WOOD HARVESTING

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COMPARATIVE STUDY OF THE IMPACT OF THREE SKIDDING METHODS ON ADVANCE REGENERATION

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Abstract

This study compares the destruction of advance regeneration when three different skidder types are used: cable, grapple and clambunk, under comparable stand and terrain conditions. Six study blocks located on Domtar Inc.'s logging operations at Mistassini, Qc, were assessed before and after harvesting. Results on pre- and post-harvest regeneration levels, machine productivity and degree of soil disturbance are presented.

Introduction

In recent years, forest companies in eastern Canada, particularly in Quebec, have developed an interest in protecting the advance regeneration already established under the forest canopy before harvesting. The advantages of this approach, as well as the techniques advocated, have been discussed elsewhere [Canuel 1989; Gingras 1990; Hardy 1988; Ruel 1987].

Several company officials surveyed were of the opinion that destruction of advance regeneration occurred mainly during the skidding phase of operations. This raised a question whether it was possible to skid using traditional systems, without causing an excessive reduction in the regeneration stocking levels?

The objective of this study was to provide an answer to this question by carrying out a comparison of cable, grapple and clambunk skidders, working under homogenous stand and site conditions. The cooperators for the study were the Quebec Ministry of Forests (MFO) for the pre- and post-harvest assessment; Laval University for regeneration surveys looking at the effect of distance to the landing (done by an undergraduate student); Domtar Inc., Mistassini Division, Qc, and its contractors by providing equipment, supervisory personnel, and the study areas; and FERIC for productivity, regeneration assessments and site disturbance studies.

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KEYWORDS: Felling, Skidding, Regeneration protection, Cable skidder, Grapple skidder, Clambunk skidder, Soil disturbance, Productivity.

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Study Methods

Of the areas proposed by Domtar, two study sectors were chosen by FERIC and the MFO. The first featured a variable depth (175-420 m) and the second had a more consistent depth of up to 450 m. Each sector was divided into three blocks of approximately equivalent width. The choice of skidder configuration for each block in each sector was done by random selection (see Figure 1).

An initial stand cruise was done by FERIC, with two 400-m^2 plots established in each block. The regeneration survey done by the MFO consisted of a 2-ha sample plot in each block. Within this plot, a pre-harvest regeneration inventory was done using 98 circular subplots each measuring 4 m^2, systematically distributed. In each subplot, a tally by species was made of seedlings or layers which measured between 5 cm and 3 m in height. A soil profile was also examined in each block. An inventory of advance regeneration stratified by distance from the landing was conducted by Laval University.

Harvesting operations took place between July 3 and August 1, 1990. Felling productivity was measured in four of the six blocks, and skidding productivity was measured in all six blocks. The study method was basically to measure the volume produced over a given time interval. During the felling phase, the volume was measured either by counting the stems while felling, or by scaling the bunches at the stump. The volume skidded was obtained either by scaling the bunches before skidding, or by scaling the loads at roadside. When scaling the bunches on the cutover, the angle of the bunch in relation to the skid trail was also recorded.

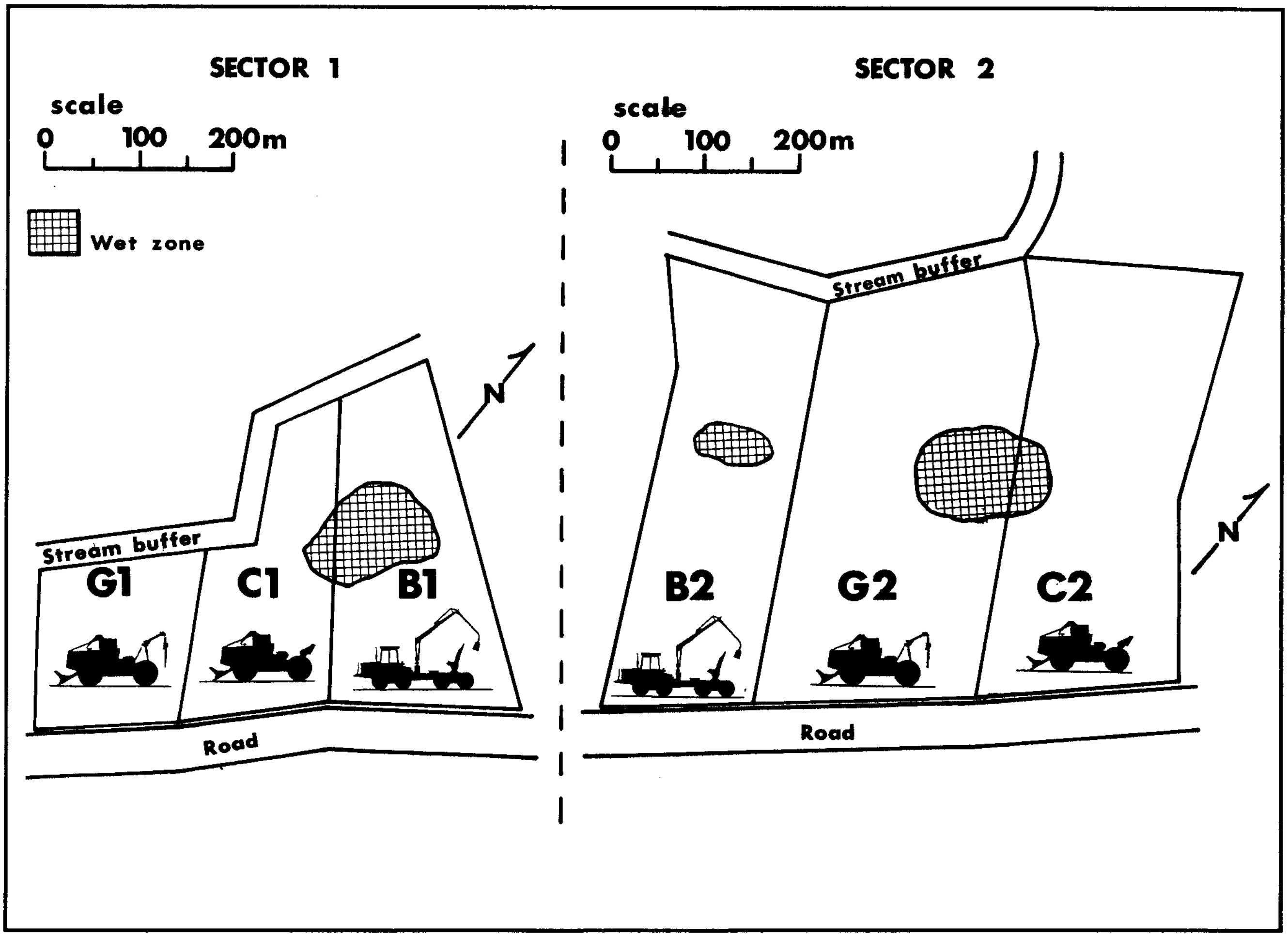

Figure 1. Study sectors divided according to machines.

The surviving regeneration levels were inventoried two months after the harvest, using the same sampling technique as the pre-harvest survey. Moreover, Laval University also measured the regeneration after harvesting, but stratified according to the distance to the landing. Finally, a survey using linear transects measured the width of the skid trails and the protection corridors (i.e., the areas between skid trails undisturbed by machine passage). Also, the degree of soil disturbance was measured (type, depth, area) and the related presence of surviving regeneration.

Study Areas

The study was carried out in a Domtar logging area located about 130 km north of Mistassini, Quebec. The site and stand characteristics of the blocks are given in Table 1.

It should be noted that in the first sector, the soil bearing capacity decreased from the southwest corner towards the northeast, that is, from block G1 (grapple skidder) towards block B1 (clambunk skidder). Likewise, there was a large wet zone in the centre of block G2 (grapple skidder) and steep depression towards the rear of this block.

Harvesting Equipment

Felling

To keep the factors other than those related to skidding as constant as possible, more than 66% of the study area was felled with the same feller-buncher: blocks G1, C1, B1, B2 and 60% of block G2. The study machine was a Timberjack Timbco 2520 equipped with a Forano shear head. The owner had lengthened the boom by 0.65 m, giving an overall reach of 8.3 m.

Table 1. Description of the study areas

Skidder	Cable		Grapple		Clambunk	
Block	C1	C2	G1	G2	B1	B2
Area (ha)	3.7	8.4	2.7	9.8	4.8	6.8
Merchantable volume (m^3)[1]	890	1600	590	1860	1200	1160
Maximum depth (m)	305	440	175	440	420	450
Stand						
Type[2]	S100	S70F30	S85F15	S85F15	S100	S100
Merchantable stems/ha	1550	1100	1000	1350	1400	1200
Hardwood stems/ha	0	150	0	50	0	0
Average volume/stem (m^3)	0.16	0.17	0.22	0.14	0.18	0.14
Average volume/ha (m^3)	240	190	220	190	250	170
Site						
CPPA classification	3.1.1	2.1.1	2.1.1	2(4).1.1(2)	3(4).1.1	2(3).1.1
Maximum slope (%)	3	10	5	15	3	5
Depth of humus (cm)	22	18	18	17	22	18
Drainage class[3]	6	4-5	4	4-5	6	5
Depth of water table (cm)	10	35	>50	38	18	27

1 Estimated from the sample plots and extrapolated to the block areas.
2 E.g. S85F15: composed of 85% spruce and 15% balsam fir.
3 Anon. 1978.

Since the Timbco feller-buncher had to be moved to another area, a second machine was brought in to complete felling the study site, namely the other half of block G2 and all of block C2. The second feller-buncher was a Tanguay FB221, also equipped with a Forano shear head and a reach of 9.8 m.

Skidding

The cable and grapple skidders were a Treefarmer model C7E and C7D, respectively. Both were equipped with four, 81-cm wide, forestry tires with chains. The cable skidder flew six 3.6-m chokers, and had a total weight of 8900 kg. The grapple skidder was heavier, weighing 11 000 kg, and was equipped with an Esco 2.5-m grapple.

The clambunk skidder was an FMG Lokomo 933, equipped with a FMG 140 crane which had a maximum reach of 7 m. This machine weighed 20 000 kg distributed over four oscillating bogies fitted with 65-cm wide tracks. The clambunk had a maximum opening of 3.0 m^2.

Pre-Harvest Regeneration

The advance regeneration was very abundant and relatively uniform among the blocks (Table 2), particularly for stocking levels. Stocking is generally judged to be the most critical variable following a harvesting operation (Frisque *et al.* 1978).

The regeneration was mainly composed of black spruce layers with a varying proportion of balsam fir (9 to 48% of the number of stems). Stems of 5 to 30 cm in height were the most numerous. In block B2, where regeneration was not as dense, there were proportionately more stems with a height of more than 30 cm.

Table 2. Regeneration before harvesting

Skidder	Block	Stocking (%)				Density (stems/ha)			
		Fir	Black spruce		Total	Fir	Black spruce		Total
			Seedlings	Layers	Coniferous		Seedlings	Layers	Coniferous
Cable	C1	45	0	80	91	6 000	0	15 600	21 600
	C2	56	0	74	92	15 800	0	17 000	32 800
Grapple	G1	51	8	69	90	9 600	900	13 900	22 400
	G2	26	0	76	85	3 900	0	22 800	26 700
Clambunk	B1	55	9	90	98	7 300	200	31 300	38 800
	B2	17	9	91	93	1 600	100	16 300	18 000

Productivity Study

To avoid biasing the results, the same machine operators were used on their respective machines on both shifts over the entire study. They were all experienced operators. Before beginning the harvesting, the study's focus was explained to the foremen and operators. It was stressed that the priority was not to compare the productivity of each machine but rather the relative efficiency of the three methods of skidding to protect the advance regeneration. MFO representatives discussed the preferred work methods to be used with most of the operators working on the site. In spite of this, the operators preferred to maintain a high degree of productivity. This implied sacrificing some of the advance regeneration when the bearing capacity of the soil was low (blocks B1 and G2) or when recovering wood in sectors with steep slopes (block G2). As during normal operations, the operators were paid in relation to their daily production.

Operations took place during both day and night shifts. However, productivity data were collected only during the day shift.

The productivity data are summarized in Table 3. These results cover the periods when FERIC conducted time studies, and do not represent the total period of time elapsed to harvest each block. In all, 15.9 hours of time studies were conducted on the feller-bunchers and 67.1 hours on the skidders.

The Timbco feller-buncher obtained average productivities between 238 and 274 stems/PMH (productive machine-hour). The highest productivity was measured in block B2, where wood was felled for the Lokomo. With this machine, it was not necessary for the feller-buncher to prepare large bunches, because loading was done with a knuckleboom. The lowest productivity was observed in block G2, where wood was felled for the grapple skidder. For this machine, it was preferable to prepare larger bunches to maximize payload. It was also more important to place the piles as parallel as possible to the skid trails.

The Tanguay feller-buncher obtained average productivity levels of 249 and 294 stems/PMH. The operators of this machine gave priority to productivity and placed lesser importance on the tree piling angle. The operators of the Timbco placed their piles at an average angle of 20 to 30° from the trail. The Tanguay operators placed theirs at an average angle of 60°.

In spite of the attention given to protecting regeneration, the skidders all maintained high productivity, especially in the second sector because of the better bearing capacity of the soil. In Table 3, the productivity data have been standardized at a skidding distance of 200 m to facilitate comparisons.

The clambunk skidder achieved the highest productivity of the three machines (197 and 290 stems/PMH), with the biggest payloads (8.7 and 15.5 m^3). The productivity of the cable skidder was relatively constant in the two sectors, averaging 157 and 173 stems/PMH (5.4 and 7.1 m^3/load). Finally, the grapple skidder had an average payload of 2.9 and 3.1 m^3, achieving productivities of 132 and 197 stems/PMH at an average distance of 200 m.

An interesting statistic noted was the average density of wood at the piles. A high average density implies that there was a greater volume to skid for the same length of landing. This implies *more frequent trips* by the skidder per trail and the necessity of piling higher at the landing. The grapple skidder met with both the lowest and highest densities, with 4.0 m^3/m of landing in the first sector, and 8.1 m^3/m of landing in the second. The clambunk skidder met with average conditions, with 6.0 and 7.2 m^3/m of landing. The cable skidder had to skid 5.6 and 7.6 m^3/m of landing. During the FERIC studies, the average skidding distances were the shortest in sector 1 (90 to 220 m) and varied from 210 to 390 m in sector 2.

Post-Harvest Regeneration and Site Disturbance

Most areas maintained a stocking level of at least 60% after the harvest (Table 4). The most abundant post-harvest regeneration levels were found in the blocks where the clambunk skidder had worked (B1 and B2). The lowest stocking levels, resulting from a 37% reduction, were located in the second sector (G2) where the grapple skidder worked. In the other blocks, the stocking reductions were between 20% and 31%.

The results obtained by the cable and clambunk skidders were consistent in both sectors. The additional losses of regeneration brought about by the lower soil bearing capacity of blocks C1 and B1 in the first sector were offset by the losses attributed to the increased number of skidder trips in sector 2.

Table 3. Productivity data summary (during FERIC study)

Skidder	Cable		Grapple			Clambunk	
Block	C1	C2	G1	G2[1]	G2[2]	B1	B2
Felling							
Machine	Timbco	Tanguay	Timbco	Timbco	Tanguay	Timbco	Timbco
Productive Machine Hours[3] (PMH)	0.5	5.2	N/M[5]	5.2	1.0	N/M	4.0
Trees cut	132	1284	N/M	1230	294	N/M	1094
Volume cut (m^3)	21	221	N/M	177	42	N/M	158
Trees/PMH	265	249	N/M	238	294	N/M	274
Volume/PMH (m^3)	42	43	N/M	34	42	N/M	39
Bunches scaled	89	92	0	268	0	0	0
Average bunching angle (°)	30	60	N/M	20	N/M	N/M	N/M
Skidding							
Machine	C7E cable	C7E cable		C7D grapple	C7D grapple	Lokomo 933	Lokomo 933
Productive Machine Hours[3] (PMH)	13.1	12.6		3.4	19.8	7.9	10.3
No. of trips	65	38		62	174	29	22
Trees skidded	2211	1574		826	3807	1398	2377
Volume skidded (m^3)	349	271		178	548	252	342
Volume per load (m^3)	5.4	7.1		2.9	3.1	8.7	15.5
Average distance (m)	165	390		90	210	220	250
Standardized productivity[4]							
Trees/PMH	157	173		132	197	197	290
Volume/PMH	25	30		28	28	35	42
Piling density (m^3/m of landing)	5.6	7.6		4.0	8.1	6.0	7.2

1 West part of block G2 harvested by the Timbco.
2 East part of block G2 harvested by the Tanguay.
3 During the FERIC studies.
4 Skidding distance standardized to 200 m for comparison purposes.
5 N/M not measured.

Table 4. Regeneration stocking level (%) before and after harvest

Skidder	Block	Before harvest	After harvest	Real decrease	Relative decrease[1]
Cable	C1	91	62	29	32
	C2	92	61	31	34
Grapple	G1	90	70	20	22
	G2	85	48	37	44
Clambunk	B1	98	73	25	26
	B2	93	73	20	22

1 Relative decrease = $\frac{\text{Before harvest - After harvest}}{\text{Before harvest}} \times 100$

The stocking of the surviving regeneration in the grapple skidder blocks was much lower in sector 2 than in sector 1. The low 20% stocking reduction in sector 1 can be explained by better soil drainage and short skidding distances. The serious stocking reduction in block G2 indicates that, for the prevailing site conditions (low bearing capacity, long skidding distance and high piling density), this type of machine is not adequate for protecting advance regeneration unless considerable care is taken.

Skid trails are the main reason for advance regeneration destruction (Table 5). They result in an absence of regeneration over 20% to 40% of the cutover area. Lateral sweep resulting from moving trees out to the skid trails caused negligible destruction of regeneration, except with the cable skidder.

Table 5. Causes of destruction of advance regeneration during harvesting, %

Skidder	Block	Regeneration destroyed			No advance regeneration	Total
		Trail	Sweeping	Total		
Cable	C1	21.0	8.5	29.5	8.5	38.0
	C2	28.0	4.5	32.5	6.5	39.0
Grapple	G1	25.0	0.5	25.5	4.5	30.0
	G2	40.0	0.0	40.0	12.0	52.0
Clambunk	B1	21.0	1.0	22.0	5.0	27.0
	B2	20.5	0.0	20.5	6.5	27.0

Skid trails were defined as being the distance separating the outside edges of the ruts. They covered between 26% and 42% of the area (Table 6). The shorter skidding distances in sector 1 allowed the machines to follow the trails better and to maintain relatively wide protection corridors. In sector 2, the greater skidding distances caused the machines to leave the original skid trails. This decreased the width of the protection corridors.

Table 6. Width and percent coverage of skid trails and protection corridors

Skidder	Block		Trail	Corridor
Cable	C1	width (m)	3.8	10.3
		coverage (%)	27	73
	C2	width (m)	4.9	8.9
		coverage (%)	36	64
Grapple	G1	width (m)	4.7	10.0
		coverage (%)	32	68
	G2	width (m)	5.7	8.0
		coverage (%)	42	58
Clambunk	B1	width (m)	3.9	10.9
		coverage (%)	26	74
	B2	width (m)	3.8	8.3
		coverage (%)	31	69

Table 7 shows the degree of soil disturbance created during harvesting. Felling and skidding operations cause disturbance ranging from light to severe over 23% to 46% of the area. As for the preceding results, the disturbance level on grapple skidder block G2 was rated the most severe. The proportion of undisturbed ground is relatively well correlated with the post-harvest stocking level.

Table 7. Level of site disturbance (%) after harvesting

		Level of disturbance		
Skidder	Block	None	Light[1]	Severe[2]
Cable	C1	66.5	17.0	16.5
	C2	60.5	16.5	23.0
Grapple	G1	68.0	23.0	9.0
	G2	54.0	12.5	33.5
Clambunk	B1	77.0	6.5	16.5
	B2	69.0	16.5	14.5

1 Light disturbance: crushed vegetation or litter.
2 Severe disturbance: exposed humus or mineral soil.

The regeneration survey stratified according to the distance to the landing was carried out in sector 1 only. The survey was done using 5 continuous sampling lines, equidistant and parallel to the road, and covering a depth of 170 metres from the road. The difficulty in comparing the three skidding methods based on the values presented in Table 8 lies in the different skidding distances of the blocks. For the grapple skidder, there was a significant variation in relative loss of stocking in relation to increasing distance from the road. In this block, the sampling distance corresponded more or less to the depth of the block. However, there was little

Table 8. Relative stocking reductions in relation to the distance to the road (sector 1), %

		Distance to the road (m)				
Skidder	Block	50	80	100	140	170
Cable	C1	25	32	38	43	42
Grapple	G1	28	28	34	10	16
Clambunk	B1	40	19	24	31	23

correlation between the relative reduction (percent) in stocking, and the skidding distance for the cable skidder and clambunk skidder. It can therefore be assumed that these machines stayed within the skid trails throughout the blocks, and that even at the far end of the sample zone, the number of trips was sufficient to destroy part of the advance regeneration.

Discussion

Productivity

The operators' productivity levels seemed little affected by work methods which favoured protecting the regeneration, either during felling or skidding. Other authors have observed that feller-buncher productivity can be somewhat reduced, but that skidders are not overly affected by measures taken to protect regeneration (Brace 1990; Gingras 1990; Froning 1980).

The Timbco feller-buncher, which was the only machine to work with all three skidding methods, had the highest productivity in the clambunk skidder block where it was not essential to prepare large bunches. With the cable skidder, it was also not necessary to prepare large bunches. However, there was a slight loss of time when the first trees in a bunch were laid down since a hole was dug with the head to facilitate choking. The buncher's productivity was slightly lower in the grapple skidder blocks for two reasons: first, it had to prepare large bunches to maximize the skidder's payload; second, to facilitate loading and reduce the sweeping action of the trees, the feller-buncher operator placed the bunches in the trail behind the machine when the feller-buncher was cutting toward the road. This required a little more time. It is important to note that these measures also had the objective of minimizing site disturbance in the protection corridors between the skid trails, thereby providing more protection to the regeneration.

The productivity of the cable skidder was influenced mainly by the feller-buncher's work, that is, the size of the bunches and, of course, the average skidding distance. During the study, the cable skidder operator normally followed the skid trails but was not always careful to use the same turn-around point. Likewise, he did not hesitate to leave the skid trail if the machine was loaded and he needed traction, especially in sector 2.

The productivity of the grapple skidder was high in sector 1 because of the short skidding distances and the good bearing capacity of the soil. It was lower in sector 2 because of the longer skidding distances, steep slopes at the back of the block and the presence of a wet area in the centre. Moreover, it was in the second sector that the highest volume of wood was extracted in relation to the landing area. It was thus sometimes difficult to find the space required to pile the wood at roadside. This situation forced the machine to leave the skid trails several times. In spite of this, the operator did his best to stay in the trails and use the same turning areas as often as possible, even if he had to back up for 100 m to do so. When the piles were located less than 75 m from the landing, the grapple skidder operator made the trip in reverse, which maximized productivity and minimized unnecessary manoeuvres on the site. When skidding distances were long, more than 200 m, the operator loaded his machine with two bunches. After bringing the first one into the trail, the second bunch was carried on top of the first, then both were loaded in the trail. In the strips where the feller-buncher operator had placed the bunches almost parallel to the trail (angle of 0 to 15°), loading was much easier.

The clambunk skidder demonstrated the highest productivity while producing the best of regeneration protection results. This machine benefited from its high payload, its knuckleboom loading and quick unloading. However, it experienced flotation problems on soft terrain. The feller-buncher had to be called in several times to pull it out when stuck. Indeed, 16% of the time measured by FERIC (3.5 hours out of 21.7 hours) were lost in unloading and reloading the machine so it could be extracted from soft areas. In block B1, the feller-buncher had to build a temporary bridge with felled trees to allow the clambunk to cross a particularly wet zone. The cable skidder would perhaps have been better suited to work in these conditions.

Protection of the Regeneration

Most of the blocks studied could be considered as adequately regenerated immediately after harvesting, since their stocking level exceeded 60%. Nonetheless, in two cases the reduction in stocking during the study was over 30%. An average reduction of 34% has been observed where no regeneration protection measures had been taken (Ruel 1988). It should be noted that the surveys were carried out two months after the harvest. Positive variation (seeding in, vigour renewal, etc.) or negative variation (desiccation, diseases, etc.) in the results could occur over a longer term.

The stocking reductions associated with the cable skidder are comparable with some poorer results obtained during other regeneration protection trials carried out by the MFO (Figure 2). This resulted from several contributing factors. First, the planned work method was not fully implemented (felling angle in sector 2, choice of places to turn around, leaving the skid trails). Moreover, this skidder had to deal with a site having a low bearing capacity in the one sector and long skidding distances and high piling densities in the other. In the first block (C1), the piles were placed at 30° and they lined up easily in the axis of the trail at the time of winching. In the second block (C2), the felling angle was closer to 60°. This resulted in increased lateral sliding of the bunches when winching, and therefore in more sweeping of the protection corridors. This consequence is however not obvious from Table 5 because of the frequency with which the machine left the skid trails.

Even though the results obtained with the grapple skidder showed the greatest reduction in stocking in the study, stocking levels are still higher than those obtained in a previous study carried out in Abitibi, Quebec (Figure 2). However, the previous study was carried out on poorly-drained clay soil where the skidder had problems with traction even though high-flotation tires were used. Under good conditions, like those in sector 1 of the present study, grapple skidders are capable of performing well in protecting regeneration. They remain sensitive to various factors such as the skidding distance, piling density and the bearing capacity of the soil, which also affect their productivity. **Because of lower productivity and reduced ability to protect regeneration, this type of skidder should not be used under conditions such as those in sector 2.**

The results obtained with the clambunk skidder are among the best obtained in this study and are comparable with other studies (Figure 2). This machine provided very good results in terms of regeneration protection while maintaining high productivity, even though the soil bearing capacity of the first sector was low. Clambunk skidders have certain advantages compared to the other machines, such as the ability to reduce sweeping of regeneration by tree tops when loading, as well as the ability to travel in reverse when returning empty.

Nevertheless, the ruts caused by the clambunk skidder were the deepest of the three machines, and this in spite of the four track-mounted tandem drive axles. The high payload of this machine makes it possible to limit soil disturbance when operating on solid ground, since the number of trips needed to transport a given volume is greatly reduced when compared to the other machines. On soft ground however, the large payload becomes a handicap.

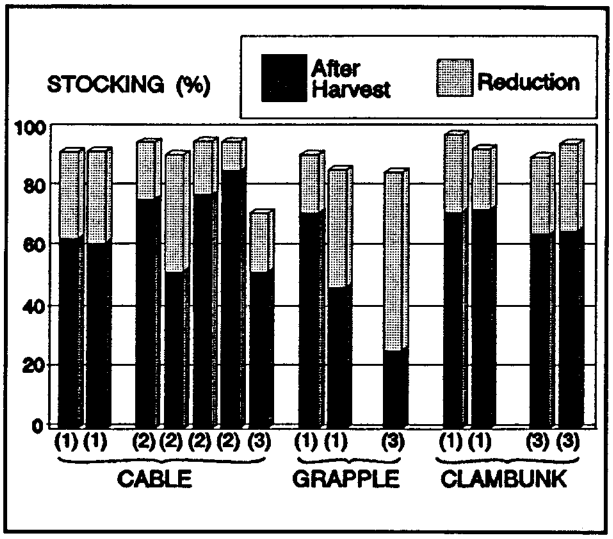

Figure 2. Comparison of the results of this study (1) with those obtained on the North Shore (2) and in the Abitibi region (3); Ruel 1988.

Conclusions

Overall, the study went well and highlighted the important factors which determine the feasibility of protecting the advance regeneration during skidding. The critical factors are the bearing capacity of the soil, the working methods of the operators, the spacing of the skid trails which is directly related to the reach of the feller-buncher's boom, the stocking level of the advance regeneration before harvesting, the average pile density (m^3/m of landing) and the type of skidder.

The study objective was to compare the ability of three skidder types to protect regeneration. Though some variation in operating conditions limits the range of application of the results, certain tendencies stand out. The grapple skidder showed some capacity to protect the regeneration under optimum operating conditions. However, the results were unsatisfactory in difficult conditions. As for the clambunk skidder, it was the most productive and was generally able to give good regeneration protection results. The cable skidder gave intermediate results, even though it had to work under certain operating constraints. The results obtained with this machine could have been improved by fully implementing the recommended working methods.

Regardless of skidder configuration, the use of a good working method, including careful planning and adequate supervision, is of great importance. Certain problems (cluttered landing, skidding distance) could have been avoided by better planning.

The maintenance of an adequate amount of advance regeneration on the cutover constitutes a first step in ensuring the development of a productive stand. However, this is not assured unless the regeneration manages to survive and develop adequately. The possibility of shortening the rotation age using the regeneration already established remains to be verified, but could be one of the important reasons to use this approach. Consequently, the study sample plots will be remeasured in the future.

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