MACHINE PRODUCTIVITY FOR SHEAR BLADE SITE PREPARATION IN MANITOBA

- A File Report -

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ABSTRACT

During January and February of 1986 shear blade site preparation data was collected from thirty-two plots on Manitoba Crown Land. This File Report summarizes the data collection procedures and general observations made to date. Future work will involve expanding the data base to permit more extensive analysis of the data. The aim of this research is to develop predictive equations correlating implement productivity to site conditions for shear blade site preparation in Manitoba.

Key words: Cost estimates; mechanical site preparation; shear blading;

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INTRODUCTION

The focus of many forest management activities centers upon the renewal of non-satisfactorily regenerated (NSR) forest lands. Quality site preparation is crucial in determining the success of these regeneration efforts. Site preparation has three main purposes:

1) Reduce the amount of undesirable vegetation
2) Create a favorable microsite to ensure seedling survival and promote optimal growth, and
3) Remove physical obstacles to subsequent management activities.

Sound silviculture planning matches equipment and site conditions to obtain the desired quantity of high quality planting sites. Often, however, a compromise must be struck amongst available equipment, budget constraints, and desired results (Sutherland, 1985). To ensure the efficient allocation of silviculture funds, cost estimates are necessary to:

1) Estimate returns from forest management activities,

2) Evaluate management alternatives, and

3) Plan reforestation programs and budgets.

To be of value in planning, cost estimates should be accurate over a wide geographic area and a variety of conditions. Broad cost averages and rules of thumb do not account for a variety of forest and job conditions; consequently they are limited in application and should be used with care. Mills et al. (1985) reported that estimates of financial returns are more sensitive to errors in treatment cost than to errors in timber yields or stumpage estimates. Thus, sound planning is dependent upon accurate, site specific cost estimates.

This shear blade study is part of a larger forest economics project funded and implemented under the Canada-Manitoba Forest Renewal Agreement. The project, entitled Economics of Intensive Forest Management, seeks to develop economic guidelines for various silvicultural treatments (such as shear blading, disc trenching, planting, pre-commercial thinning, and herbicide application) to ensure the most cost effective use of intensive management funds. This File Report summarizes the work completed to date in developing cost estimates for shear blade site preparation in Manitoba.

LITERATURE REVIEW

Research by Hilliker _et al._ (1969) studied the costs of different forestry operations in Wisconsin. Project costs, in hours, were estimated as a function of specific site characteristics. For a number of treatments (planting, machine operations, timber stand improvement, and white pine blister rust control) a single factor or a combination of factors were identified as a primary cost determinant and used to explain the systematic variation in the data set. Several different site preparation treatments (shearing, raking, windrowing, discing, furrowing) were aggregated into two types of machine operations - pushing equipment and pulling equipment. This aggregation of treatments and the small sample size resulted in equations with limited application.

A study by Olson _et al._ (1978) derived cost functions for site preparation, planting, herbicide spraying, prescribed burning, and timber stand improvement activities using silviculture data from two public land management agencies in Minnesota and Michigan. In the case of site preparation, total project cost was regressed upon two variables -- total acres treated and a dummy variable to indicate whether the implement was pushed or pulled by the prime mover. From a sample of twenty-eight projects, they estimated fixed costs to equal $86.00 per project and variable costs to equal $84.01 per hectare plus or minus $17.30 per hectare depending upon whether the machine was pushing (-$17.30) or pulling (+$17.30). Ninety-six percent of the variation in the data was explained by the two independent variables.

Research completed by Mills et al. (1985) found that the real cost of silvicultural treatments (site preparation, reforestation, intermediate treatments, and slash disposal) rose by 20 percent per year over the period 1975-78. In their study, direct costs of silvicultural treatments were estimated from service contracts awarded on National Forests throughout the United States over the period 1975-78. The cost of site preparation was regressed as a function of acres treated, number of multiple areas per contract, average diameter at breast height of standing trees, number of bids received, and elevation. Equations were developed for three forest groups: southern pine, douglas fir, and ponderosa pine/white pine. Adjusted R^2 values ranged from 0.38 to 0.65 with standard errors between 64 and 82 percent. Mills et al. suggest that some of the cost variation may be due to characteristics of individual project managers rather than silvicultural objectives or site conditions.

STUDY APPROACH

The approach adopted for this study was to collect field data describing site conditions prior to treatment and to measure machine time required to create the prescribed treatment under the measured conditions. The approach, therefore, is to develop predictive equations which relate machine productivity (ha/h) to a complex of site conditions. Once established, these predictive equations can be used to estimate variable costs of creating the treatment.

This approach is particularly useful in determining treatment costs because machine productivity estimates are consistant over time. Changing prices of labour and capital (machines) need not be considered. In addition, it provides flexibility in that wage and machine prices applicable to a geographic region at a given time can be used in determining treatment costs. Inclusion of site condition variables in the equations add accuracy to the productivity estimates.

Time data collected during the preliminary stages of this study was based solely on productive machine time. To fully estimate costs for a particular treatment, an estimate of non-productive time (e.g. repair and maintenance, travel time, supervision, etc.) is also required. As yet, no attempt was made to measure this component of treatment costs. To some extent, such costs are common to different types of site preparation work; therefore as the study expands to include a variety of treatments, estimates of non-productive times will be attempted.

DATA COLLECTION AND ANALYSIS

Three shear blade projects, referred to as the Riverton Burn, Rice Creek, and Bluff Road, were studied on Manitoba Crown Lands during January and February of 1986 (Figure 1). Shear blade site preparation is most often implemented in the winter months for two reasons: First, the frozen soil improves access and traction. Second, stems and stumps shear more easily when they are frozen as compared to green.

For each project a contract was awarded by the Manitoba Department of Natural Resources, Forestry Branch to the contractor submitting the lowest bid. All operators used a Catepillar D8H tractor mounted with a Rome K/G blade to prepare sites for spring planting. Operators were instructed and monitored by Forestry Branch personnel to reduce the amount of undesirable vegetation and remove slash and stumps. In order to preserve the nutrient capital of the sites, operators were to minimize disturbance of the surface layers.

Data was collected and analysed in three separate phases:

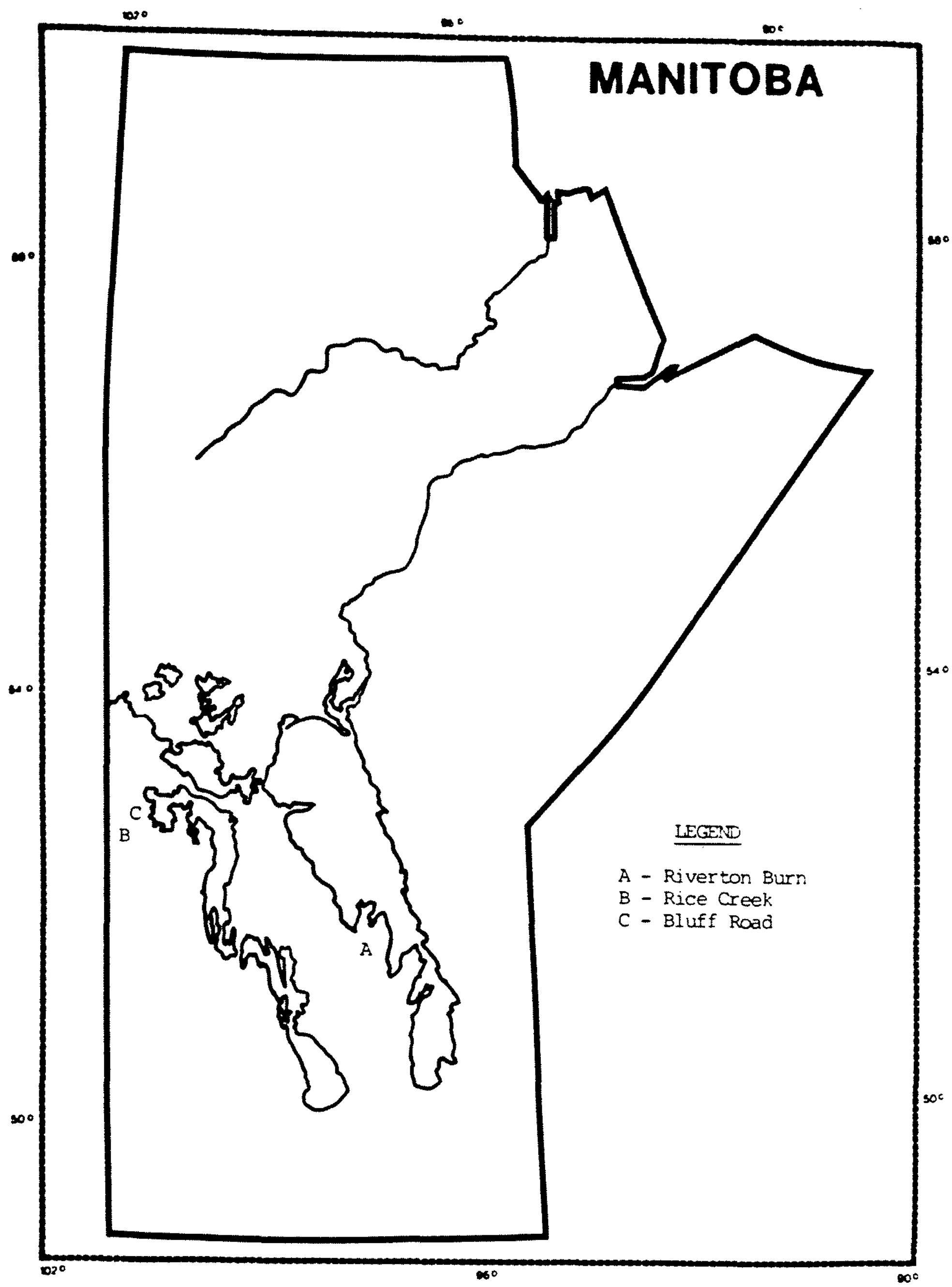

Figure 1. Location of shear blade site preparation research in Manitoba, 1985-86.

pre-treatment; treatment; and post-treatment.

Pre-treatment Phase. The first step of the Pre-treatment Phase was to observe the work technique of the operator to determine work patterns, number of passes required to create a completed strip, and prepared strip width.

Following these initial observations, a 200 m long transect was established in the untreated portion of the stand parallel and adjacent to the treated strips. The transect was located such that it would fall approximately in the centre of the treated strip during the machine's next pass and was situated so as to avoid unusual manoevering such as machine turn around. End points of the transect were conspicuously marked to facilitate time measurements during the treatment phase.

Along the 200 m transect, 3 samples points were located at 50, 100, and 150 m. At each sample point, a variable radius plot was established using a prism with 2 m2 basal area factor. Diameter at breast height (dbh) and total tree height was measured and recorded by species for all standing stems (including dead trees and snags) that tallied as "in". In addition, a 100 m2 circular plot was established at the sample point centre and height and diameter of stumps occurring within the circular plot were recorded. The amount of slash was determined at each sample point following the methods described by Van Wagner (1968, 1982). To measure slash loadings, diameters of all pieces of slash intersecting a 10 m long transect extending from the sample point and parallel to the treated strips were measured and recorded. Snow depth and slope were also recorded at each sample point.

Data collected from each sample point are intended to describe average pre-treatment site conditions applicable to the 200 m segment while subsequent time measurements were based on the entire 200 m length. The three sample points are therefore sub-samples of a plot 200 m in length with its width to be determined by the width of the treated strip after the machine has completed its passes. A typical plot layout is presented in Figure 2.

Treatment Phase. During the treatment phase time measurements and machine activity counts were collected for each 200 m plot. Time measurements were based on the amount of time required for the machine to travel the 200 m length of the plot. Four to eight passes were required by the machine to create a prepared strip of desired width. The number of passes varied due to differences in operators' work technique. Total time to treat a plot was therefore a summation of times from each machine pass needed to create the desired strip width.

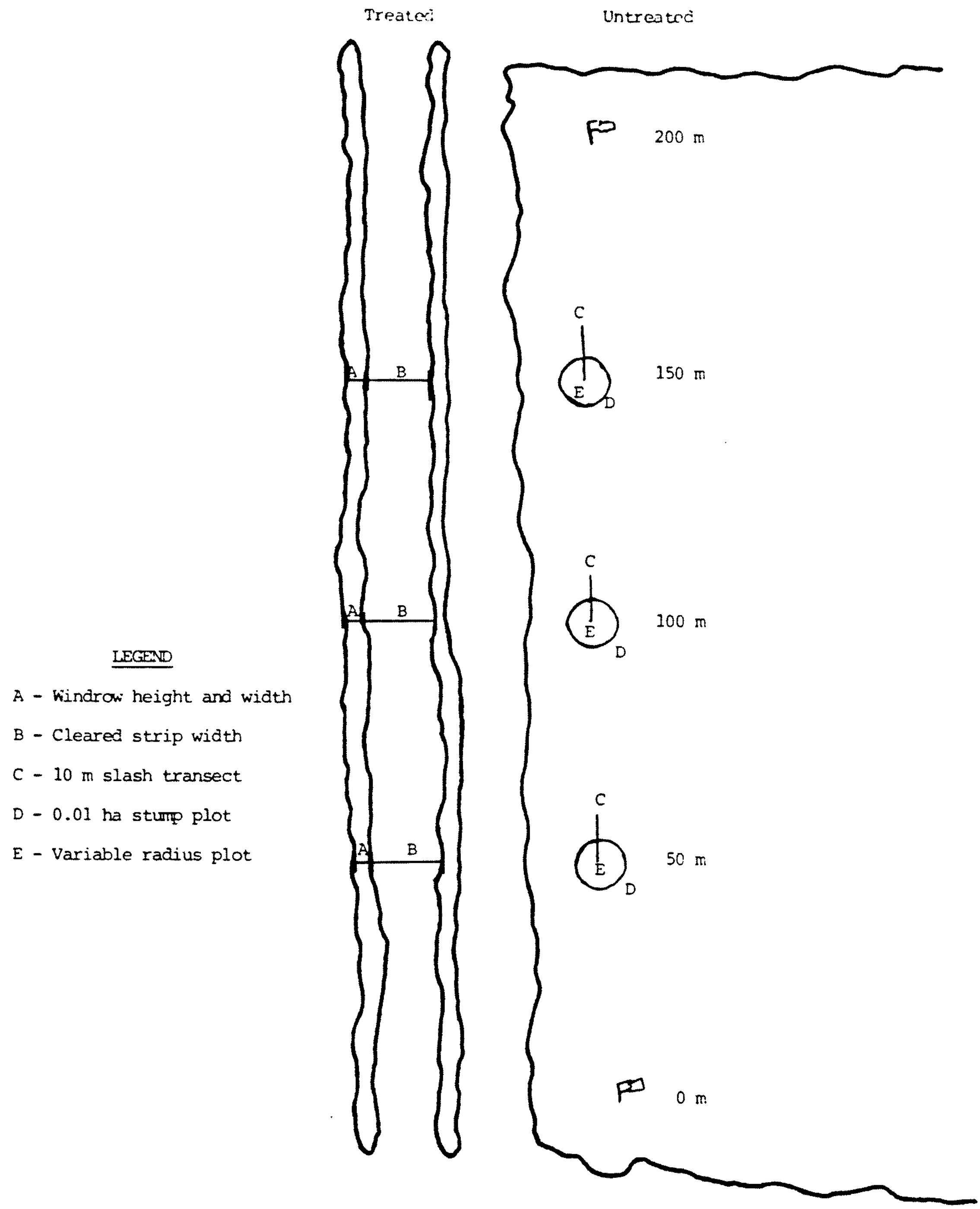

Figure 2. Sample plot layout and data measurements for shear blade site preparation research.

Persons located at the ends of the 200 m plot signalled the timer to indicate when the machine blade entered or exited the plot. Times were measured by stop watch and recorded to the nearest second.

Machine activity while in the plot was monitored at 30 second intervals by the timer. Five activity categories were used:

1) Forward - traveling in a forward direction
2) Reverse - traveling in a backward direction
3) Manouvering - making repeated attempts to push over large trees or place debris in the windrows
4) Stopped - no motion
5) Other -

Frequency of occurence for each activity category was determined for the plot. These activity counts are intended to help explain variations in work technique which may result from differing site conditions and ultimately affect machine productivity.

Post-treatment Phase. The Post-treatment Phase consisted of two components - final strip measurements and data compilation. Following treatment of the strip, cleared strip width, windrow width, and windrow height were measured at 50, 100, and 150 m within the plot.

Data obtained at each sample point were expanded to per ha values. These values were averaged to provide a general description of the 200 m plot. Gross area treated and net area treated (gross area less windrows) were calculated by multiplying total strip and cleared width averages by the 200 m length. These values along with the time measurement permitted the calculation of gross and net productivity in ha per h. In addition, site preparation efficiency (net area/gross area) was calculated to provide an estimate of the area available for planting.

PRE-TREATMENT STAND HISTORY

The following discussion summarizes the site characteristics for each shear blade project.

Riverton Burn. The Riverton Burn Project (T27, R2EPM) is located in Manitoba's Interlake Region. This area consisted of a merchantable black spruce (*Picea mariana*), balsam poplar (*Populus balsamifera*), trembling aspen (*Populus tremuloides*), and white birch (*Betula papyrifera*) stand which had burned in 1972. Salvage logging was done the year following the fire to remove a portion of the spruce component, however, numerous dead standing stems remained. An understory of aspen/poplar suckers varying in density had developed since the fire. The site was essentially flat with no stones present. Average snow depth was approximately 15 cm. After an initial sample, very few sound stumps were found. It was determined that stumps were not a limiting factor to implement productivity and consequently were not measured.

Rice Creek. The Rice Creek Project (T43, R28WPM) is located in the Porcupine Mountain Provincial Forest of Manitoba's Western Region. This area had been periodically logged for black spruce over the past two decades. Age of the cutover ranged from 1 week to 25 years.

Research plots were established in a portion of the cutover that was between ten and fifteen years old. A fragmented, residual stand of white birch, trembling aspen, and non-merchantible black spruce was present at the time of treatment. In some areas of the cutover no regeneration was present, the only vegetation being a grass cover. Other portions of the cutover were fully stocked with a young stand of sapling-sized white birch. The terrain was quite variable with slopes ranging from 0 to 13 degrees. Rocks were present and evenly distributed over the site. Their occurence however could be classified as infrequent. Average snow depth was 80 cm.

Due to the age of the cutover, few sound stumps and slash were present. The extreme depth of the snow prevented accurate measurement of slash and stump conditions, thus this component of the pre-treatment assessment was excluded. It was felt that while slash and stump information could be interesting, these parameters would not have a significant influence on implement productivity in light of the slope, snow depth, and tree characteristics. Height and width of the windrows, however, may serve as an indicator of the amount of material (including snow) that was moved by the machine.

Bluff Road. The Bluff Road Project (R25WPM, T46) is located 30 km north of the town of Mafeking on Provincial Highway 10 in Manitoba's Western Region. This site had been partially logged for black spruce over the past 10 years. In the fall of 1985 a contractor harvested and chipped all standing material less than 40 cm at the base. Those stems larger than 40 cm remained on the site. The age of the stumps varied from 3 months to 10 years. The site was essentially flat with infrequent rocks occurring throughout. Snow depth ranged up to 20 cm.

OBSERVATIONS

For each study area, shear blade site preparation was prescribed to reduce competition from undesirable vegetation and to facilitate subsequent tree planting. Each operation began by cutting/shearing a cleared swath around the perimeter of the treatment block. This swath was created to provide access for the tree planters.

Machine operators were instructed to prepare parallel cleared strips from 7 to 12 m in width. To achieve the desired strip width, the operator made several passes with the prime mover and blade, each pass widening the strip. After the first pass, subsequent passes overlapped by approximately 50 percent; the net effect being the area was treated twice. The number of passes per strip varied between four and eight and were dependent upon the site conditions and the operator's work technique. Once a strip was completed, the operator would begin a new strip in the adjacent untreated stand.

The following discussion summarizes the observations and production rates for each shear blade project. Due to the limited sample size (32 plots) and the variable nature of the data, no statistical analyses have yet been performed.

Riverton Burn. A contract was tendered and awarded to shear blade approximately 267 ha of Crown Land. Bids were submitted and payments made on a per ha basis. The operators used a 1968 D8H Catepillar with a 4.1 m wide Rome K/G Blade. The blade angle resulted in an effective shearing width of 3.1 m. Two operators worked around the clock in alternating six hour shifts.

Gross productivity ranged from 1.03 to 1.45 ha/h with the average efficiency for the fifteen observations equal to 73 percent. From our observations, the one factor which made the most dramatic influence on productivity was the presence of large diameter white birch stems. Repeated attempts were required to knock over these stems. Spruce, aspen, poplar, and snags of similar size, however, would be sheared off with little difficulty. Table 1 summarizes the site characteristics and production rates for the Riverton Burn project.

Rice Creek. Both operator and equipment were hired based upon a rental rate submitted as a competitive bid. Payments were based upon the times generated by a service recorder that was attached to the prime mover.

A 1974 Catepillar D8H equipped with a 3.4 m wide Rome K/G blade was used to clear strips 8.1 to 10.6 m wide. The severity of the conditions, (ie slope, snow depth, and tree size), influenced the operator's work technique making it necessary to complete five to eight passes per cleared strip.

This resulted in lower rates of productivity. In an attempt to increase production, the operators were instructed by Department of Natural Resources staff to avoid large diameter trees. While this did improve productivity, it may have reduced the net area treated and available for planting. Although the operators worked up and down slopes, a fifth activity category, Sliding, was added to the list of activities. Sliding refers to the forward or lateral movement of the prime mover in which no shear blading nor windrowing took place.

Gross productivity for the plots ranged from 0.35 to 0.55 ha/h with an average efficiency equal to 66 percent. The value of 66 percent may in fact be an underestimate since the major component of the windrows was snow. Table 1 summarizes the site characteristics and implement productivities for the Rice Creek Project.

Bluff Road. The operator (different than the Rice Creek Project) and equipment were hired under a rental agreement based on a competitive bid with payment made at an hourly rate. As in the case of the Rice Creek Project, payments were based upon operatiming times as indicated by a service recorder.

A 4.1 m wide Rome K/G blade mounted on a 1974 Catepillar D8H tractor was used to prepare strips ranging in width from 13.9 to 16.8 m. Gross productivities calculated from the sample plots were in the 0.94 to 1.95 ha/h range.

The relative absence of standing material and the flat conditions were conducive to high rates of productivity. The two limiting factors appeared to be the occurence and size of green stumps and the distribution of slash. It was noted that green stumps would not shear easily and brought the prime mover to a violent stop. To minimize this jarring effect, the operator would lift his blade slightly, reducing the effectiveness of the treatment. Average efficiency was calculated to be 81 percent. Table 1 details the site conditions and production rates for the Bluff Road Project.

FUTURE RESEARCH

To date, a sampling procedure has been established for the collection of shear blade site preparation data. Information has been gathered for a total of 32 plots located at three different sites on Manitoba Crown Land. Future work will involve augmenting the data base to cover the wide range of conditions under which shear blading is implemented. Once an extensive data base has been accumulated, predictive equations relating productivity to site conditions will be developed and tested.

Table 1. Site characteristics and average machine production rates for shear blade site preparation in Manitoba.

Study Area	Total Stems per Hectare	Slash (m^3/ha)	Stump Characteristics			Efficiency (%)	Productivity (ha/h)[a]	
			No./ha	Ave. Diam. (cm)	Ave. Ht. (cm)		Net	Gross
Riverton Burn	4063	107.3	b	b	b	72.9	0.90	1.23
Rice Creek	1352	c	c	c	c	65.7	0.28	0.43
Bluff Road	76	40.1	1624	15.6	6.2	80.8	1.11	1.36

a) Productive machine and operator time only.

b) Stump measurements not taken.

c) Stump and slash measurements not taken due to excessive snow depth.

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