaluation possible:
Soil surface is concealed by the presence of harvesting debris, interfering with evaluation.

Appendix II

Cost assumptions

	Caterpillar 320/Keto 150	Timberjack 1210
Working life (years)	5	5
Scheduled machine hours (SMH/year)	4 000	4 000
Purchase price ($)	450 000	350 000
Residual value ($)	45 000	35 000
Licensing ($/year)	500	500
Insurance ($/year)	18 000	14 000
Interest rate (%)	7	7
Utilization rate (%)	85	85
Repair cost ($/life of machine)	562 500	350 000
Fuel consumption (L/PMH)	25	14
Fuel price ($/L)	0.50	0.50
Oil and lubricants ($/PMH)	1.00	0.50
Wages and benefits ($/SMH)	25.00	25.00
Fixed machine cost ($/PMH)	35.42	27.58
Variable machine cost ($/PMH)	46.59	28.09
Labor cost ($/PMH)	29.41	29.41
Total cost ($/PMH)	111.42	85.08