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A STUDY OF TWO WINTER CRUSHING OPERATIONS

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Abstract

Crushing, also commonly known as trampling, is a method of site preparation whereby heavy machinery is used to knock down and run over dead and unmerchantable trees, and unwanted vegetation. This treatment is usually followed by a prescribed burn or a slash windrowing operation to eliminate as much of the downed material as possible prior to planting.

This method of site preparation has been practiced in the past in Ontario for the treatment of difficult sites. Despite its limited use and the operational concerns involved, there is potential for this type of treatment on sites having heavy residuals and brush. This report gives details and results obtained during field studies undertaken by FERIC on two winter crushing operations in Ontario.

Introduction

The conversion of prime sites close to mills from unmerchantable to merchantable forest cover is becoming increasingly attractive because of anticipated future wood shortages and high transportation costs associated with long hauling distances.

Heavy equipment, such as tracked tractors and skidders equipped with blades, are required to knock down and crush the heavy residuals and unwanted vegetation often found on backlog and N.S.R. (Not Satisfactorily Regenerated) sites and insect-killed stands. The best results are obtained when the operation is carried out during the winter season while the ground and trees are frozen.

During the winters of 1987 and 1989, FERIC conducted short-term detailed studies of crushing operations on the limits of Spruce Falls Power and Paper Company Ltd., near Kapuskasing, Ontario and of Domtar Forest Products in White River, Ontario, respectively. At the Spruce Falls operation, FERIC also observed a brief trial using a downing chain attached to two tracked tractors.

Both test sites were scheduled for prescribed burning during the following summer season. The prescribed burn was successfully conducted on the Domtar operation, however, constant rainfall during the following two summers prevented this treatment on the site at Spruce Falls. This site was later treated using shear and straight blades to create planting corridors in the downed material.

Although crushing has been practiced for a few years in Ontario, little information on this type of operation is available. This study on crushing operations is part of a broader project aimed at investigating different methods for treating difficult sites.

Sites and Operations

Spruce Falls Power and Paper Company Ltd.

Crushing operation

The Spruce Falls operation was studied in March 1987. A total of 113 hectares on five different locations situated approximately 8 km from Kapuskasing were crushed during that winter. The company had har-

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vested the softwood component on these sites in 1945 and again in 1986. However, the specific site studied by FERIC was not cut in 1986 because of its low merchantable volume. This site was fresh to moist with shallow humus over a clay soil. Slope was negligible. Additional information on the terrain and stand conditions are provided in Table 1.

During the FERIC study, two Caterpillar D7G tracked tractors (Figure 1) equipped with straight blades were used to crush a 6.84-ha block. The operators sectioned off a part of the block with a first pass and then proceeded to crush the section in concentric passes. All standing trees and shrubs were crushed to the ground except for a few large-diameter black spruce and balsam poplar. At the beginning of the study, the two machines worked together on the same section with one machine following the other, crushing their respective strips. For safety reasons and time lost waiting for the other machine, the operators subsequently decided to work separately on their own sections of the block. Both machines were operated on two 10-hour shifts/day. The operators had limited experience on this type of operation, but had considerable experience operating tractors on woodlands operations.

Figure 1. Caterpillar D7G tractor during the crushing operation.

Downing chain trial

During FERIC's visit, the company also conducted a *brief* trial using a downing chain dragged between two tractors to knock down small-diameter softwoods and brush. The objective was to determine the effectiveness and potential increase in productivity through the use of a downing chain.

Two Caterpillar D7G tractors and a heavy anchor chain measuring 49 m in length were used for the trial. The chain was comprised of smaller links at both ends of the chain and larger links towards the center. Four heavy links each measuring 33 cm in width and 103 cm in length made up the 4.3-m long center section of the chain.

The operators treated the area in a run-by-run pattern, perpendicular to the road. As the machines moved forward in the stand, the trees between them were broken off and flattened by the chain. However, a number of operational problems were encountered. The chain was not as effective at breaking off small trees and brush; these would often simply spring back up after a pass. Because the chain was not strung tightly between the two machines, the chain formed a loop, thus downing and gathering the trees in a windrow in the center of the pass. Also, when the chain encountered larger hardwoods, one and sometimes both machines would spin out, causing obstacle delay times. Because the operators could not see through the stand, coordination of the two machines was difficult. This resulted in variable pass widths, measuring 10 to 20 m wide. Travel speeds averaged 53 m/min in the easier sections.

Shearblading operation

Frequent rainfall during the spring and summer of 1987 and 1988 prevented a prescribed burn to eliminate the heavy slash produced from the crushing operation. During this period of time, most of the fine fuels, such as needles and twigs, necessary to provide a good burn had fallen to the ground.

In August 1989, the company decided to shearblade the site in preparation for planting. The purpose of the treatment was to produce planting corridors by pushing the downed material into windrows and also to remove the duff layer over the humus without exposing the mineral soil.

A variety of V-blades, shear blades and straight blades mounted on Caterpillar D7G and D8K tracked tractors were used over the 165 ha treated in total. FERIC conducted a detailed time study on the two machines that were operating in the site of the earlier crushing study.

Both tractors studied were Caterpillar D8K models; one was equipped with a standard straight blade while the other used a Rome K/G clearing blade. These machines produced corridors by pushing the debris to one side of the machine, thus leaving windrows of debris between the corridors. The corridors were produced in a run-by-run pattern perpendicular to a strip road. The operator using the 3.8-m wide Rome clearing blade made a first pass by pushing the debris to one side until he reached the end of the block. On its way back, the machine enlarged the corridor by pushing debris in the opposite direction. The operator using the 4.7-m wide straight blade made only one pass per corridor.

Domtar Forest Products

Crushing operation

FERIC conducted a second crushing study in February 1989 on the limits of Domtar Forest Products near White River, Ontario. Two different operations were observed by FERIC at this location; the first using a tracked tractor in a budworm-killed stand composed mainly of balsam fir, and a wheeled skidder crushing pockets of unmerchantable and dead trees left standing after the harvesting operation.

A Caterpillar D8K tractor equipped with a straight blade was used to crush the budworm-killed stand. The 3.5-ha block studied by FERIC was mostly flat to gently rolling with a small hill having slopes up to 25%. A few live spruce trees also remained after the budworm infestation. Further details on the terrain and stand conditions are provided in Table 1.

On this site, the operator crushed the stand in concentric passes around the block by simply knocking down the standing trees with the front blade and riding over them. Steeper sections of the block were crushed while traveling downhill only.

At the time of the study, the operator had several weeks of experience on this type of operation. The machine was scheduled to operate on two 10-hour shifts/day. A total of 469 hectares were treated during the winter season.

A Tree Farmer C8C grapple skidder with the grapple removed was used to crush small clumps of residuals in an adjacent cutover. The stand had been mechanically harvested the previous year using feller-bunchers and cable and grapple skidders. The sites treated were generally flat and free of obstacles and had a snow depth of 86 cm at the time of the study. Additional information on the terrain and stand conditions are provided in Table 1.

The operator treated the area by traveling throughout the cutover, crushing small pockets of small-diameter spruce and fir. The operator knocked down the trees using the blade when traveling forward (Figure 2) or with the butt plate when the machine was in reverse. The small areas were crushed in a run-by-run pattern as well as in concentric passes. FERIC studied the machine while it treated two clumps of residuals measuring 0.58 and 0.93 hectares respectively.

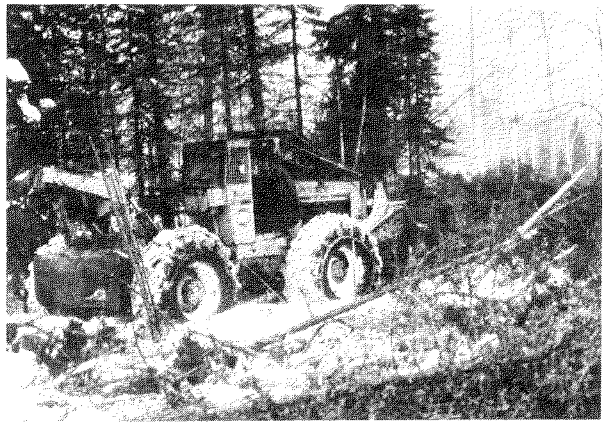

Figure 2. Tree Farmer C8C skidder crushing small clumps of residual trees.

The owner/operator of the skidder had limited experience on crushing operations, but had considerable experience operating a skidder for site preparation and logging. He worked one 10- to 12-hour shift/day. During the winter season, a total of 192 ha were treated with the skidder.

Specifications and dimensions of the equipment used on the crushing and shear blading operations in Kapuskasing and White River are provided in Appendix 1.

Prescribed burn

A prescribed burn on 1006 hectares was conducted by the Wawa District Fire Operations personnel of the Ontario Ministry of Natural Resources on August 11th & 12th, 1989. The burn area was comprised of recent cutovers and of the sections crushed by the skidder and tractor.

The entire area was divided into three major blocks. These blocks were successively ignited during the two days with the use of a helicopter and a helitorch. The prescribed burn operation was carried out successfully and was terminated early on the third day.

Assessments

The site conditions were assessed prior to the crushing treatment using 100-m^2 circular plots. Tree size and density, slope and terrain conditions were measured.

The post-treatment measurements consisted of evaluating the plantability at roughly every 2 m along 20-m transects. On the Spruce Falls operation, the measurements were taken within the planting corridors after the shearblading operation, while at Domtar they were made after the prescribed burn.

Results

Pretreatment Assessments

The results from the pretreatment assessments are summarized in Table 1.

Table 1. Terrain and stand conditions - crushing operations.

	Spruce Falls Kapuskasing, Ont.	Domtar White River, Ont.	
	tractor	tractor	skidder
1. Terrain			
Area (ha)	6.84	3.45	1.51
CPPA Classification	3(4).1.1	2.2.2(3)	2.2.1
- ground bearing capacity*	moderate to poor	good	good
- ground roughness	very even	slightly uneven	slightly uneven
- slope	level	gentle to moderate	level
Snow depth (cm)	70	83	86
Temperature	-10°C	-15°C	-15°C
2. Stand			
- composition %			
softwood	68	90	86
hardwood	32	10	14
- density (trees/ha)	1410	1800	850
- tree diameter at dbh (cm)	14.0	12.2	13.5
- tree height (m)	12.6	9.8	11.4
- stand volume (m^3/ha)**	144	163	114
- brush density (stems/ha) dbh < 10 cm	5 490	5 028	6 750

* Ground was frozen during crushing operations, thus providing excellent bearing capacity.
** Represents gross volume including softwood, hardwood and dead trees.

The tree diameter, height, and species composition, were generally quite similar on the two crushing operations. However, stand density on the skidder site at Domtar was only about half that on the other two sites, and brush density was somewhat higher. The ground bearing capacity was good on all the sites because the ground was frozen during the study, however, some soft ground was encountered during the shearblading operation at Spruce Falls. The terrain was similar on all sites except for the 25% slopes in one part of the Domtar tractor site.

Detailed Time Studies

Crushing operations

The results of the detailed time studies on the crushing operations at Spruce Falls Power and Paper and at Domtar Forest Products are shown in Tables 2, 3, and 4.

Table 2 gives a summary of the time distribution within the Productive Machine Hours (PMH) and the number of minutes per hectare for each of the time elements.

Effective Productive Time (EPT) is the time when the machine actually travels forward while crushing the stand. EPT accounted for 63% of the total time with the two tractors at the Spruce Falls operation, while rates of 57% and 47% were obtained with the tractor and skidder respectively, at the Domtar operation.

Time spent to maneuver the machine reached 39% of the total time with the skidder, while it accounted for between 5% and 13% when using the tractors. Time spent dealing with obstacles was low for all the machines.

Delay times comprised 27% and 20% of the total time for the tractors at Spruce Falls and Domtar respectively, but only 7% for the skidder at Domtar. The main causes for delays at the Spruce Falls operations were supervision and cleaning debris off the machine, representing 40% and 19% of the total delay time. At the Domtar operation, time spent for cleaning accumulated snow and dust off the radiator of both the tractor (48%) and the skidder (51%) accounted for much of the total delay time. The reasons for the other delays are provided in Table 3.

Productivity rates in terms of area treated per hour are presented in Table 4.

A productivity rate of 0.57 ha/PMH *per machine* was achieved with the D7G tractors at Spruce Falls and

0.45 ha/PMH for the D8K tractor at Domtar. Travel speeds of 53 m/min were recorded at Spruce Falls as opposed to speeds of 44 m/min with the heavier D8K tractor at Domtar. Although the two D7G tractors at Spruce Falls were only equipped with 4.27-m wide blades, these machines produced average pass widths of 3.14 m while the passes made with the D8K tractor at Domtar averaged 3.02 m wide though equipped with a 4.72-m wide blade. The pass widths were narrower than the blade widths because the passes overlapped somewhat.

The lower productivity rate of 0.18 ha/PMH when using the skidder was caused mainly by lack of traction in the 86-cm deep snow and the higher maneuvering time. The operator had to frequently turn the machine around and try to crush the area while in reverse because the machine would simply spin out in the deep snow.

Table 2. Summary of productive time - crushing operations

Time Elements	Spruce Falls			Domtar					
	Caterpillar D7G tractor*			Caterpillar D8K tractor			Tree Farmer C8C Skidder		
	Time (min)	%	min/ha	Time (min)	%	min/ha	Time (min)	%	min/ha
Effective Productive Time (crushing only)	456	63.3	66.7	264	57.3	76.5	237	46.9	157.0
Maneuver (turn)	33	4.6	4.8	60	13.0	17.4	197	39.0	130.5
Obstacles	11	1.5	1.6	9	2.0	2.6	25	5.0	16.6
Travel	24	3.3	3.5	38	8.2	11.0	12	2.4	7.9
Delays**	197	27.3	28.6	90	19.5	26.1	34	6.7	22.5
Total	721	100	105.2	461	100	133.6	505	100	334.5

* Data for two Caterpillar D7G tractors combined.
** Includes delays of <15 min.

Table 3. Breakdown of delays - crushing operations

Cause of Delay	Spruce Falls		Domtar			
	Caterpillar D7G tractor*		Caterpillar D8K tractor		Tree Farmer C8C skidder	
	min/ha	%	min/ha	%	min/ha	%
Personal	4.5	15.7	-	-	1.4	6.3
Supervision	11.6	40.6	-	-	-	-
Clean radiator	-	-	12.6	48.1	11.4	51.1
Put out fire in engine compartment	-	-	8.8	33.6	1.5	6.7
Clean air filter	-	-	0.5	1.9	-	-
Remove debris from machine	5.5	19.2	4.3	16.4	0.4	1.8
Engine cool down			-	-	7.6	34.1
Prepare access road	1.2	4.2	-	-	-	-
Let other machine by	0.1	0.4	-	-	-	-
Clean strip road	4.9	17.1	-	-	-	-
Repair canvas on engine	0.8	2.8	-	-	-	-
Total	28.6	100	26.2	100	22.3	100

* Data for two Caterpillar D7G tractors combined.

Table 4. Productivity summary - crushing operations

	Spruce Falls	Domtar	
	Caterpillar	Caterpillar	Tree Farmer
	D7G Tractor*	D8K Tractor	C8C Skidder
Total PMH (h)	12.01	7.68	8.42
Area (ha)	6.84	3.45	1.51
Productivity per machine (ha/PMH)	0.57	0.45	0.18
Travel speed (m/min)	53	44	NA
Average width of pass (m)	3.14	3.02	NA

* Data for two Caterpillar D7G tractors combined.

Shearblading operation

On this operation, FERIC timed the two Caterpillar D8K tractors for approximately 4 hours. During this period, the machines equipped with the shear blade and the straight blade obtained productivity rates of 0.63 ha/PMH and 1.07 ha/PMH respectively. The operator using the shear blade produced wider planting corridors and windrows as he made two passes per corridor. Additional information obtained from the time study is provided in Table 5.

Table 5. Productivity summary - shearblading operation

	Rome K/G blade	Straight blade	Total
Total PMH (h)	4.11	3.83	7.94
Total area (ha)	2.6	4.1	6.7
Productivity (ha/PMH)	0.63	1.07	0.84
Average width of pass (m)	5.6	3.7	4.5
Average width of windrows (m)	4.3	3.4	3.7

Post-treatment Assessments

The results obtained from the post-treatment assessments are presented in Table 6.

Table 6. Plantability assessment summary

		Spruce Falls Crushing & Shearblading*		Domtar Crushing & Prescribed Burn	
		Rome K/G	Straight	Tractor	Skidder
Good	- no/ha	1131	972	2000	1500
	- %	56	46	80	60
Marginal	- no/ha	303	486	75	750
	- %	15	23	3	30
Plantable	- no/ha	1434	1458	2075	2250
	- %	71	69	83	90
Non-plantable	- no/ha	586	655	425	250
	- %	29	31	17	10
Total	- no/ha	2020	2113	2500	2500
	- %	100	100	100	100

* Plantability assessed in the planting corridor only.

Spruce Falls Power and Paper Co. Ltd.- Crushing followed by shearblading

The plantability of the sites prepared with the Rome K/G shearblade (Figure 3) and the straight blade were quite similar; 71% of the planting spots were considered acceptable with the shear blade and 69% with the straight blade. However, the straight blade-equipped machine produced 93 more planting spots/ha than the shear blade.

Exposed clay mineral soil and the presence of debris were the cause of 65% and 27% respectively of the non-plantable spots for the two machines combined.

Figure 3. Planting corridor produced by the Rome shear blade.

Domtar Forest Products Ltd. - Crushing followed by prescribed burn

The results obtained from the post-burn assessments show that the fire eliminated a large amount of the downed material left from the crushing operation (Figure 4).

A total of 2500 potential planting spots/ha were produced on the sites studied by FERIC. Of these, 83% and 90% were considered plantable on the tractor and skidder sites respectively. However, 1/3 of the plantable spots on the skidder site were classed as marginal because the burn did not reduce the duff layer sufficiently (i.e. < 5 cm). The presence of deep humus, debris and rock were the reasons for the non-plantable spots on the skidder site. On the tractor site, the presence of rock was the only cause of non-plantable spots.

Figure 4. Crushed site after the prescribed burn.

Discussion

Crushing Operations

During the studies, all the machines were able to crush the various sites without great difficulty. The trees at Spruce Falls normally broke off near the ground, while at Domtar they were generally uprooted. This was probably caused by the shallow soil over rock at Domtar. On all the sites, a large portion of the white birch did not break off at ground level and therefore would partially spring back up.

The D7G tractors at Spruce Falls obtained a higher productivity rate than the D8K tractor at Domtar. At Domtar, lower travel speeds and more maneuvering time were required because of the slopes, and the operator there did not take advantage of the D8K's additional power to use more of the blade width.

The most common cause of delays was the frequent need to clean the radiator and engine compartment of accumulations of snow and debris. During crushing operations, a considerable amount of debris inherently falls onto the machine and can accumulate on the radiator and inside the engine compartment, creating a fire hazard. On a few occasions, debris inside the engine compartment indeed caught fire which had to be extinguished.

The skidder used for crushing pockets of unmerchantable trees obtained the lowest productivity rate. The machine's lack of traction in deep snow and the additional time required to maneuver the machine *within* the pockets or to turn around contributed greatly to this low productivity. However, despite their low productivity when actually crushing, skidders can be more effective for treating small, scattered pockets in mechanically-harvested areas because of their lower hourly costs and greater mobility for moving between sites.

The trial with the downing chain was short-lived as the chain often simply bent over the small trees and brush, could not pull over the larger hardwoods, and produced windrows of downed trees. Windrows of trees would prevent the prescribed burn from spreading throughout the entire area because the debris is not distributed evenly on the ground. Coordination between the two machines was also very difficult because the operators could not see through the stand. However, there is potential for this type of operation to increase productivity. The use of a shorter downing chain would most likely ensure better visibility and communication between the machines and operators. Also, heavier and more powerful tractors could probably pull down the larger hardwoods.

The following estimated crushing costs are based on calculated hourly rates of $84, $114, and $71 for the Caterpillar D7G and D8K tractors and Tree Farmer C8C skidder respectively, and the productivity rates obtained during FERIC's studies. The hourly rates include fixed and operating costs, operator wages and fringe benefits. The estimated costs for the crushing operations using tractors at Spruce Falls and Domtar were $147/ha and $253/ha, and $394/ha for the area crushed by the skidder. It should be noted that the estimated skidder operation cost applies only within the pockets actually crushed, and would be lower when considering the entire area.

Shearblading Operation

Because of the loss of the burning window, shearblading the crushed sites was used as an alternative method of site preparation at Spruce Falls. A lower number of plantable spots/ha were produced because of the area lost to the windrows of debris. Also, the quality of the planting spots depended greatly on the operator's ability to remove part of the duff layer without exposing the clay mineral soil. Nevertheless, the machines were able to treat the sites and obtained acceptable plantability. The cost of shearblading at Spruce Falls was calculated at $136/ha.

Prescribed Burn

The prescribed burn of the crushed sites at Domtar produced a greater number of planting spots/ha and higher quality planting spots than with the shearblading operation at Spruce Falls. The fire was able to reduce considerably the debris left from the crushing operation, as well as most of the duff layer. The major reason for the non-plantable spots was the presence of rock. The cost of the prescribed burn was approximately $90/ha according to the Ontario Ministry of Natural Resources.

Conclusions

Tracked tractors are more suitable than skidders for crushing sites having heavy residuals and brush. Tractors are more productive because they provide more drawbar pull and power, and can thus maintain a more constant forward speed while crushing in snow. Wider passes are also possible because of the wider dozer blades. However, skidders can be more cost effective for crushing small scattered clumps of residuals within an entire cutover.

Prescribed burning, where possible, will often provide good results at a reasonable cost. An intense burn can reduce the downed material as well as the duff layer to provide the maximum number of planting spots required.

On shearblading operations, a significant portion of the area can be lost to windrows. These cannot usually be burned because they contain high concentrations of duff, humus and sometimes mineral soil. It is also more difficult to produce a consistent quality of microsites. Nevertheless, shearblading remains a viable option barring other alternatives.

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Disclaimer

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Appendix 1

Specifications of the Equipment

	Caterpillar D7G tractor	Tree Farmer C8C skidder	Caterpillar D8K tractor with Rome K/G shear blade	Caterpillar D8K tractor with straight blade
Net power (kW)	149	134	224	224
Width of blade (m)	4.27	2.46	3.76	4.72
Weight (kg)	19 660	11 249	31 563	31 661
Ground pressure (kPa)	69	61 (front) 37 (rear)	86	86
Ground clearance (cm)	35	51	43	43