LABOR PRODUCTIVITY AND COSTS OF MOTOR-MANUAL RELEASE OF SPRUCE FROM HARDWOODS IN MANITOBA

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INFORMATION REPORT NOR-X-312

FORESTRY CANADA
NORTHWEST REGION
NORTHERN FORESTRY CENTRE
1990

This publication is based on a study funded by the Canada-Manitoba Forest Renewal Agreement of 1984-89.

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Catalogue No. Fo46-12/312E
ISBN 0-662-17632-4
ISSN 0704-7673

This publication is available at no charge from:
Forestry Canada
Northwest Region
Northern Forestry Centre
5320 - 122 Street
Edmonton, Alberta
T6H 3S5

A microfiche edition of this publication may be purchased from:
Micromedia Ltd.
Place du Portage
165, Hôtel-de-Ville
Hull, Quebec
J8X 3X2

Printed in Canada

De Franceschi, J.P.; Bell, F.W. 1990. *Labor productivity and costs of motor-manual release of spruce from hardwoods in Manitoba.* For. Can., Northwest Reg., North. For. Cent., Edmonton, Alberta. Inf. Rep. NOR-X-312.

ABSTRACT

Labor productivity and costs for brush saw and chain saw release of white spruce *(Picea glauca* (Moench) Voss) from a trembling aspen *(Populus tremuloides* Michx.) overstory are described for operations in 25- and 55-year-old spruce-aspen stands in Manitoba. Labor production in the 25-year-old stand averaged 26.6 hours per hectare with chain saws and 28 hours per hectare with brush saws. Productivity in the 55-year-old stand averaged 34.4 hours per hectare with chain saws. The study also examined the effect of stand characteristics on labor production. Simple equations for estimating labor productivity from stand statistics are presented. These equations show that for given stand characteristics, chain saws outperform brush saws and that the difference between the two saw types increases with stand density. Treatment costs for the operations are estimated using the average labor production observed and the equations to predict labor productivity from stand characteristics.

RESUME

L'article décrit la productivité et les coûts de la main-d'œuvre nécessaire à des opérations de dégagement à la scie à broussailles et à la scie à chaîne de l'épinette blanche *(Picea glauca* (Moench) Voss) poussant sous un couvert dominant de peupliers faux-trembles *(Populus tremuloides* Michx.) qui ont été effectuées dans des peuplements d'épinettes-peupliers faux-trembles de 25 et de 55 ans du Manitoba. Dans le peuplement de 25 ans, la productivité moyenne était de 26,6 heures par hectare pour les opérateurs de scie à chaîne et de 28 heures par hectare pour les travailleurs utilisant la scie à broussailles. Dans le peuplement de 55 ans, le travail à la scie à chaîne donnait une productivité moyenne de 34,4 heures par hectare. Cette étude s'est également penchée sur les effets des caractéristiques du peuplement sur la productivité de la main d'œuvre. Le rapport présente aussi des équations simples permettant d'estimer la productivité de la main-d'œuvre à partir des caractéristiques du peuplement. Ces équations montrent que la scie à chaîne, dans un peuplement présentant des caractéristiques données, permet d'obtenir un rendement largement supérieur à celui de la scie à broussailles et que la différence entre ces deux types d'outil augmente avec la densité du peuplement. Les coûts des opérations sont estimés à partir de la productivité moyenne observée de la main-d'œuvre et des équations servant à prédire la productivité de la main-d'œuvre selon les caractéristiques du peuplement.

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The exclusion of certain manufactured products does not necessarily imply disapproval nor does the mention of other products necessarily imply endorsement by Forestry Canada.

INTRODUCTION

The white spruce *(Picea glauca* (Moench) Voss) - trembling aspen *(Populus tremuloides* Michx.) complex is characteristic of the extensive Mixedwood Section B.18a of the Boreal Forest Region (Rowe 1972). Typically, spruce in these stands is overtopped by the faster growing aspen, and spruce growth is restricted. When the spruce crowns eventually reach the aspen canopy, the whipping action of the aspen branches damages the spruce leaders, and spruce height growth is further impaired. Releasing the spruce from the competing aspen can result in substantial improvements in spruce growth over a wide range of ages (Yang 1989).

Several options are available for releasing spruce from competing aspen. Some possibilities include aerial and ground applications of herbicides, hand-girdling, and stem injections with herbicides. These methods are not always suitable. Dead aspen trees can remain standing for 10 years or more; consequently, spruce leaders could still be damaged as they grow into the dead aspen tops (Steneker 1976). Herbicide use may meet resistance from the public. Hand-felling may be a promising method of releasing spruce from hardwood competition in mixedwood stands. This method eliminates as many of the competing hardwoods as desired and is environmentally acceptable. Cost information on such treatments, however, is lacking.

This study was established to provide information on costs of conducting motor-manual release treatments in spruce-aspen stands. The objectives of the study were twofold: 1) to measure labor production rates over a range of stand conditions for both brush saws and chain saws in young stands and for chain saws in older stands, and 2) to assess damage to crop trees. This report describes labor requirements and costs of release operations in 25- and 55-year-old spruce-aspen stands in Manitoba. Results are based on release operations conducted during the summer of 1987.

STUDY AREA DESCRIPTION

The study areas were located in the Duck Mountain Provincial Forest in Township 26, Ranges 25 and 26 (WPM), near the town of Grandview, and in Township 31, Range 25 (WPM), near Dragline Lake.

Two stands were selected for the release operation: a 25- and a 55-year-old stand, both originating from wildfire. Postfire salvage logging had occurred in portions of the younger stand, so few standing remnants of the fire remained. Ground slash was generally light in the young stand and almost nonexistent in the older stand. Local topography was flat to gently rolling. Few exposed rocks were observed.

Trembling aspen, balsam poplar *(Populus balsamifera* L.), and white spruce were the dominant tree species throughout the study areas, with jack pine *(Pinus banksiana* Lamb.) occurring frequently in the 25-year-old stand at Dragline Lake. Willow *(Salix* spp.) and dogwood *(Cornus stolonifera* Michx.) were the most common shrub species. Stand statistics before treatment are presented in Table 1 by stand and by type of saw used in the release operation. Pretreatment stand conditions are illustrated in Figure 1.

STUDY METHODS

The Release Operation

The silvicultural prescription for the release operation called for removal of all hardwoods and 2-m spacing of the remaining spruce. Large areas containing only hardwoods were not treated and, therefore, not included in the calculation of total area treated.

The study was conducted from July 6 to September 7, 1987, in a fully operational setting. Four hourly paid workers were hired to operate the saws. The first week of the operation was a training period for the cutters. None of the workers were experienced with brush saws, but all had previously worked with chain saws in logging-type work. These workers were concerned only with carrying out the silvicultural prescription and required no interaction with the research team.

Felling was done with both brush saws and chain saws in the 25-year-old stand and only chain saws in

Table 1. Stand statistics before treatment

Stand age (years)	Saw type	All species (including dead standing): Trees/ha ≤1 cm dbh[a]	All species: Trees/ha >1 cm dbh	All species: Average dbh[b] (cm)	All species: Average height[b] (m)	Living spruce trees: Trees/ha ≤1 cm dbh[a]	Living spruce trees: Trees/ha >1 cm dbh	Living spruce trees: Average dbh[b] (cm)	Living spruce trees: Average height[b] (m)
25	Brush saw	14 638	4 452	3.9	5.8	4 019	1 696	2.4	3.2
25	Chain saw	14 023	4 217	4.6	6.3	3 021	1 010	2.3	3.1
55	Chain saw	3 292	3 988	10.3	10.6	135	1 494	8.2	7.7

[a] Includes stems <1.3 m in height.
[b] Based on trees with >1 cm dbh.

the 55-year-old stand. Cutters worked in 20-m-wide parallel strips, felling trees in an "S" pattern. The supervisor designated which saw type was used in the 25-year-old stand. Although brush saws are considered most efficient where tree stumps are less than 10 cm in diameter (Bella 1974), the choice of saw was independent of stand conditions but aimed at providing approximately equal amounts of area (and time) to each cutter on each saw type. Equipment used in the operation was the Husqvarna Model 165R and the Stihl Model FS 353AV brush saws and the Pioneer P41 and Jonsered 520 and 620 chain saw. These saws had been used elsewhere in the region and were not purchased specifically for the project.

Data Collection and Analysis

Production data were collected at two levels: block level and sample plot level. Block level data provided overall production rates for the operation, while sample plot data were required to determine effects of stand characteristics on labor productivity. For the release operation, or block level, daily time records maintained for each cutter formed the basis for determining overall labor requirements. A record was also kept of time spent on unproductive activities such as walking into the cutting site from the roadside in the morning and returning at the end of the day, preparation, tool maintenance, repairs, and any unscheduled work breaks in excess of 15 minutes. For the sample plot level, data were collected for each of 52 plots (100 m^2) established for each combination of (a) brush saws in 25-year-old stands, (b) chain saws in 25-year-old stands, and (c) chain saws in 55-year-old stands. A total of 156 plots were distributed at 13 plots per cutter for each combination of saw type and stand.

Tree dimensions—height and dbh (diameter at breast height)—were measured, and counts of stems less than breast height (1.3 m) were obtained prior to treatment for all standing stems on each sample plot. Slash conditions were determined from a transect established along one plot diagonal, following methods outlined by Van Wagner (1982). Tree measurements provided stand statistics, while slash data quantified ground-slash obstacles that might impede cutters' movements.

Timing started or stopped as the cutter entered or exited the plot. The cutter was not restricted to staying within plot boundaries but was free to follow his usual cutting pattern. During the treatment, a count was made of the cutter's activities at 20-second intervals. The frequency of occurrence was recorded for the following activities:

felling: cutting a tree at the stump,
brushing: clearing shrubs or clumps less than 1.3 m in height,
hang-ups: releasing a felled tree lodged in a standing tree,
walking: walking from one tree to another, and
other: activities not included above.

These activities were recorded to provide information on the components of productive time.

After treatment was complete, tree dimensions and stem counts were obtained for all standing stems. Residual spruce were assessed to determine the

Figure 1. Photographs of untreated (a) 25-year-old stand and (b) 55-year-old stand.

extent of damage caused by the treatment. Damage classes for the spruce were

1) broken leader or stem,
2) broken lateral branches,
3) saw damage, and
4) tree buried and pressed down by slash.

Sample plot data were used with regression methods to develop relationships between stand variables and labor productivity. The dependent variable was the hours per hectare required to create the prescribed treatment.

RESULTS

Average Labor Production

A total of 19 ha was treated in the 25-year-old stand and 6.6 ha in the 55-year-old stand. Based on daily time records, production in the 25-year-old stand averaged 26.6 hours per hectare with chain saws and 28.0 hours per hectare with brush saws. In the 55-year-old stand, production averaged 34.4 hours per hectare using chain saws. These production rates included all time spent at the work site (all time for which cutters were paid) and reflected the average stand conditions prevailing throughout the study area.

Observations of daily worker activities provided a measure of productive time (time spent on cutting or cutting-related tasks) and a distribution of the components of unproductive time. These time elements are summarized by stand and saw type in Table 2. Chain saws operated at somewhat higher efficiency in the older stand, where about 79% of the time was productive compared with 75% in the younger stand. Brush saws in the younger stand were the least efficient at 71%. The largest difference in each unproductive category was in the "other" group, at 16% for brush saws compared to 11% for chain saws. The "other" category included refueling, and brush saws perhaps required more frequent refueling stops.

Stand Characteristics and Labor Productivity

Effects of stand characteristics on labor production were determined from time measurements on 100-m^2 sample plots. These time measurements are productive times, since cutters were timed only while treating the 100-m^2 sample plots.

25-year-old Stand

High variation in production was observed for both chain saw and brush saw treatments in 25-year-old stands. Both stand density and tree size affected labor productivity rates. In particular, the number of trees per hectare cut and the average height of cut trees were found to be the most effective explanatory variables for predicting labor production. These variables are both practical and easily determined when estimating labor production rates in the field.

The following regressions were developed to estimate labor productivity rates for brush saws and chain saws in 25-year-old stands:

Productivity equation for brush saws:

$$TIME = 6.32 + 0.0002728 \cdot X_1 + 0.0002648 \cdot X_2$$
$$R^2 = 0.48 \quad \text{Standard error} = 5.0 \qquad (1)$$

Table 2. Average labor productivity for release operation and distribution of daily cutter activities

Stand age (years)	Saw type	Total area treated (ha)	Average production (h/ha)	Daily cutter activities (%)					
				Productive time	Morning preparation	Walk to cutting site	Afternoon preparation	Mechanical downtime	Other
25	Brush saw	9.7	28.0	70.6	6.4	1.3	3.0	2.5	16.2
25	Chain saw	9.3	26.6	74.9	6.3	2.0	4.0	2.0	10.8
55	Chain saw	6.6	34.4	78.7	5.9	1.7	2.2	0.1	11.4

Productivity equation for chain saws:

$$\text{TIME} = 6.70 + 0.0001756 \cdot X_1 + 0.0001094 \cdot X_2$$
$$R^2 = 0.37 \quad \text{Standard error} = 3.8 \qquad (2)$$

where TIME = hours per hectare (productive time only) and is based on time required to treat a 100-m^2 plot and does not include rest breaks, refueling, or walking in; X_1 = number of trees cut (per hectare) with dbh $\leq$1 cm; and X_2 = number of trees cut (per hectare) with dbh >1 cm times the average height (metres) of cut trees.

Independent variables in regressions (1) and (2) were significant at the 0.01 level of probability. The *F*-test indicated the two regressions differed, suggesting a statistical difference existed between the saw types.

Chain saw productivity in the 100-m^2 sample plots averaged 11.7 hours per hectare of productive time, while brush saws averaged 15.7 hours, a difference of 4.1 hours or 35% in favor of chain saws (Table 3). The advantage displayed by the chain saw in the 25-year-old stand applied only to two cutters (cutters 2 and 3), while the remaining cutters worked at much the same rate with either tool. Since cutters worked in the same stands with both tools, differences in cutter performance may be the result of varying experience levels.

Slash effects on labor productivity could not be established. This was likely due to generally light slash loadings throughout the study area.

55-year-old Stand

Treatment in the 55-year-old stand was restricted to chain saws because of the larger tree sizes. As in the younger stand, labor productivity varied considerably and was related to stand conditions.

The following regression was developed to estimate labor production with chain saws in 55-year-old stands:

Productivity equation for chain saws:

$$\text{TIME} = 0.946 + 0.005513 \cdot X_1 + 0.006091 \cdot X_2$$
$$R^2 = 0.50 \quad \text{Standard error} = 5.7 \qquad (3)$$

where TIME = hours per hectare (productive time only) and is based on time required to treat a 100-m^2 plot and does not include rest breaks, refueling, or walking in; X_1 = number of trees cut (per hectare) with dbh >1 $\leq$8 cm; and X_2 = number of trees cut (per hectare) with dbh >8 cm.

Production observed in the 100-m^2 sample plots in this stand averaged 17.6 hours per hectare of productive time. The relatively light slash loadings did not allow for assessments of slash effects on labor production rates.

Components of Productive Time

Cutter activities were recorded during the sample plot time measurements to determine components of productive time. The distribution of such

Table 3. Average labor productivity for sample plots in 25-year-old stands

Cutter identification	Productivity[a] (h/ha) Brush saw	Chain saw
1	12.9	10.9
2	14.5	10.4[b]
3	21.2	11.8[b]
4	14.4	13.4
All cutters	15.8	11.7[b]

[a] Productive time only, based on time measurements while treating a 100-m^2 sample plot.
[b] Indicates significant difference between saw types by *t*-test at 5% level.

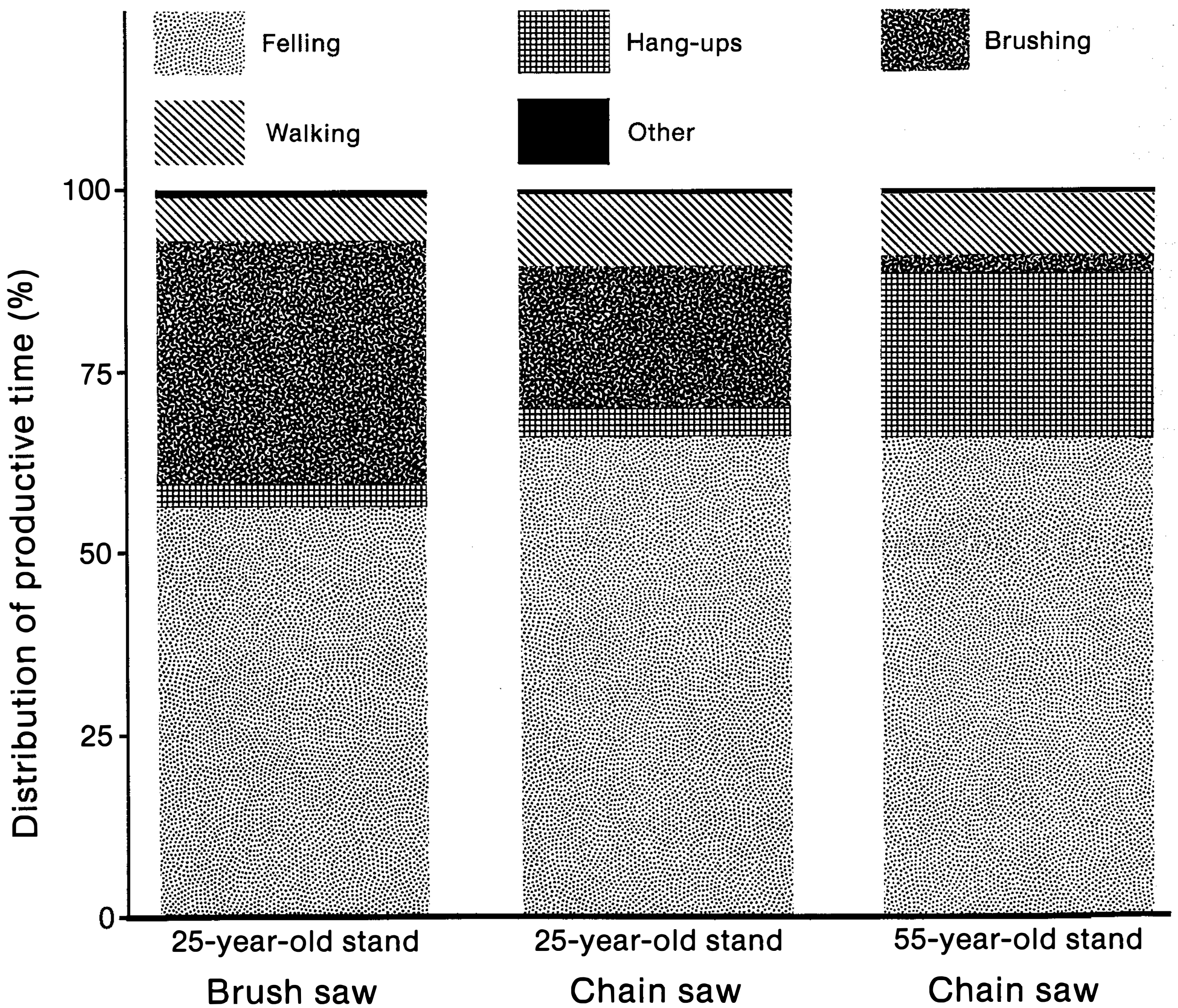

Figure 2. Distribution of components of cutters' productive time.

activities illustrates how stand characteristics contributed to labor requirements and where cutters could improve performance. The distribution of these activities is presented in Figure 2.

Felling with chain saws consumed about 66% of productive time in both stands. In the 25-year-old stand, brush saws used 57% of productive time for felling.

Brushing was an important time element of the work in 25-year-old stands. Cutters using brush saws spent 33% of productive cutting time brushing compared with 20% for chain saw use. The younger stands with a higher incidence of aspen suckers and other smaller hardwood regeneration require more time for brushing than older stands. The operation of brush saws seems to require more space for maneuvering; therefore, cutters may spend more time brushing.

Releasing of hang-ups accounted for 22.6% of cutters' productive time in the 55-year-old stand. Older stands require more labor in both handling and guiding the taller felled trees, as well as in dislodging them from the residual spruce. This time element could likely be reduced with experience.

Damage to Residual Spruce Trees

The incidence of damage to the residual spruce was measured to determine the effect of treatment on the physical condition of crop trees. Table 4 provides treatment summaries of damage by damage classes.

Generally, damage to the residual stand in terms of percentage of trees affected was low, with only 5-7% of residual spruce classed as damaged. For all stands and treatments, damage was more frequent among trees greater than 1 cm dbh than among smaller ones.

In the 25-year-old stand, damage class 4 (tree buried and pressed down by slash) was the most common damage and occurred three times as often after chain saw use than after brush saw treatment. This damage was created when crop trees were covered and even pressed down and bent by felled trees.

Treatment in the 55-year-old stand resulted in an even distribution of damage among all four damage classes.

Posttreatment Stand Conditions and Volumes Felled

The intent of the release treatment was not only to release the spruce from the hardwood overstory but also to leave a well-stocked healthy stand. Posttreatment statistics are presented in Table 5 by stand and for each saw type.

Treatment in the 25-year-old stand resulted in 2400-3000 residual stems per hectare, most of which were spruce. In the 55-year-old stand, 1232 spruce and no hardwoods were left after the treatment. These treatments left densities with spacing averaging 1.8 to 2.0 m in the young stand and 2.8 m in the older stand.

The 55-year-old stand yielded almost 1500 hardwood stems per hectare of merchantable size (stems with dbh greater than 10 cm). Table 6 summarizes number of stems and volumes cut in the 55-year-old stand. Felled hardwoods averaged 179 m^3 of total volume per hectare for all tree sizes. Of this total, 145 m^3 was merchantable volume. These volumes are a potential source of revenue.

Treatment Costs

Treatment costs common to any release operation are mainly composed of two factors: labor and machines. Other factors more specific to an individual operation could include such items as profit, amount of supervision, block layout, and camp costs. Such cost items, however, are too specific to an individual operation to generalize here. This section presents treatment costs based on labor and saw costs only. First, labor wage rates and saw hourly rates are presented; secondly, treatment costs for labor and machines are determined using production data derived from this study.

Treatment costs are presented for two scenarios: one in which stand data are not available and costs are based on overall averages, and the other in which stand characteristics are known and costs are based on labor productivity estimates (using the productivity equations). Costing methodology is presented in such a way that other wage and machine costs can be easily substituted.

Table 4. Treatment-damaged residual spruce by damage class

		Spruce with <1 cm dbh						Spruce with >1 cm dbh						Spruce all sizes		
			% damage[a], by damage class[b]						% damage[a], by damage class[b]						% damaged[a], for all damage classes[b]	
Stand age (years)	Saw type	No. plots with damaged spruce	1	2	3	4	Total	No. plots with damaged spruce	1	2	3	4	Total	No. plots with damaged spruce	Average	Range[c]
25	Brushsaw	17	0.4	0.3	0.0	5.2	5.9	12	0.5	0.3	0.4	5.5	6.7	24	6	2-100
25	Chain saw	12	0.2	0.1	0.0	4.0	4.3	17	0.9	0.0	0.0	17.2	18.1	22	7	2-67
55	Chain saw	1	0.0	0.0	0.0	1.0	1.0	14	1.0	0.9	1.6	1.4	4.9	15	5	4-56

[a] Percentage based on all plots: 52 plots per treatment, with zero assigned to plots with no damaged spruce.
[b] Damage classes: 1) broken leader or main stem; 2) broken lateral branches; 3) saw damage; 4) tree buried and pressed down by slash.
[c] Percentage based only on plots having at least one damaged spruce.

Table 5. Stand statistics after treatment

Stand age (years)	Saw type	All species: Trees/ha ≤1 cm dbh[a]	All species: Trees/ha >1 cm dbh	All species: Average dbh[b] (cm)	All species: Average height[b] (m)	Spruce only: Trees/ha ≤1 cm dbh[a]	Spruce only: Trees/ha >1 cm dbh	Spruce only: Average dbh[b] (cm)	Spruce only: Average height[b] (m)
25	Brush saw	1940	988	2.4	3.3	1912	988	2.4	3.3
25	Chain saw	1700	671	2.4	3.0	1692	663	2.2	2.9
55	Chain saw	88	1144	8.7	8.1	88	1144	8.7	8.1

[a] Includes stems <1.3 m in height.
[b] Based on trees with >1 cm dbh.

Table 6. Timber volumes felled in release of spruce in 55-year-old stands[a]

	Total stand (stems >1 cm dbh)				Merchantable stand (stems >10 cm dbh)			
	Poplars		Spruce		Poplars		Spruce	
Attribute	Number (per ha)	Volume (m^3/ha)	Number (per ha)	Volume (m^3/ha)	Number (per ha)	Volume[b] (m^3/ha)	Number (per ha)	Volume[b] (m^3/ha)
Before treatment	1846	179.3	1494	43.8	1494	144.9	500	27.0
After treatment	2	0.3	1144	38.2	2	0.2	435	23.6
Amounts felled	1844	179.0	350	5.6	1492	144.7	65	3.4

[a] Volumes are from Honer (1967).
[b] Merchantable volume based on 15 cm stump height and 7.5 cm top diameter inside bark.

Labor

Labor costs are based on total time spent on the job, including both productive and unproductive time, since labor payment is normally for total time. An hourly pay rate of $10.00 and fringe benefits of 35%, for a total labor cost of $13.50 per hour, have been assumed. The $10.00 hourly pay is the midpoint of the 1989 wage rate paid by the Manitoba government for general forestry labor.

Machines

To demonstrate equipment costs, a method reported by Ellingston (1987) for brush saws is used for both saw types used in this study (Table 7). Operating life is 1500 hours with no salvage value, and the fuel consumption rate is 1.25 litres per hour.

Estimating Treatment Costs

This study has provided data for two cost estimation methods. Scenario one (Table 8) is based on the average labor productivity determined for the duration of the operation; scenario two provides labor productivity estimates as a function of stand characteristics (Table 9).

Scenario one:

The first method, which is a case study approach, is based on the average number of hours of labor

Table 7. Equipment costs

Expenditures	Machine	
	Brush saw	Chain saw
Fixed costs (ownership)		
Purchase price in Edmonton	$850.00	$475.00
Repairs same as purchase	$850.00	$475.00
Total	$1700.00	$950.00
Fixed costs per hour	$1700.00 ÷ 1500 h = $1.13/h	$950.00 ÷ 1500 h = $0.63/h
Variable costs (operating)		
Fuel $0.50/L at 1.25 L/h	$0.62/h	$0.62/h
Lubricant at 25% fuel cost	$0.16/h	$0.16/h
Variable costs per hour	$0.62/h + $0.16/h = $0.78/h	$0.78/h
Total costs (fixed plus variable)	$1.13/h + $0.78/h = $1.91/h	$0.63/h + $0.78/h = $1.41/h

required to treat one hectare. Project costs based on this method give an indication of the costs expected in stands whose characteristics, on the average, are similar to those included in this study. Treatment costs using averages for the whole operation are presented in Table 8. These costs are based on the average production observed for the entire operation. Such costs would be applicable for stands similar to those included in this study and hence display the limitations inherent in a case study approach. If either stand conditions or operational methods differ, these costs might not apply.

Scenario two:

The second method of estimating costs is more flexible and more generally applicable because stand conditions pertinent to a specific operation can be used. Labor requirements are determined from the appropriate productivity equation: (1), (2), or (3). Costs using this method are illustrated using actual stand data from sample plots in the study area. For the 25-year-old stands, one of the densest plots in the study was chosen so as both to illustrate the higher range of costs that can occur in such stands as well as to emphasize the cost differential between brush saws and chain saws that occurred in this study. For the 55-year-old stand, a plot containing spruce and hardwoods in both size categories required by the regression equation was chosen, although this plot was in the lower density classes. Labor production derived from the equations is an estimate of productive time only and must be adjusted to total time according to Table 2. Adjustments, however, can be tailored to the specific operation. For example, if no walk-in or -out time will be required, then productive time can be increased. Table 9 demonstrates costs based on labor estimates from regression equations (1) to (3).

The number of trees that were actually removed from the plot in the 55-year-old stand were 900 aspen and poplar and 400 spruce per hectare. This yielded 119 m^3/ha in total volume or 98 m^3/ha of merchantable volume in aspen, poplar, and spruce greater than 10 cm dbh.

Table 8. Estimating treatment costs based on average labor productivity (scenario one)

	25-year-old stand		
Variables	Brush saw	Chain saw	55-year-old stand (chain saw)
Labor	28 h/ha at $13.50/h = $378.00/ha	26.6 h/ha at $13.50/h = $359.10/ha	34.4 h/ha at $13.50/h = $464.40/ha
Machine	28 h/ha at 71% productive time[a] = 19.88 h/ha	26.6 h/ha at 75% productive time = 19.95 h/ha	34.4 h/ha at 79% productive time = 27.18 h/ha
	Cost at $1.91/h[b] = $37.97/ha	Cost at $1.41/h[c] = $28.13/ha	Cost at $1.41/h[c] = $38.32/ha
Total costs	$378.00 + $37.97 = $415.97/ha	$359.10 + $28.13 = $387.23/ha	$464.40 + $38.32 = $502.72/ha

[a] Time is adjusted because the machine operates only during productive times.
[b] $1.91/h is the estimated brush saw cost derived from adding the fixed ($1.13/h) and variable or operating ($0.78/h) costs (Table 7).
[c] $1.41/h is the estimated chain saw cost derived from adding the fixed ($0.63/h) and variable or operating ($0.78/h) costs (Table 7).

Table 9. Estimating treatment costs based on stand characteristics (scenario two)

25-year-old stand

Stand statistics before treatment:
Number of trees ⩽1 cm dbh = 78 900 (2900 spruce)
Number of trees >1 cm dbh = 5100 (3000 spruce)
Average height = 5.4 m

Prescription: Remove all hardwoods, leave 2000 well-spaced spruce trees.

Number of trees to cut:
⩽1 cm dbh = 78 900 (all trees in this size category)
>1 cm dbh = 3100 (2100 hardwoods, 1000 spruce)
Assume average height of trees to cut = 6.0 m

Labor production:
Brush saws, equation (1) = 32.77 hours per hectare
Chain saws, equation (2) = 22.58 hours per hectare
Adjust productive time to total time (from Table 2):
Brush saws at 71% efficiency = 46.15 hours per hectare
Chain saws at 75% efficiency = 30.11 hours per hectare

Costs:
a) Brush saw operation
Machine: 32.77 hours at $1.91/hour = $62.59/ha
Labor: 46.15 hours at $13.50/hour = $627.75/ha
Total: $690.34/ha

b) Chain saw operation
Machine: 22.58 hours at $1.41/hour = $31.84/ha
Labor: 30.11 hours at $13.50/hour = $406.48/ha
Total: $438.32/ha

55-year-old stand

Stand statistics before treatment:
Number of trees >1 and ⩽8 cm dbh = 2600 (900 spruce)
Number of trees >8 cm dbh = 1800 (1700 spruce)

Prescription: Remove all hardwoods, leave 1200 well-spaced spruce trees.

Number of trees to cut:
>1 and ⩽8 cm dbh = 2600 (all trees in this size category)
>8 cm dbh = 600 (500 spruce)

Labor production:
Chain saws, equation (3) = 18.93 hours per hectare (productive time)
Adjust productive time to total time (from Table 2):
Chain saws in 55-year-old stands at 79% efficiency = 23.96 hours per hectare

Costs:
Chain saws: 18.93 hours at $1.41/hour = $26.69/ha
Labor: 23.96 hours at $13.50/hour = $323.46/ha
Total: $350.15/ha

SUMMARY AND DISCUSSION

This study has provided information on labor productivity for motor-manual release operations in 25- and 55-year-old spruce-aspen stands in Manitoba. Overall production rates in 25-year-old stands averaged 26.6 hours per hectare using chain saws and 28 hours per hectare using brush saws. Productivity in the 55-year-old stand averaged 34.4 hours per hectare using chain saws. Average production figures are based on the total time spent on the operation by the cutters and represent a treated area of 19 hectares in the 25-year-old stand and 6.6 hectares in the 55-year-old stand.

This study has also provided simple equations for estimating labor requirements from stand data. Use of the equations indicated chain saws outperformed brush saws in the younger stands, in terms of productive times for given stand conditions, and that the differences increased with density and tree size. These equations, however, do not explain the levelling-off of labor production rates expected at high densities (Bella 1974; Lemon 1981). In this study, regression models that could have captured this relationship did not yield reliable estimates due to high variation and few observations in the upper density classes.

The productivity differential between chain saws and brush saws observed in this study is likely indicative of expectations for similar work in Manitoba, at least for the next few years until workers gain experience. Ellingston (1987) reports workers in eastern Canada require at least two full seasons to become fully proficient at brush saw operation.

There are advantages to owning a chain saw over a brush saw that will tend to influence the saw owner. Chain saws are more versatile. They can be used for a variety of tasks, while brush saws are limited to release and spacing work. The higher initial price and lack of service centers in remote areas could be another deterrent to increased use of brush saws. Brush saws, however, are considered safer to use and less tiring for the operator than are chain saws, and they are more efficient where density exceeds 10 000 stems per hectare (Lemon 1981). Based on experiences in eastern Canada, disadvantages of brush saws can be overcome through increased productivity as workers gain experience in brush saw operation.

Cutters in the 25-year-old stand spent considerable time brushing; 33% of brush saw productive time and 20% of chain saw time was spent on this activity. Managers could reduce treatment costs by instructing cutters to fell only stems competing, or that will compete, with the spruce.

Spruce release in 25- and 55-year-old stands, using motor-manual methods, was shown to be operationally feasible in that little damage to crop trees was observed. The most common damage in the younger stand was caused by felled stems burying or pressing down on residual spruce. Future examination of this operation is required before the severity of this type of damage can be fully assessed.

Releasing the spruce understory from overtopping aspen is beneficial to tree growth in the residual stand (Yang 1989). Such treatment may also be economically attractive. Revenue can be derived from the merchantable-size trees in older stands to offset treatment costs. The 55-year-old stand in this study yielded 145 m^3/ha of merchantable aspen volume in trees with dbh 10 cm or greater; remaining were 1144 spruce stems per hectare, 435 of which were greater than 10 cm dbh. In younger stands, treatment creates an established spruce stand with high growth potential at a cost lower than that of establishing a plantation.

Ultimately, the treatment costs must be weighed against the benefits and be compared with alternative methods of release before a fully informed treatment decision can be made.

ACKNOWLEDGMENTS

The assistance provided by Gary Ardron of the Manitoba Forestry Branch, Winnipeg, in arranging for equipment and field crews and in locating study areas is gratefully acknowledged. Shelley Vescio, Manitoba Forestry Branch, Winnipeg, and Steve Fletcher, Forestry Canada, Edmonton, assisted with data processing.

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