CHIPPING ROADSIDE DEBRIS WITH THE BRUKS CHIPPER IN WEST-CENTRAL ALBERTA

1994

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ABSTRACT

In the summer of 1993, the Forest Engineering Research Institute of Canada (FERIC) evaluated a Swedish-built Bruks chipper mounted on a 6-wheel-drive forwarder, working on three sites in west-central Alberta. The chipping technique was an alternative to burning the roadside debris accumulations created by stroke delimbers. The purpose of the study was to determine the costs, productivity, and operational feasibility of the Bruks chipper treating roadside debris. Pre- and post-treatment assessments and a time analysis were conducted. Short-term productivity of the chipper and forwarder, as measured by FERIC, averaged 282 m^3 of stacked debris/PMH, which corresponded to 627 m^2 of areal coverage/PMH and 47 lineal roadside m/PMH. Production costs were calculated to be \$0.65/stacked m^3, or \$158.95/ha (cutover area). The number of plantable spots obtained varied from 931 to 1336/ha. Further studies are required to evaluate alternative debris treatments, and to determine the effects of chip accumulations on forest regeneration.

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INTRODUCTION

Full-tree harvesting with roadside stroke delimbing creates accumulations of tops and limbs that can be fire hazards, occupy productive forest area, and are visually unattractive. Commonly, piling and burning treatments have disposed of these accumulations. Public concern about smoke emissions from controlled burns has led forest companies to consider alternative treatments. However, little work on this subject has been done in western Canada. Unfavourable wood fibre markets for energy and other products have not supported utilization of debris material. In eastern Canada, piling, chipping, and other treatments have been used, as discussed by Desrochers and Ryans (1991).

In 1993, Millar Western Industries Ltd. of Whitecourt, Alberta, conducted a trial with a mobile Bruks chipper. The purpose of the chipping trial was to comminute roadside debris accumulations, thereby reducing fire hazards and increasing the productive forest area available. No precedents of similar experience are known in western Canada and the effects of chip piles on biophysical site properties and subsequent seedling establishment are not well understood.

The Forest Engineering Research Institute of Canada (FERIC) evaluated the Swedish-built Bruks chipper mounted on a 6-wheel-drive forwarder (Figure 1), working on three sites in western Alberta in the summer of 1993. The objective of the study was to determine the cost, productivity, and operational feasibility of the Bruks chipper in treating roadside debris.

Figure 1. Bruks 1002CT chipper mounted on a Kockums 85-35 forwarder.

EQUIPMENT DESCRIPTION

The Bruks 1002CT chipper was designed to be mounted on a forwarder for off-road, or terrain, chipping. Terrain chipping was introduced in the Nordic countries in the 1970s and was a popular technique there in the 1980s. Six Bruks machines were used in eastern Canada in 1985 for at-the-stump full-tree utilization harvesting (Richardson 1986).

The Bruks 1002CT chipper used in this study is manufactured by Bruks Mekaniska AB in Sweden, and is owned and operated by Rocan West Forestry Ltd. of Whitecourt, Alberta. The Bruks was selected because it was readily available and relatively inexpensive to contract. The chipper and forwarder were both eight years old.

The Bruks 1002CT is a two-knife drum-type chipper with a drum width of 1 m and an infeed opening of 78 x 45 cm. The unit is powered by a dedicated 217-kW Scania DS11 motor mounted on the rear of the forwarder. The forwarder's grapple is used to feed debris onto the chipper's infeed chain / hold-down roller assembly (Figure 2). The operator positions the output spout from inside the cab to direct the placement of chips (Figure 3). The size of chip can be varied from 20 to 40 mm by adjusting the distance between the drum knives and the anvil. The chipper drum could be replaced by a hog fuel chopper; however, this was not done during the study.

The contractor made several modifications to the machine to adapt it to chipping debris. A larger dedicated engine was installed for added power. The fuel tank capacity was increased to 500 L and the output spout was altered to throw chip material further. The unit weighs approximately 9000 kg.

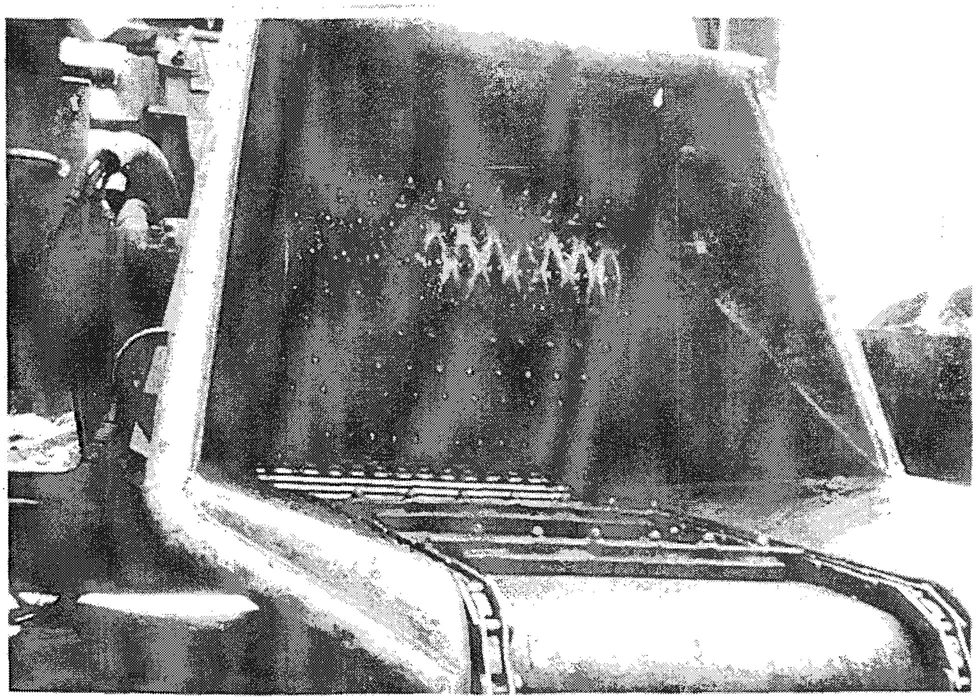

Figure 2. Infeed hopper and chain.

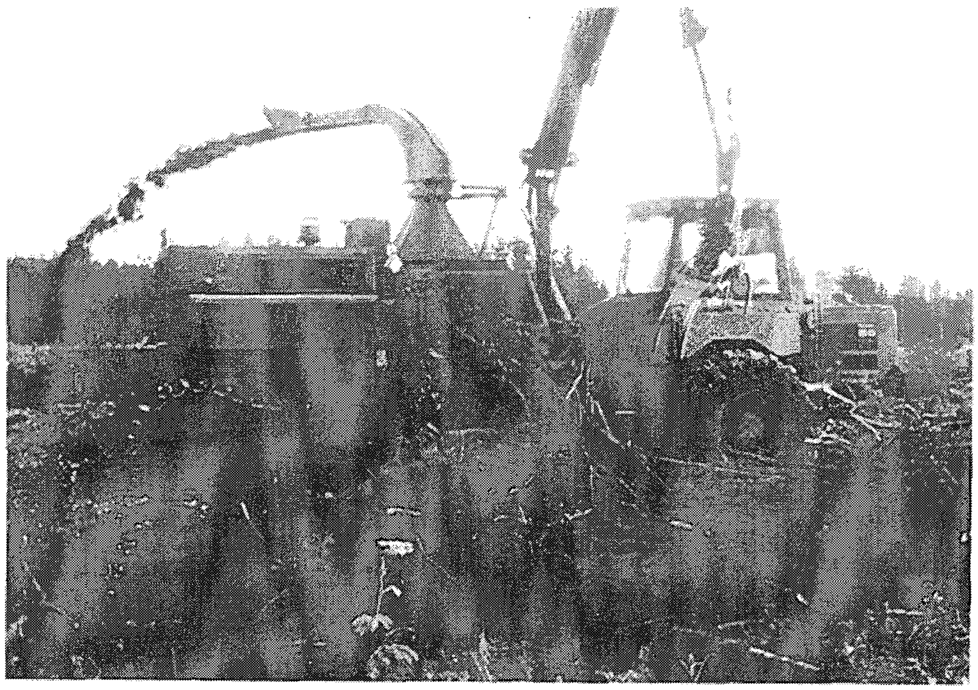

Figure 3. Operator directs chips with output spout.

The Bruks chipper was mounted on a Swedish 15-t Kockums 85-35 forwarder equipped with a 123-kW motor and a Clark powershift transmission.

SITE DESCRIPTION

The study sites were located 40 km southwest of Whitecourt, Alberta (Figure 4) in the Upper Boreal Cordilleran Ecoregion (Corns and Annas 1986). The three study blocks were located in Millar Western's cutting area within 3 km of each other. As shown in Table 1, the harvested stands were predominantly lodgepole pine and trembling aspen with minor components of paper birch, white spruce, and black spruce. Harvesting was carried out in the winter of 1992/93 with feller bunchers, grapple skidders, and stroke delimbers.

STUDY METHODS

Two work techniques were monitored in the study. The original prescribed treatment called for a broadcast reduction of debris to a specified depth (approximately 25 cm); this depth was considered the maximum to allow a disc trencher to prepare plantable spots. Two months after operations commenced, at the start of the FERIC study, a corridor technique was tried in an effort to increase machine productivity and to avoid disc trenching on sites where site preparation was not required on

Figure 4. Location of study sites.

Table 1. Description of study blocks.

Block no.	Area (ha)	Stand height (m)	Species composition (%Pine:Aspen)	Volume harvested (m^3/ha)
1	33.9	22	80:20	264
2	35.6	23	90:10	304
3	20.1	24	90:10	210

the remainder of the block. Corridors 2.5-m wide were created with debris depths sufficiently thin (approximately 15 cm) for planters to screef patches 30 x 30 cm in mineral soil (Figure 5). The volume of debris chipped was reduced by forming piled rows 1-m high and 2.5-m wide with the material displaced from the corridors with the forwarder grapple. Alberta Land and Forest Services stipulated that debris piles must be reduced to heights below 1 m to alleviate fire hazard. The target planting density was 1400 seedlings/ha. The operator was initially instructed to direct chips onto road edges. Later, chips were also spread onto roads.

Pretreatment assessment of debris accumulations (Figure 6) quantified factors that might affect machine productivity. Sample plots, varying from 40 to 110 m in length, were located within representative roadside parcels corresponding to approximately one hour of processing time. The number of debris piles per sample plot and the depth per pile varied between samples. A total of 22 plots were sampled throughout the three blocks. Sub-plots of individual piles within plots were also used in the analysis. The stacked, loose volumes of debris piles were determined from pile heights (measured at 5-m intervals), and from average pile widths. Measuring exact volumes of pieces and piles was not possible. Within the piles, large coniferous pieces exceeding 3 m in length were counted, and diameters of both coniferous and aspen pieces exceeding 10 cm in diameter were tallied.

FERIC monitored the broadcast and corridor treatments of sample plots with stopwatches. The chipper and the forwarder activities were sampled at intervals of 12 seconds.

During the post-treatment assessment, the volume and depth of remaining debris, the number and

Figure 5. Corridors with plantable spots and piled rows.

Figure 6. Debris.

quality of plantable spots, and the distribution of chips were measured. Stacked volumes of debris piles formed with the corridor technique were measured according to pretreatment methods. It was not possible to compare the post-treatment volumes of broadcast and corridor treatments because measurement methods were different. Plantable spot surveys were conducted along a transect located at the centre of the debris piles. Sample plots 3.99 m in radius were located every 10 m. The area and the maximum depth of chip accumulations spread on roads and ditches were measured when possible. Chip piles further than 5 m from the outside track of the road, with widths greater than 2.5 m, and depths exceeding 10 cm were deemed to occupy productive area. This area was measured.

Multiple-regression was applied to determine which pretreatment factors affected machine productivity. Mean productivities for broadcast and corridor treatments were analysed using the Student T-test.

Information on stand volume and contractor hours was supplied by Millar Western Industries Ltd. and used to determine costs per harvested volume.

RESULTS

The results of the pretreatment assessment are shown in Table 2. The average prorated volume of debris ranged between 4808 and 5807 stacked m^3/ha, with average pile depths varying from 44 to 83 cm. The samples in one block consisted of pure coniferous material and the other two blocks had,

Table 2. Pretreatment assessment of debris samples.

Block no.	Sample plots (no.)	Debris piles (no.)	Average width of samples (m)	Average depth of samples (m)	Total debris coverage (m^2)	Average debris volume[a] (m^3/ha)	Conifer content (%)	Average diameter conifer >10 cm (cm)	Average diameter aspen (cm)	Pieces >3 m long (no.)
1	6	23	15.2	0.44	6139	5197	83.0	18.8	18.2	144
2	7	15	14.0	0.83	6239	5807	100.0	14.4	n/a	911
3	9	26	12.8	0.77	7157	4808	80.1	17.4	15.0	575

[a] Prorated from sample plots, scaled pile volumes.

roughly, a 20% component of aspen debri. Block 1 had fewer but larger pieces, while Block 3 had many smaller pieces.

Machine productivity for debris chipping can be expressed in a number of ways. The direct expression is the quotient of treated units (length, area, or volume) and machine time (i.e., m/PMH, m^2/PMH, or m^3/PMH). A second way is to express debris-chipping productivity in relation to the volume of merchantable timber harvested from the block, again as m^3/PMH. This second expression of productivity puts debris chipping in the same context as all other block treatments, thus allowing a more meaningful analysis of overall treatment economics. Table 3 illustrates the Bruks productivities in both direct and relative units.

The statistical analysis found no significant differences between mean productivities (stacked volumes) for broadcast treatment (265 m^3/PMH) and corridor treatment (298 m^3/PMH). Productivity was variable among all samples.

Downtime involving replacement or repair of old parts occurred several times during the FERIC study. Knives were replaced every day or day and a half, depending on the amount of dirt and stones encountered. Over the 13-day observation period of 72.5 PMH, knives were sharpened off-site eight times and filed manually on-site six times. Replacement and filing required, respectively, 1 h and 0.5 h of labour. Knives could be resharpened by machine approximately 20 times before being discarded.

The average time to process each of the 22 monitored plots was 83 min. The chipper was active for 26 and 38% of the machine's productive time (Table 4). With the corridor treatment, the operator spent about 10% of the time creating corridors and forming piles. Subsequently, the number of grapple cycles per minute and the proportion of time the chipper was working were 30 to 35% lower than for the broadcast treatment. In both techniques, the largest proportion of time was spent extending the boom and grabbing material (37% and 42% for broadcast and corridor, respectively), and feeding material into the chipper (36% and 28% for broadcast and corridor, respectively).

Table 3. Bruks productivity summary.

Block no.	Machine productivity, relative to sample dimensions			Machine productivity, relative to harvested volume[b] (m^3/PMH)
	Volume[a] (m^3/PMH)	Areal (m^2/PMH)	Lineal (m/PMH)	
1	287	740	57	238
2	268	485	35	183
3	296	655	49	216
Average	282	627	47	212

[a] Stacked volume determined by FERIC survey.
[b] Company provided data, converted from scaled weight.

Table 4. Distribution of chipper and forwarder activities for broadcast and corridor treatments.

Forwarder activities	Treatment			
	Broadcast		Corridor	
	Both forwarder and chipper active (%)	Only forwarder active (%)	Both forwarder and chipper active (%)	Only forwarder active (%)
Extend boom and grab	19.2	18.1	15.3	26.9
Feed slash into chipper	9.8	17.7	6.7	16.7
Help infeed material	7.0	1.2	3.9	0.4
Sort/make piles	0.0	1.1	0.1	10.6
Move machine	1.4	15.3	0.4	12.1
Other work	0.2	5.8	0.0	2.0
Wait, delay		3.2		4.9
Total 100%	37.6	62.4	26.4	73.6
Grapple cycles/min (no.)		2.0		1.3
Total hours sampled (PMH[a])		12.7		23.1

[a] Delays >15 min not included.

Multiple regression of a number of factors measured during pretreatment assessment indicated that a significant relationship existed only between volume of material and processing time (Figure 7). Other factors such as pile depth before and after treatment, piece diameter, number of large pieces, proportion of aspen, and area treated were highly variable in relation to the time required for processing.

The post-treatment assessment of the corridor samples showed the debris volume was reduced by 55% of the original volume. It was not possible to make pre- and post-treatment volume comparisons of broadcast treatments because measurement methods were different. Pile depths were reduced by 66 and 70%, from 73 cm down to 25 cm for the broadcast area, and from 75 cm down to 21 cm for the corridor area. These depths were adequate to provide 931 to 1336 plantable spots/ha in the areas of densest accumulations. In both treatments the majority of the plantable spots were tallied as requiring light screefs (Table 5). Corridor widths were slightly wider than the 2.5-m target width.

The corridor debris piles averaged 87 cm in height, although 14% of the samples had average heights exceeding the 1-m level for fire hazard reduction (118 cm).

The operator was successful in directing chips onto the ditches and roads (Figure 8). The average area and maximum depth of chip piles was 38.1 m^2 and 49 cm, respectively, for the broadcast and corridor treatments combined (Table 6). An average of 1.4 chip piles were formed per 100 m^2 of debris. Maximum depths of the piles occurred adjacent to roadside ditches because the operator was initially discouraged from directing chips onto roads. It was not possible to measure chip-pile distri-

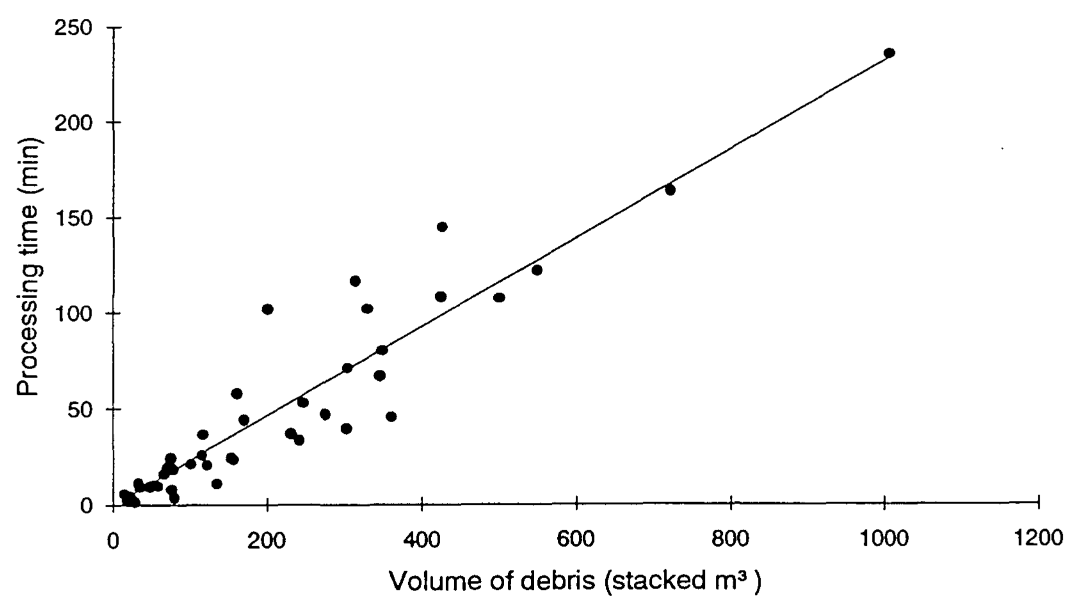

Figure 7. Relationship between debris volume and predicted processing time, $y=0.2x-1.6$, $r^2=0.88$, alpha=0.05.

Table 5. Post-treatment assessment.

Treatment	Depth of chips (m)	Volume (m³/ha)	Corridor width (m)	Pile width (m)	Plantable spots No./ha	Plantable spots Requiring light screefs (%)
Broadcast	0.25	n/a	n/a	n/a	931	54
Corridor	0.21	2154	2.65	2.58	1336	61

Figure 8. Distribution of chips spread on roads and ditches.

Table 6. Distribution of chips spread on roads and ditches.[a]

Samples (no.)	Average piles/ 100 m² sample (no.)	Average area occupied per chip pile (m²)	Average maximum depth of chip pile (cm)
11	1.4 (0.5)	38.1 (20.6)	49 (15)

[a] Parenthesis indicate standard deviation.

bution on half of the samples because the chips were mixed with previously treated piles. Only two of the eleven samples had chip piles occupying small proportions of productive area (i.e., <5 m^2 per 100 m^2 sample).

A machine-cost analysis of the equipment in this trial (using FERIC's standard costing formula) is presented in the Appendix. The projected owning and operating cost for a used 6-wheel drive Kockums 85-35 forwarder and a Bruks 1002CT chipper is $127.43/h. A utilization factor of 70% was used because of maintenance associated with the knives and age of the equipment. This cost does not include expenses for travel to the site, supervision, or profit. Based on this hourly cost, the production cost is $0.65/$m^3$ of stacked roadside volume or $158.95/ha (cutover area). Production costs relative to harvested volumes are $0.61/$m^3$. This compares with piling and burning production costs of $0.25/$m^3$, relative to harvested volumes (pers. comm. A. Jacobs, Assistant Woodlands Manager, Millar Western Industries Ltd., August 1993).

DISCUSSION

It is difficult to accurately determine machine productivity because of problems encountered when measuring debris volumes. The stacked volumes in this study are over-estimates because they are derived from scaled pile dimensions and are not actual wood volumes.

A direct relationship between debris volume within the sample piles and processing time was demonstrated. Delays and lower productivity rates in terms of stacked volumes were often observed when processing large coniferous pieces and aspen material. At times there was inadequate power for the engine to maintain high rotation speeds when chipping large pieces (i.e., snags) or dense loads. When rotation speed dropped below a certain limit, the infeed chain would stop until engine speed recovered. The operator was advised not to chip large unmerchantable logs because they were time consuming and did not occupy much plantable area. Productivity may have been affected by the proportion of densely compacted fine material as well.

The operator had used the broadcast chipping technique method for the two previous months, and then began using the corridor treatment at the onset of the study. Consequently, he was still learning and developing both techniques. Variation in operator technique may have overshadowed other factors affecting machine productivity such as pile depth, piece size and diameter, proportion of aspen, and area treated. No significant differences in productivity were found between the broadcast and corridor techniques because of high variation with both treatments.

Both treatments required the operator to position the machine at an oblique angle to the road to reach the debris at the back of the pile, to facilitate infeeding, and to provide visibility for directing the chips onto ditches and roads. With the corridor technique, this manoeuvring involved driving over piles, which increased maintenance problems because the machine, particularly the infeed chain, was sometimes damaged by doing this.

Both techniques adequately achieved the treatment objectives. A small proportion of the corridor piles exceeded the Alberta Land and Forest Services' 1-m height limit for acceptable fire-hazard reduction, but this was considered acceptable due to anticipated settling. However, some risk of spontaneous combustion from the compost effect in the chip piles may remain.

The broadcast technique sufficiently reduced slash levels (25 cm depth with 931 plantable spots/ha), thus facilitating site preparation with a disc trencher. The plantable spots obtained with the corridor technique were just under the target density of 1400 spots/ha. However, the plantable-spot survey was conducted in the most dense debris accumulations, therefore the total area without plantable spots was relatively small. Some over-stocking could be anticipated for areas treated with both techniques because of the high concentration of lodgepole pine cones.

The chipping treatment successfully alleviated the debris occupancy problem, but has created another undesirable condition. The average maximum chip depth of 49 cm, and the volume of chips piled in the ditches and roads may have adverse effects on the biophysical site characteristics. The high carbon:nitrogen ratio may cause serious nutrient deficiencies as the chip material decomposes. Soil temperature and moisture regimes may be seriously altered as well. High volumes of chips were produced from the dense aspen tops. Leachates from aspen chips could cause toxicity problems.

Millar Western Industries Ltd. intends to combine follow-up treatment of chip accumulations with rehabilitation treatments of secondary roads. Chips will be spread out 15 cm in depth over the road surface. Then the road will be ripper plowed to create furrows and raised plantable spots on berms. An excavator will pull organic material (debris and humus) from the road edges onto the ripped road surface. Fertilizer trials will also be established.

During a FERIC-organized field excursion of researchers, and industry and government participants to the study site, the proposed method of disposing of chips with road rehabilitation was deemed suitable for the volume and distribution of chips observed within the study. However, heavy debris piles and excessive chip accumulations that could not easily be spread to depths less than 30 cm were deemed unacceptable because negative site impacts are anticipated (pers. comm. D. McNabb, Soils Physicist, Alberta Environmental Centre, October 1993).

The cost and effectiveness of treating chip accumulations with road rehabilitation have not been determined. The high clay and silt component of the soils in west-central Alberta contribute to poorly aerated, moist cold conditions that may not favour the rapid breakdown of woody material. The effects of different quantities of chips on forest regeneration are not well understood.

The productivity of debris treatments with the Bruks could be increased by combining preparation of plantable spots with road rehabilitation treatments. Less volume and area could be treated with the Bruks if the ripper plow were used to create plantable spots. Alternatively, treatment of chip piles may be avoided by modifying the spout of the Bruks to rotate continuously and scatter the chips in shallow depths throughout the roadside area.

Modification of harvesting practices could reduce or eliminate roadside debris problems. Small-to-moderate-sized roadside piles could be spread out to facilitate preparation of plantable spots. If the grapple skidders are working in proximity to the stroke delimber, grapple loads of tops and debris could be scattered back out in the cutblock.

Utilization of debris for fuel or pulp chips may be an alternative to disposal or concentration of material. FERIC has recently investigated new technology with the potential to remove significant amounts of bark and impurities from chips for pulping (Araki in progress).

Chips could be collected in containers and utilized for hog fuel. Another approach might be to substitute the drum of the Bruks for a hog-fuel chopper. Redistributed debris accumulations could be chopped on site using an excavator-mounted mulcher such as the Brown Brontosaurus (Hunt 1992). The contractor suggested adapting a forwarder to collect roadside debris from piles and distribute the coarse material throughout the cutblock, thus ensuring retention of nutrients on site.

CONCLUSIONS

FERIC, in cooperation with Millar Western Industries Ltd., evaluated a Swedish-built Bruks chipper mounted on a 6-wheel-drive forwarder, working on three sites in western Alberta. The purpose of the chipping treatment was to comminute roadside debris accumulations to reduce fire hazard, and to increase the available productive forest area. The objective of the study was to determine the costs, productivity, and operational feasibility of the Bruks chipper in treating roadside debris.

Sampling was conducted on 22 plots 40 to 110 m in length with average depths of 44 to 83 cm and average sample volume equivalencies of 4808 to 5807 m^3/ha (cutover area). It is difficult to accurately determine machine productivity because debris volumes cannot be easily measured.

Productivity of the chipper and forwarder measured in this study averaged 282 stacked m^3/PMH, which corresponded to an area of 627 m^2/PMH and 47 lineal roadside m/PMH. The company reported average debris chipping productivity of 212 m^3/PMH relative to the harvested volume from the study blocks. A direct relationship between debris volume and processing time was demonstrated. Other factors such as pile depth before and after treatment, piece diameter, number of large pieces, proportion of aspen, and area treated were highly variable in relation to the time required for processing.

The results of this study show the production cost of chipping with the Bruks 1002CT to be $0.65/stacked m^3 or $0.61/harvested m^3, and $158.95/ha (cutover area).

Two work techniques were monitored in the study. The broadcast treatment uniformly reduced debris depth to an extent that a disc trencher could prepare plantable spots. The corridor treatment chipped a large proportion of the debris, then bunched debris into piles with material removed from corridors with the forwarder grapple. The corridor depth was sufficient for planters to create plantable spots. No significant differences in productivity were found between the two techniques.

The treatment objectives were achieved in terms of reducing the depth of the continuous pile to less than 1 m to decrease fire hazards. Debris depths were sufficiently reduced with the broadcast treatment to facilitate site preparation with a disc trencher, and to provide plantable spots (931/ha). An adequate number of plantable spots (1336/ha) were achieved with the corridor technique.

The effects of chip accumulations on site biophysical qualities are poorly understood and more studies are required. Potentially negative impacts on soil nutrition, temperature, and moisture could impair conifer regeneration. Follow-up treatment of chip accumulations will be combined with rehabilitation of secondary roads.

As studied in this project, the overall feasibility of using the Bruks chipper to treat debris on sites harvested with stroke delimbers depends on several factors:

- Effects of chip accumulations on forest regeneration.
- Acceptability of the Bruks' treatment costs.
- Cost and effectiveness of alternative treatments.

The trial with the Bruks chipper was a first attempt toward developing alternative techniques to burning. The Bruks chipper was designed to produce usable chips rather than to dispose of debris. Perhaps greater efficiency could be obtained using technology designed more specifically for debris handling. Development of new techniques may facilitate utilization of debris material. Modification of harvesting practices could help alleviate some roadside debris problems.

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Appendix

Machine Costs: Bruks 1002CT Chipper and Kockums 85-35 Forwarder

OWNERSHIP COSTS	
Total purchase price[a] (P) $	300 000
Expected life (Y) yr	4
Expected life (H) h	8 000
Scheduled hours per year (h) = (H/Y) h	2 000
Salvage value as % of P (s) %	15
Interest rate (Int) %	10.0
Insurance rate (Ins) %	4.0
Salvage value (S) = ((P•s)/100) $	45 000
Average investment (AVI) = ((P+S)/2) $	172 500
Loss in resale value ((P-S)/H) $/h	31.88
Interest ((Int•AVI)/h) $/h	8.63
Insurance ((Ins•AVI)/h) $/h	3.45
Total ownership costs (OW) $/h	43.95
OPERATING COSTS	
Fuel consumption (F) L/h	30.0
Fuel (fc) $/L	0.30
Lube and oil as % of fuel (fp) %	15
Annual tire consumption (t) no.	0.4
Tire replacement (tc) $	8 500
Annual tire chain consumption (ch) no.	0.4
Tire chain replacement cost (chc) $	6 000
Annual knife consumption (k) no.	20
Knife replacement cost (kc) $	350
Annual operating supplies (Oc) $	5 000
Annual repair and maintenance (Rp) $	75 000
Shift length (sl) h	10.0
Wages (W) $/h	18.00
Wage benefit loading (WBL) %	35
Fuel (F•fc) $/h	9.00
Lube and oil ((fp/100)•(F•fc)) $/h	1.35
Tires ((t•tc)/h) $/h	1.70
Tire chains ((ch•chc)/h) $/h	1.20
Knives ((k•kc)/h) $/h	3.50
Operating supplies (Oc/h) $/h	2.50
Repair and maintenance (Rp/h) $/h	37.50
Wages and benefits (W•(1+WBL/100)) $/h	24.30
Prorated overtime (((1.5•W-W)•(sl-8)•(1+WBL/100))/sl) $/h	2.43
Total operating costs (OP) $/h	83.48
TOTAL OWNERSHIP AND OPERATING COSTS[b] (OW+OP) $/h	127.43
Excluding interest $/h	118.81
Average production (stacked m^3/PMH)	282
Utilization factor (U)	0.7
Average production cost,	
Interest included = ($/h)/(($m^3$/PMH)•U) $/$m^3$	0.65
Interest not included = ($/h)/(($m^3$/PMH)•U) $/$m^3$	0.60

[a] Used Bruks 1002CT chipper $150 000, used Kockums 85-35 forwarder $150 000.
[b] These costs are based on FERIC's standard costing methodology for determining machine ownership and operating costs. These costs do not include supervision, profit, or overhead, and are not the actual costs for the contractor or company studied. Annual costs for repairs and maintenance were provided by the contractor.