

MACHINE PRODUCTIVITY FOR DISC
TRENCHERS, DRUM CHOPPERS, AND
BRACKE SCARIFIERS IN MANITOBA.

A File Report

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ABSTRACT

Machine productivity for site preparation methods was examined at various locations throughout Manitoba during 1986. Data collection techniques are described and summaries are provided for machine productivity and treatment results for disc trenching, drum chopping and Bracke scarifying. Preliminary findings show wide variation in site conditions, machine productivity and treatment results. Additional data must be collected before reliable productivity trends can be developed.

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INTRODUCTION

The focus of Manitoba's silviculture program is on the reforestation of lands which have been harvested or destroyed by wildfire. During the period 1981-85, manual tree planting more than doubled from 3.4 to 9.0 million trees per year (Manitoba Natural Resources 1987). Mechanical site preparation showed similar gains during the same period - from 1800 to almost 5000 ha per year (Manitoba Natural Resources 1987).

Improvements in nursery facilities achieved under the Canada-Manitoba Forest Renewal Agreement have increased provincial nursery/greenhouse capacity so that by 1989, 20 million seedlings annually will be available for planting. These future increases in tree planting will necessitate greater disbursements for site preparation.

Mechanical site preparation is a large component of reforestation expenditures. Sound forest management dictates that equipment be matched to site to obtain the desired number and quality of planting spots at the lowest cost. Thus forest managers require site specific data on machine costs, productivity, and treatment results to facilitate planning reforestation programs and budgets. In addition, private contractors engaged in reforestation work also need such information to assist them in preparing realistic bids that reflect the difficulty of preparing particular sites.

This study was initiated to determine costs of mechanical site preparation in Manitoba. Specifically, the purpose of this study is to describe how site conditions affect machine productivity and ultimately costs. The study is part of Project C/M-7.2, Economics of Intensive Forest Management, and is funded by the Canada-Manitoba Forest Renewal Agreement. The objective of this project is to develop economic guidelines for a variety of silvicultural treatments through determination of labor and/or machine productivities and costs. To date, file reports relating to Project C/M-7.2 have summarized data collection techniques and labor/machine productivity estimates for manual tree planting, pre-commercial thinning and shear blade site preparation (De Franceschi and Steele 1987, 1986; Steele and De Franceschi 1986).

This file report summarizes work completed in developing productivity estimates for three kinds of mechanical site

preparations: disc trenching, drum chopping and Bracke scarification; based on data collected during the 1986 field season. Study methods used in determining pre- and post- treatment site conditions and machine productivity estimates are presented.

DESCRIPTIONS OF STUDY AREAS AND OPERATIONS

Fifteen areas receiving mechanical site preparation treatments were sampled during the 1986 season. Site preparation methods included in the sample were disc trenching (TTS 35 and Delta), drum chopping (2.1 and 2.4 m wide drums) and Bracke patch scarifying (two and three frame). The following section provides some comments on operational methods along with a brief description of the study areas. Table 1 presents a summary of study area stand histories while an overview of pre-treatment site conditions is provided in Table 2. General locations of study areas selected in 1986 are shown in Figure 1.

All study areas were treated on an operational scale. Table 3 lists the site preparation tool, the prime mover, and the method of payment used at each study area.

Study areas 1 to 7 and 11 to 14 are located in the Sandilands Forest Reserve of the Southern Forest Region. Soils on those sites are fine to coarse sands and topography is flat. Stones occurred only on study areas 5, 6, and 7. At time of treatment soils were generally dry with moist conditions encountered only at area 1. Soil depth (i.e. depth to which a steel bar could be pushed into the ground before encountering bedrock or large stones - maximum depth 35 cm) averaged 30 cm or greater and duff thickness 5 cm or less. In general there were few if any residual stems, however the machine operator avoided clumps of dense mature stems. Slash cover was light to moderate. In areas 1 to 7 where the disc trencher was used, stump occurrence was infrequent averaging less than 500 per ha with average diameters ranging from 15 to 24 cm and heights 18 to 27 cm. Stumps were more frequent on the drum chopped areas - areas 11 to 14 - (average ranging from 600 to 1162 per ha).

Study areas 8 to 10 were treated with the Delta disc trencher. These study areas are located in the Duck Mountain (study area 8), and Porcupine (study area 9) Provincial Forests both in the Western Forest Region, and in the Interlake Forest Region (study area 10). Soils in

TABLE 1. Summary of stand histories and locations of study areas.

Study area			Stand history		Site preparation implement	
Area no.	Reference name	Location	Original stand	Disturbances		
1	Junction 18&31	T6,R10EPM	Jack pine, aspen, white spruce	Logging 1983-86, drum chopped 1986	TTS 35	Disc trencher
2	Small block 31	" "	Jack pine	Logging 1984	"	"
3	Marchand 20-1	" "	Jack pine, white birch	Logging 1965-68, drumchopped and barrelled 1968	"	"
4	Sandilands 18	" "	Jack pine	Wind 1983, salvage logging 1985	"	"
5	Project 33A	T7,R10EPM	Jack pine, aspen	Logging 1985	"	"
6	Project 33B	" "	Jack pine	Logging 1970-73, disc trenched in 1973, fire 1984	"	"
7	Project 33C	" "	Jack pine	Logging 1960's, disc trenched 1974	"	"
8	Jackhead Road	T30,R1EP	Black spruce, tamarack, aspen white birch	Logging 1984-86	Delta	Disc trencher
9	Pine River A&B	T32,R24WP	Black spruce, aspen, w. birch	Logging 1965-70	"	"
10	Rice Creek	T43,R28WPM	Black spruce, tamarack, white birch	Logging over last 20 years (1966-86)	"	"
11	Moodie 2-A&B	T2,R12EPM	Jack pine, aspen, white birch	Logging 1985-86	Drum chopper	(2.4m drum width)
12	Sawmill 31	T5,R10EPM	Jack pine, aspen, white birch	Logging 1985-86	"	"
13	Pipeline 31A	T7,R10EPM	Jack pine	Logging 1986	"	"
14	Woodridge	T4,R11EPM	Jack pine	Logging 1985-86	(2.1m drum width)	
15	Jenpeg	T65,R6EPM	Black spruce, aspen	Logging 1983-86	Bracke	(2 and 3 frame)

TABLE 2. General description of site conditions before treatment.

General location of study areas	Study areas	General soil descriptions				Duff thickness	Topography	Residual stems	Slash	Stumps
		Texture	Stoniness	Moisture *	Depth **					
Sandilands Forest Reserve (Southern Region)	1-7, 11-14	Fine to coarse sand.	Stone-free except at areas 5, 6 and 7.	Dry except moist at area 1.	30 cm or greater	5 cm or less	Flat	Few or none	Light to moderate	Infrequent at areas 1-7, frequent at areas 11-14.
Duck Mtn and Porcupine Prov Forest (Western Region), Interlake Region.	8-10	Clay loam, or loamy sand.	Stoney at areas 8 and 9, no stones at area 10.	Moist at areas 8 and 9, dry at area 10.	23-31cm at areas 8 and 9, >35cm at area 10.	7 to 9cm	Flat to gently rolling	Common (clumps avoided by operator)	Moderate to heavy	Common
Northern Forest Region (Jenpeg Dam)	15	Clay	No stones	Moist	>35 cm	10 cm	Flat to gently rolling	None	Heavy	Frequent

* Moisture - soil moisture conditions at time of treatment.

** Depth - soil depth based on depth to which a steel bar could be pushed into the ground before encountering bedrock or large stones - maximum depth of 35 cm.

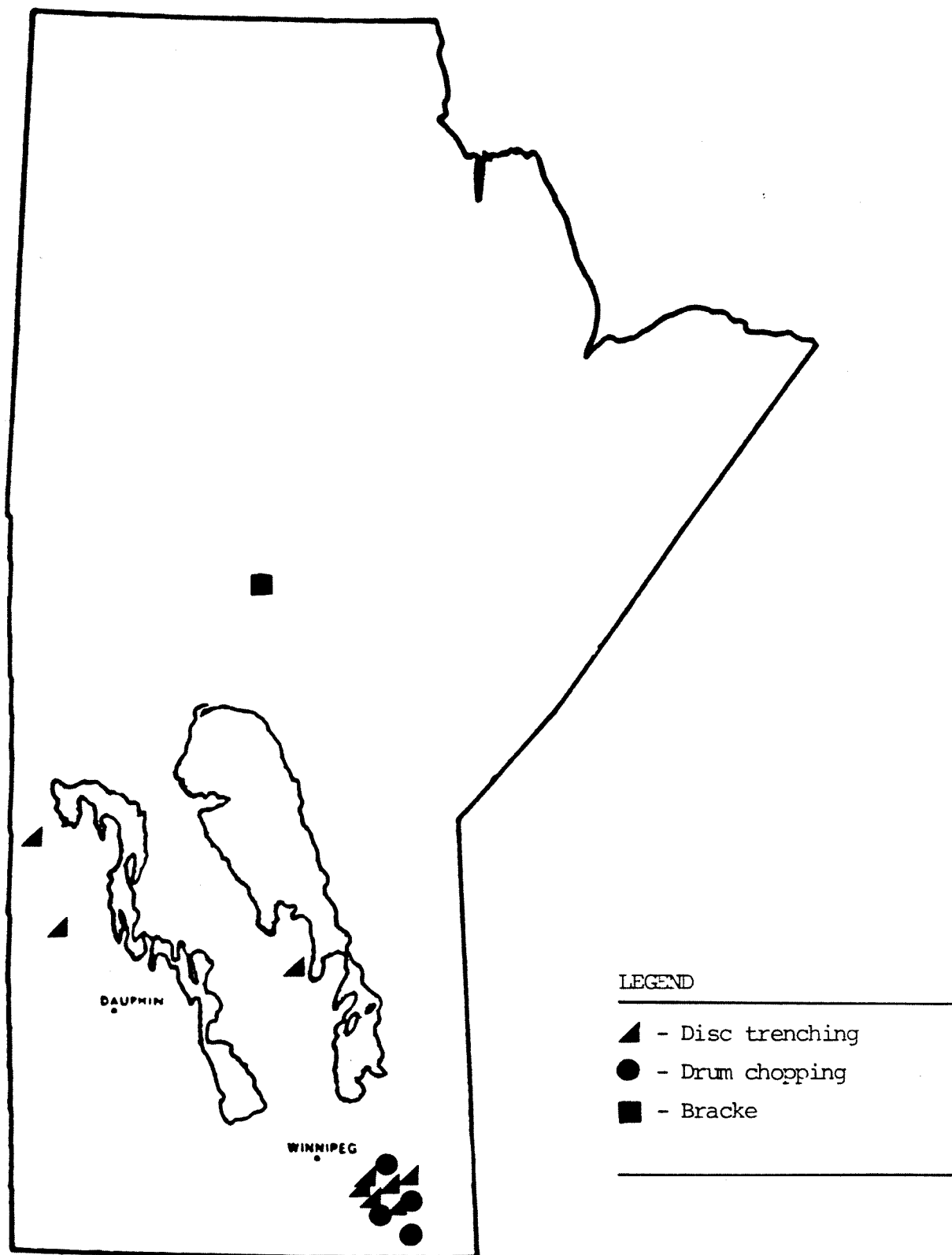


Figure 1. General location of mechanical site preparation study areas.

TABLE 3. Scarifying tool, prime mover and method of payment used at each study area.

Study area	Scarifying tool	Prime mover	Method of payment
1 to 7	Disc Trencher TTS 35	Clark 440 skidder (119 kw)	Contracted hourly rate
8 to 10	Disc Trencher TTS Delta	John Deere 740A skidder (144 kw)	Contracted hourly rate
11 to 13	Drum Chopper 2.4 m wide drum	D6 Caterpillar tractor (56 kw)	Contracted hourly rate
14	Drum Chopper 2.1 m wide drum	John Deere 550 tractor (52 kw)	Provincial hourly paid employee
15	Bracke Patch scarifier (2 and 3 frame)	Caterpillar 528 skidder (130 kw)	Contracted on an area basis

these areas are generally clay loams or loamy sands and topography varies from flat to gently rolling. At time of treatment soils were moist in areas 8 and 9 and dry at area 10. Stones were common at areas 8 and 9 thus soil depth averaged 23 to 31 cm. Area 10 was free of stones and soil depth exceeded 35 cm. Duff thickness averaged 7 to 9 cm at all three areas. Residual stems were more common on these study areas than at the Sandilands sites but again, the operator avoided dense clumps of residual stems. Slash cover was considered moderate to heavy. Stump occurrence was common averaging between 3200 and 4050 per ha with average diameters ranging from 12 to 15 cm and heights about 23 cm.

Study area 15, treated with the Bracke scarifier is located in the Northern Forest Region in the vicinity of the Jenpeg dam. Soils in the sampled area were a stone free clay and exceeded 35 cm in depth with duff thickness averaging 10 cm. Topography is flat to rolling. At the time of treatment, soils were moist. No standing stems remained after the logging operation however slash cover was heavy. Stump counts averaged 1370 per ha and diameter and height averaged 20 and 23 cm respectively.

STUDY METHODS

Field observations were conducted to measure site conditions both before and after treatment, as well as to measure machine time required to create the treatment. Data collection was therefore done in three phases:

- (1) the pre-treatment assessment phase which provided measures of those site factors thought to influence machine productivity and/or implement effectiveness;
- (2) the time study phase which provided machine productivity data; and
- (3) the post-treatment assessment phase which measured how well the objectives of the treatment were met.

The pre-treatment assessment was conducted on sample plots established in the untreated portion of the block. The machine was then timed as it treated the plot, and finally the treated strip was assessed to determine treatment effectiveness.

At each study area, the machine was observed prior to data collection to determine the machine's work pattern. The research team

was then able to establish sample plots without interfering with the machine's normal work patterns. This meant there was no disruption to the machine operator nor was there any interaction required between the operator and the research team.

Many of the data items and collection techniques were similar for each site preparation method. Therefore study methods for each phase of data collection are described once for all three site preparation methods together and exceptions for each noted as they occur.

Pre-treatment assessment

Sample plots were placed in the untreated portion of the block a short distance ahead of the equipment and far enough away to avoid any disruption to the machine's normal work pattern. The plot was located such that it would lie approximately in the centre of the machine's next (or subsequent) pass and was situated to avoid any unusual manoeuvring such as machine turn around.

A sample plot consisted of a 50 m long transect with 2 m square quadrats located at the 5, 15, 25, 35, and 45 m mark of the transect. Quadrats were then examined to determine pre-treatment site conditions based on observations on vegetative cover, slash loadings, soil and duff measurements, brush counts (standing stems less than 1.3 m tall) and size and frequency of stumps and residual stems. These site factors were measured following methods described by Sutherland (1986). Since stumps and residual stems likely are among the more important factors affecting machine productivity (and perhaps effectiveness), they were more intensively sampled by expanding quadrats numbers 2 and 5 (i.e. quadrats at the 15 and 45 m mark) to 3 m square.

Time study

During this phase of data collection, the time required to treat the sample plot was measured. Timing commenced when the implement entered the 50 m transect and ended when the implement exited the transect. Times were measured by stop watch and recorded to the nearest second.

Machine activity while treating the sample plot was also monitored. Activities other than forward progression, such as stopping or manoeuvring, (for example to negotiate around larger

stumps/residuals or other obstacles or wet areas) were recorded and timed and included with the total treatment time. Time required to create the treatment was based entirely on time spent within the sample plot, i.e. the 50 m transect, and did not include such unproductive time elements as repair, maintenance, rest breaks, travel time, supervision times, etc.

Post-treatment assessment

Mechanical site preparation is prescribed to accomplish one or more of the following objectives:

1. To create a favorable microsite to promote seedling survival and growth.
2. To reduce the amount of undesirable vegetation; and
3. To remove physical obstacles and facilitate subsequent management activities.

Post-treatment assessment measured the degree to which these objectives were achieved. Complete and informative evaluation requires that both quantitative and qualitative assessments be made. Qualitative information, although subjective, was based on treatment objectives identified by the forest manager. These observations were made systematically to ensure consistency and are intended to allow comparisons with pre-treatment site conditions. Given the different aims and results of site preparation with a disc trencher, drum chopper or Bracke, post-treatment assessment procedure is discussed separately for each site preparation method.

Disc Trenching

A 50 m long transect was established along a trench to approximately coincide with the location of the pre-treatment assessment sample plot. Two metre square quadrats were established at the 5, 15, 25, 35, and 45 m mark along the transect. At the centre of each quadrat, trench dimensions and degree of soil disturbance (i.e. % net mineral soil exposure) were determined. The plantability of the quadrat was then assessed in terms of the number of available planting spots, i.e. how many choices might a planter have, based on the planting criteria provided by the forest manager. The number of planting spots were categorized as either 0, 1, 2, or more than 2.

Slash conditions in the quadrat were measured along a 2 m line placed down the centre of the trench using methods described by Sutherland (1986). Frequencies and heights of residual stems taller than 1.3 m were measured for stems occurring within 1 m of the quadrat centre line. Slash and residual stem data was intended to provide a measure of the difficulty of hand planting the treated site. All values over the five quadrats were averaged to obtain a general description of treatment results.

Drum Chopping

As for the pre-treatment assessment, five 2 m square quadrats were established along a 50 m transect in approximately the same location as before treatment. Quadrats were then examined to provide measures of site conditions using methods similar to those used for disc trenching assessment.

Bracke Scarification

Following Bracke scarification, a 50 m long transect was established in approximately the same location as the pre-treatment assessment plot. This transect, which was positioned in the centre of the machine's pass, established the length of the post-treatment assessment plot, while the width was determined by the width of the machine pass.

All Bracke scalps within the plot (including attempted scalps) were counted and assigned a quality rating based on criteria provided by Manfor staff. A Class 1 scalp permitted planting in the hinge zone between scarified depression and mound. A Class 2 scalp was plantable directly opposite the hinge zone at the beginning of the scarified depression. A Class 3 scalp was plantable along the sides of the depression. Any scalp which was not plantable was rated as Class 4.

Detailed information was collected from those Bracke scalps closest to the 5, 15, 25, 35, and 45 m marks of the 50 m transect. At each selected scalp, depression length, width, and maximum depth along with mound length, width, and maximum height were measured to the nearest centimetre.

Difficulty of hand planting the treated site was assessed from slash and residual stem data. These data were determined from a transect extended from each scalp selected for detailed measurement to the next closest scalp using methods similar to the disc trenching assessment.

RESULTS

The intent of this report is to describe the methods used in this study and to provide preliminary summaries of data collected during 1986. No attempt has been made to develop machine productivity trends or to test the effect of site factors on machine productivity or effectiveness. This section therefore merely highlights some findings from the study based on data collected during the 1986 field season and provides an indication of expected average machine productivities along with some results from the treatments.

Machine productivity was determined from the times required to treat a 50 m long strip. Productivity therefore was based on an area 50 m long and width depending on the scarifying tool used. For the purpose of determining machine production rates, distance between machine passes were assumed to be 2 m for the Bracke and the disc trenchers, while for the drum chopper, the entire area was "chopped" thus no untreated space was left between passes. Area width for the TTS 35 disc trencher was set at 4.4 m (2.4 m between discs and 2 m between passes). Delta disc trencher plot width was 4.0 m (discs 2 m apart, and passes 2 m apart), and Bracke plot width was 4.0 m for the two-frame and 6.0 m for the three-frame (frames 2 m apart, and 2 m between passes). Drum chopper width was the same as the drum width, either 2.1 or 2.4 m.

Machine productivity rates in terms of ha treated per hour, are summarized for each study area in Table 4. Considerable variation in average production rates are apparent both within study areas as well as between study areas treated with the same implement. For example, average production for the TTS 35 disc trencher ranged from 1.46 at study area 1 to 1.93 ha per hour at study area 2 (study area 5 with only one observation was excluded from this comparison), a spread of almost one half ha per hour or about 30% (Table 4). Pre-treatment site conditions in terms of stand histories however also varied considerably (Table 1).

Treatment results, i.e. the degree to which the treatment objectives were achieved, must also be considered when examining machine productivity. Disc trenched and Bracke scarified sites were prepared for manual planting, therefore the number of possible planting spots or the quality of planting spots could be a useful measure of treatment effectiveness. The plantability of sites is presented in Table 5 for disc trenched study areas and in Table 6 for

TABLE 4. Machine productivity by study area for mechanical site preparation in Manitoba.

Study area	Scarifying implement	Number of plots	Machine productivity *	
			Average (ha per hour)	Range
1		15	1.46	1.32-1.55
2		4	1.93	1.89-1.55
3	TTS 35	8	1.74	1.47-1.98
4	Disc	3	1.59	1.55-1.65
5	Trencher	1	1.32	-
6		14	1.74	1.47-1.89
7		3	1.81	1.72-1.89
8	TTS Delta	5	1.41	1.11-1.60
9	Disc	2	1.04	0.92-1.18
10	Trencher	10	1.34	1.11-1.47
11	2.4 m wide	13	0.49	0.19-0.59
12	Drum	9	0.49	0.44-0.53
13	Chopper	6	0.56	0.54-0.57
14	2.1 m drum chopper	9	0.52	0.36-0.69
15	Bracke 3-frame	1	3.27	-
15	Bracke 2-frame	11	2.37	2.25-2.57

* Machine productivity is based on time required to treat a 50 m long strip. Unproductive time elements such as repairs, maintenance, rest breaks, etc. are not included.

Bracke prepared areas. Plantability of disc trenched sites (Table 5) are described in terms of the frequency of occurrence of number of planting spot choices while for the Bracke prepared sites (Table 6), the distribution of scalps by quality classes is presented. The number of potential planting spots created by a Bracke will not vary much within an area since machine settings fix this number. However the number of spots that are plantable will vary and is likely affected by a number of factors including site conditions. The percentage distribution of quality classes of Bracke scalps presented in Table 6 attempts to describe this factor.

Drum chopped areas observed in this study (study areas 11 to 14) were site prepared to facilitate subsequent disc trenching followed by planting. Results from this treatment therefore require simply that slash be flattened and/or broken into smaller pieces to allow for easier trenching. Post-treatment assessment of drum chopped areas indicated slash height was somewhat reduced although pre-treatment heights were not excessive (pre-treatment average slash heights were 13, 22, 9, and 14 cm for study areas 11 to 14 respectively, while corresponding post-treatment heights were 10, 7, 8, and 6 cm).

Slash cover in terms of slash piece size and distribution may be an important factor affecting labor productivity for manual tree planting. Slash pieces may impede a planter's movements or cause him/her to spend more time planting a seedling. Slash conditions both before and after site preparation treatments were assessed to provide a measure of the change in planting conditions resulting from the treatment. Slash conditions are summarized for disc trenched and Bracke prepared sites in Table 7. In general, treatments had little affect on slash height. In fact, for most study areas, height of slash from ground level was greater after treatment (Table 7). However the number of slash pieces encountered over a 100 m long transect (an arbitrary length was selected to represent a planter's walking path) appear to be reduced. Therefore although a planter may be required to step higher to negotiate slash, he/she will be required to step over fewer pieces as well as have fewer pieces to contend with when selecting a planting spot.

TABLE 5. Relative frequency of planting spots after disc trenching.

Study area	Scarifying implement	Planting spot frequency *			
		0 spots	1 spot	2 spots	>2 spots
		(%)			
1		3	1	8	88
2		0	0	5	95
3	TTS 35	0	5	5	90
4	Disc	0	0	7	93
5	Trencher	40	20	0	40
6		0	0	4	96
7		0	0	13	87
8	TTS Delta	20	12	12	56
9	Disc	0	0	20	80
10	Trencher	6	6	16	72

* Based on 2 m square quadrats.

TABLE 6. Relative frequency of scalp classes after Bracke site preparation.

Study area	Scarifying implement	Frequency of scalps by quality class *			
		Class 1	Class 2	Class 3	Class 4
		(%)			
15	Bracke 3-frame	56	6	10	28
15	Bracke 2-frame	68	3	1	28

* Quality classes for Bracke scalps are:

Class 1 : suitable planting spot in the hinge zone between scarified depression and mound.

Class 2 : plantable directly opposite the hinge zone at the beginning of the scarified depression.

Class 3 : plantable along the sides of the scarified depression.

Class 4 : not plantable.

TABLE 7. Pre- and post-treatment slash conditions for disc trenched and Bracke prepared sites.

Study area	Scarifying implement	Number of slash pieces per 100 m transect *						Average piece size (pieces > 5cm diameter)			
		Pieces with diameter < 5 cm		Pieces with diameter > 5 cm		Total all sizes		Diameter (cm)		Height (cm)	
		Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
1	TTS 35 Disc Trencher	165	87	35	28	200	115	8	9	9	23
2		135	48	45	22	180	70	8	10	10	21
3		281	84	34	25	315	110	9	12	10	26
4		103	110	13	7	116	117	6	8	19	13
5		420	460	40	30	460	490	6	11	24	14
6		5	9	2	1	7	10	7	11	0	10
7		100	43	0	10	100	53	-	13	-	23
8	TTS Delta Disc Trencher	856	112	108	50	964	162	7	10	21	32
9		530	95	60	45	590	140	7	9	32	22
10		292	84	90	51	382	135	6	8	21	22
15	Bracke 3-frame	590	356	120	91	710	447	8	11	15	21
15	Bracke 2-frame	426	358	87	94	513	452	9	9	13	18

* The number of slash pieces were determined from slash transects and adjusted to an arbitrary length of 100 m.

FUTURE WORK

Data collection will continue during the 1987 season. Efforts will be directed towards sites not included in the present data base. Very few observations are available for Bracke scarification therefore efforts will be made to sample this implement. Subsequent file reports will update the status of this project and provide current data summaries.

REFERENCES

- De Franceschi J.P.; Steele T. 1987. Labor Productivity for Manual Tree Planting in Manitoba. Canada-Manitoba Forest Renewal Agreement File Report, March 1987.
- De Franceschi J.P.; Steele T. 1986. Labor Productivity for Pre-Commercial Selection Thinning in Young Coniferous Stands in Manitoba. Canada-Manitoba Forest Renewal Agreement File Report, August 1986.
- Manitoba Natural Resources. 1987. Five-year Report on the Status of Forestry: Volumes 1 and 2. Manitoba Natural Resources Forestry Branch, Winnipeg.
- Steele T.; De Franceschi J.P. 1986. Machine Productivity for Shear Blade Site Preparation in Manitoba. Canada-Manitoba Forest Renewal Agreement File Report, April 1986.
- Sutherland B.J. 1986. Standard Assessment Procedures for Evaluating Silvicultural Equipment: A Handbook. Canadian Forestry Service, Great Lakes Forestry Centre, Sault Ste Marie Ontario.