1986 Site Preparation Equipment Trials in Alberta Donaren 180D Powered Disk Trencher Sinkkila HMF Scarifier

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1986

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DISCLAIMER

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ABSTRACT

The Donaren 180D powered disk trencher and the Sinkkila HMF scarifier were evaluated for acceptable disturbance and plantability on thick duff sites.

The Donaren, tested on two sites in Alberta achieved an average acceptable disturbance of 9.3% and 16.3% on Sites 1 and 2 respectively. Slash loading on the Donaren sites ranged from an average of 91 m^3/ha on Site 1 to 280 m^3/ha on Site 2. Plantable spot stocking along the furrows, based on a 2.5 m spacing with a 10% tolerance averaged 70% and 80% on Sites 1 and 2 respectively. Combined with inter-furrow spacing, plantable spots per hectare averaged 1,058 for Site 1 and 1,195 for Site 2 or 66% and 75% overall stocking respectively based on a 1,600 spots per hectare prescription. Greater down pressure on the disks at 25 bars for Site 2 compared to 0 bars on Site 1 was cited as the primary reason for the better results on Site 2. Machine utilization was high on Site 1 at 92.6% and low on Site 2 at 33.1%. Machine availability was 100% and 35.7% on Sites 1 and 2 respectively. Downtimes were associated with the prime mover. Productivity was 1.12 ha and 0.66 ha per productive machine hour (PMH) on Sites 1 and 2 respectively.

A short term trial of the Sinkkila HMF scarifier on one site in Alberta proved inconclusive due to chronic hydraulic problems with the implement. As a result, few acceptable attempts were produced. Further testing is required to fully evaluate the Sinkkila.

ACKNOWLEDGEMENTS

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INTRODUCTION

In 1986, through the Canada/Alberta Forest Resource Development Agreement (FRDA), five participants elected, under a cost sharing formula, to investigate the Donaren 180D powered disk trencher and the Sinkkila HMF scarifier to meet their own individual site preparation objectives. The participants using the Donaren 180D included the a) Alberta Forest Service, b) Canadian Forest Products Ltd., c) Procter and Gamble Cellulose Ltd., d) Blue Ridge Lumber (1981) Ltd. and e) Saskatchewan Parks and Renewable Resources under the Canada/Saskatchewan Agreement. For results of the Saskatchewan trials, see the report by Sidders *et al*, (1987)[1]. The Sinkkila was also tested in British Columbia by FERIC under the BC/Canada FRDA and was used in a short test in Alberta by the Alberta Forest Service.

The Donaren 180D powered disk trencher was first tested in Alberta in 1983 and reported on by Bamsey (1985)[2]. The Donaren, mounted on a Timberjack 520 skidder, had insufficient hydraulic flow and pressure to give full turning power to the disks. A problem within the electrical system was also encountered and proved difficult to trouble shoot (Ferdinand, Personal Communications, 1986). However, a positive feeling remained after testing that an effective job of site preparation was possible once the Donaren power needs were satisfied.

In 1982, the Forest Engineering Research Institute of Canada (FERIC) reported that the Donaren required a constant speed drive that only a prime mover with hydrostatic drive with priorities to the Donaren can deliver. A large single engine skidder may not function adequately unless there is an additional 35 kw engine to power the Donaren hydraulics (Ryans, 1982).

The Ardco model K-HSP 4 x 4 prime mover with hydrostatic drive (Appendix A), was selected to supply the power requirements of the Donaren. The Ardco being lighter than conventional log skidders (6,000 kg versus 13,698 kg for a John Deere 740A), had the potential to offer advantages in wet blocks where site preparation equipment is limited to winter operations. In 1984, winter ripping operations were as high as $370 per hectare. The lighter Ardco/Donaren combination may offer cost savings if sites can be accessed and treated in the summer months.

[1]Sidders, Derek, *et al*. 1987. Field Trials of the Donaren 180D and TTS Delta Powered Disk Trenchers in the Boreal Mixedwoods of Saskatchewan. Information Report. in Prep. Northern Forestry Centre, Canadian Forestry Service, Edmonton.

[2]Bamsey, C.R. 1985. Trials of Donaren Disk Trencher, 1983. Alta. For. Serv., Edmonton, Alta. Intern Rep. 3pp.

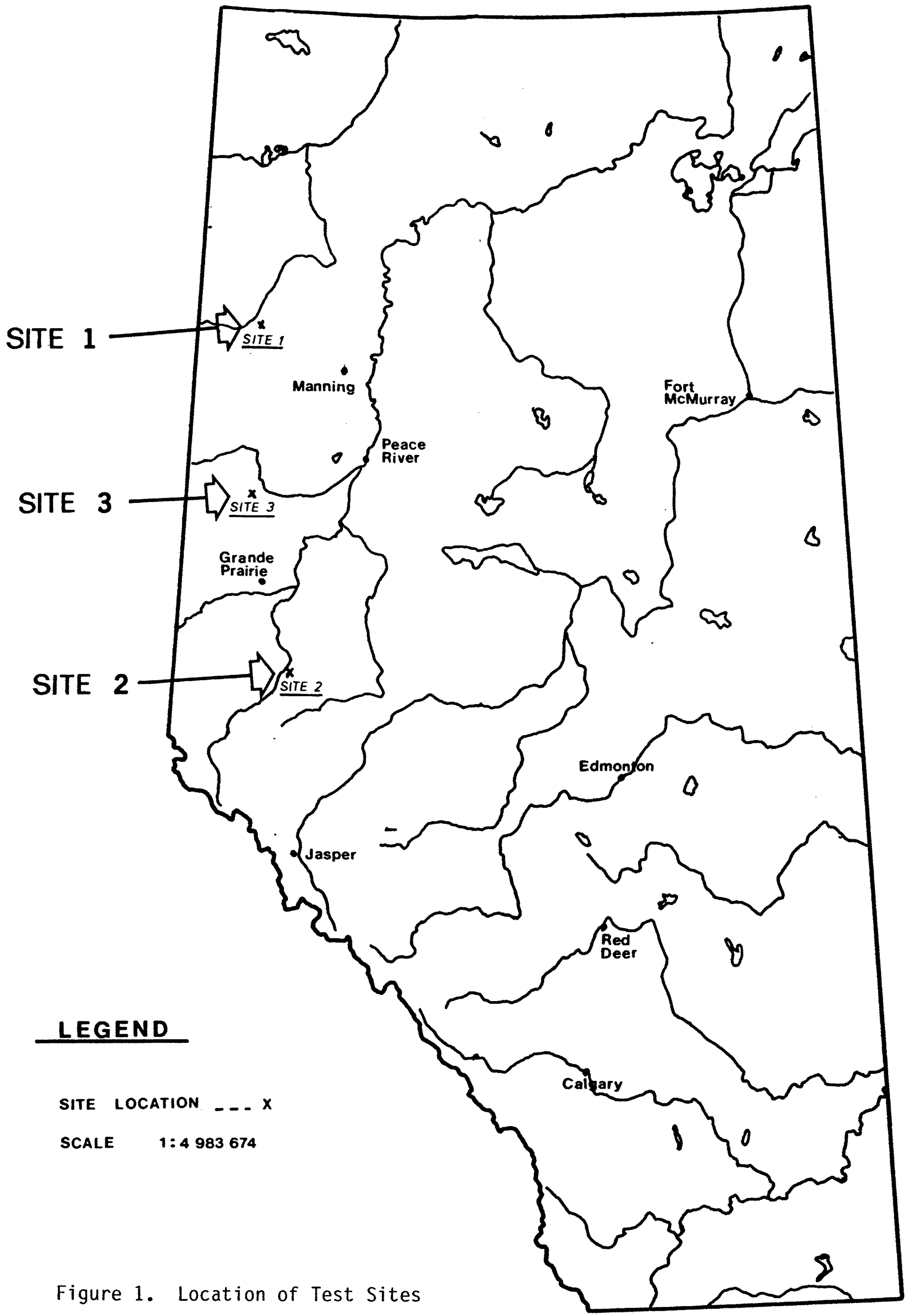


Figure 1. Location of Test Sites

The Sinkkila is a Finnish spot scarifier that has been used in Finland for the past twenty years. Mounted on a John Deere 740 skidder, the Sinkkila HMF scarifier was investigated as a site preparation tool on Alberta's clay soil where raised or mounded microsites may offer advantages for the survival and growth of spruce planting stock.

The overall objectives of the trials were to determine if the Donaren & Sinkkila could create plantable spots and expose mineral soil on a range of full-tree logged sites. Only portions of three sites were used to evaluate the effectiveness of the implements using the Great Lakes Forestry Centre's (GLFC) Standard Assessment Procedures (SAP) (Sutherland, 1986). These procedures were adopted to facilitate the collection of data using standard accepted methodology allowing comparison between sites and with other equipment trials conducted across Canada.

LOCATION AND SITE DESCRIPTION

Sites where trials were conducted are shown on the map of Alberta in Figure 1.

Site 1 - Manning

Reforestation Responsibility: Alberta Forest Service
Legal Description: Section 9 - Township (Twp) 96 - Range (Rng) 7, West of the 6th Meridian (W6M).
Tool: Donaren 180D

Site 1 is located approximately 115 km west of Manning in the mixedwood boreal region (Rowe, 1972) and the boreal foothills ecoregion of Alberta (Strong and Leggat, 1981).

Prior to harvest the 5.6 ha test site supported white spruce (*Picea glauca* (Moench) Voss), trembling aspen (*Populus tremuloides* Michx.), balsam poplar (*Populus balsamifera* L.) and white birch (*Betula papyrifera* Marsh.). Crown closure of the 120 year old stand was 51-70%. Regional topography is rolling but Site 1 is generally flat with a slight upward slope of less than 5% to the south. Soil development is from lacustrine deposits overlying glacial till and is within the gray luvisol great groups (Canadian Soil Survey Committee 1978). Texture is fine (clay to clay loam) and drainage is moderately well to imperfect (Lindsay *et al*, 1958).

Site 1 was clear-cut in the 1984/85 winter under salvage permit held by Canadian Forest Products Ltd, due to a recent spruce beetle (*Dendroctonus rufipennis* Kirby) infestation. Reforestation with 1 year old white spruce container stock is to follow in the fall of 1987.

<u>Site 2</u> - Grande Prairie

Reforestation Responsibility: Canadian Forest Products Ltd.
Legal Description: Section 7 - Twp 62 - Rng 3 - W6M.
Tool: Donaren 180D

Site 2 lies in the lower portion of the high east bank of the Smoky River, approximately 110 km south of Grande Prairie. The site is in the lower foothills of the boreal forest region (Rowe, 1972) and in the boreal foothills ecoregion of Alberta (Strong and Leggat, 1981).

The regional vegetation is lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm), white spruce, aspen and balsam fir (*Abies balsamea* (L.) Mill). The 100 year old stand of successional white spruce and balsam fir on site had a crown closure between 51-70%. Regional topography is hilly but Site 2 is also slightly terraced with slopes up to 30%, rising to the east. Soil development is on glacial outwash (Lindsay, *et al*. 1954-55) and is within the gray luvisol great group (Canadian Soil Survey Committee, 1978). Soil texture is fine (clay to clay loam) and moderately-well drained.

The 3.7 ha test area is within Canadian Forest Products' Forest Management Agreement and was clear-cut in the 1985/86 winter. Reforestation is to be with a 75% pine/25% white spruce seed mix, aerially seeded in May 1987.

Site 3 - Spirit River

Reforestation Responsibility: Alberta Forest Service
Legal Description: Section 3 - Twp 80, Rng 9, W6M.
Tool: Sinkkila HMF

Site 3 lies in the mixedwood section of the boreal region (Rowe, 1972) and borders the mixedwood and boreal foothills ecoregions of Alberta (Strong and Leggat, 1981). The site is approximately 40 km west of Spirit River, which is about 550 km northwest of Edmonton.

Preharvest composition of Site 3 was 110 year old white spruce with a crown closure of 51-70%. Topography is flat with medium-fine textured (clay loam), imperfectly drained solonetzic soil (Odynsky *et al.* 1961). Clear cutting took place under a local timber permit in the winter of 1983/84. Reforestation with 2 year container white spruce will be planted in the fall of 1987.

IMPLEMENT AND PRIME MOVER

Ardco K-HSP/Donaren 180D

The Donaren 180D powered disk trencher is manufactured in Sweden by AB Skogsbruksmaskiner (see Appendix A for specifications). The unit is entirely operated by hydraulics commanded electronically from controls mounted in the cab of the prime mover. Toothed disks are mounted on two seperate, articulating arms which can provide down pressure (0-40 bars) or lift to the disks. Rotational speed on the disks can be varied to a maximum of 30 rpm. Furrow spacing can also be adjusted hydraulically but stops must be welded to restrict the outer lateral movement of the arms. The arms deflect upwards when obstacles are encountered but will automatically reset to the specified position.

The Donaren was mounted on an Ardco K-HSP 4 x 4 lightweight skidder-type vehicle with articulated steering and frame oscillation (see Appendix A for specifications). The Ardco frame was shortened and otherwise adapted for direct mounting of the Donaren. A 6V-53 Detroit Diesel provided the power to the Sunstrand full hydrostatic drive. The hydrostatic drive maintains a more even speed when obstacles are encountered as well as providing sufficient hydraulic flow and pressure to the Donaren at low speeds (Ryans, 1984). The Sunstrand hydrostatic drive meant an independent power unit for the Donaren was not needed (Ryans, 1982).

The Ardco K-HSP has not been used in forestry work before but has been useful in seismic and oil field activity.

John Deere 740/Sinkkila HMF Scarifier

The Sinkkila scarifier-mounder is manufactured by Teraskamponentti Ky of Heinola, Finland. It consists of two arms, attached independently to the frame by a universal joint which allows deflection of the arm. Each arm has two scarifying wheels with four mattocks or teeth per wheel. The wheels systematically lock and release for patch scarifying and/or mounding using a self-contained hydraulic system electronically controlled by the operator in the cab of the prime mover. To lift or lower the arms, a hydraulic link can be provided or grapple skidder with hydraulic arch may be used.

The Sinkkila can be set for either mounding or scraping. Mounding and scraping are controlled by mattock angle to the ground, length of time mattock is in contact with the ground, and cycle time between mattock positions. The Sinkkila was mounted on a John Deere 740 A skidder (see Appendix A for specifications). For a complete description of the Sinkkila refer to Hedin's[3] report.

Operators of both prime movers were very experienced with their machines and shared a keen interest in performing their work well.

[3]Hedin, I.B. 1987 Trials of the Sinkkila HMF Scarifier in North Central British Columbia. Draft, FRDA Report, BC Ministry of Forests and Lands, Victoria. 27 pp.

ASSESSMENT PROCEDURE

All data were collected and analyzed as set out in the GLFC Standard Assessment Procedures. The assessment is divided into three components:

1) Pre-treatment Assessment
2) Time Study
3) Post-treatment Assessment

The pre-treatment assessment and the time study measured the same variables on all three sites. The post treatment assessments evaluated the fundamental characteristics of site preparation provided by the Donaren and Sinkkila and thus are inherently different surveys. The Donaren evaluation was based on the furrows while the Sinkkila evaluation was based on mounds and scalps.

For the Donaren a number of 20 m long transects were established perpendicular to the direction of travel each consisting of 10 - 2m x 2m quadrats. Percent disturbance was tallied seperately by the implement and by other causes in each quadrat. The disturbance was then categorized into soil/duff modification types based on the quality of disturbance and grouped as either acceptable or not acceptable.

Plantability was assessed along a 40 m offset in the last trench of each transect. Spots, considered to be 30 cm x 30 cm in size, were identified as plantable or not plantable along with a further description of micro-relief and presence of debris and vegetation competition.

The Sinkkila post-treatment assessment consisted of transects approximately 40 m in length established along the direction of travel. Mineral soil caps and mounds were measured and classified according to plantability criteria. Reasons for poor mounds were identified. Scalps were also measured and described as alternative planting spots using the same criteria for plantable spots as for the Donaren. A mound and its corresponding scalp together are called an attempt.

DONAREN 180D POWERED DISK TRENCHER

RESULTS

All statistical tests of significance were conducted at $\alpha = 0.1$.
Values within brackets in all tables represents a 90% confidence interval.

Pre-treatment Assessment

The results from the pre-treatment assessments on Site 1 and 2 are given in Tables 1 - 4.

Slash

The lineal tally and distribution of slash pieces from 1 to 5 cm in diameter was similar between Sites 1 and 2 as shown in Table 1 and Figure 2. The count of slash pieces larger than 5 cm in diameter was signficantly different between the sites at 0.52 and 0.90 pieces per 2 m of lineal tally for Sites 1 and 2 respectively. Figure 3 shows Site 1 with 64% of the quadrats not registering a tally while Site 2 has only 37% without tallies of large slash pieces.

Table 1. Average Tally, Diameter and Depth of Slash

Site	Slash pieces per 2 m of lineal tally 1-5 cm (No.)	Slash pieces per 2 m of lineal tally > 5 cm (No.)	Slash Diameter > 5 cm (cm)	Slash Depth (cm)	Slash Length (m)
1	7.42 *(0.76)*	0.52 *(0.08)*	13.64 *(1.19)*	14.90 *(2.02)*	3.57 *(0.37)*
2	6.89 *(0.75)*	0.90 *(0.11)*	18.72 *(1.62)*	26.28 *(3.53)*	3.89 *(0.38)*

Average diameter of slash greater than 5 cm was significantly different between Sites 1 and 2 at 13.64 cm and 18.72 cm respectively. Figure 4 shows the difference in the distribution of large slash pieces between the sites, with Site 2 having a greater occurrence of slash in the larger diameter classes. The distribution and size of slash pieces tend to have the most direct influence on scarifier effectiveness.

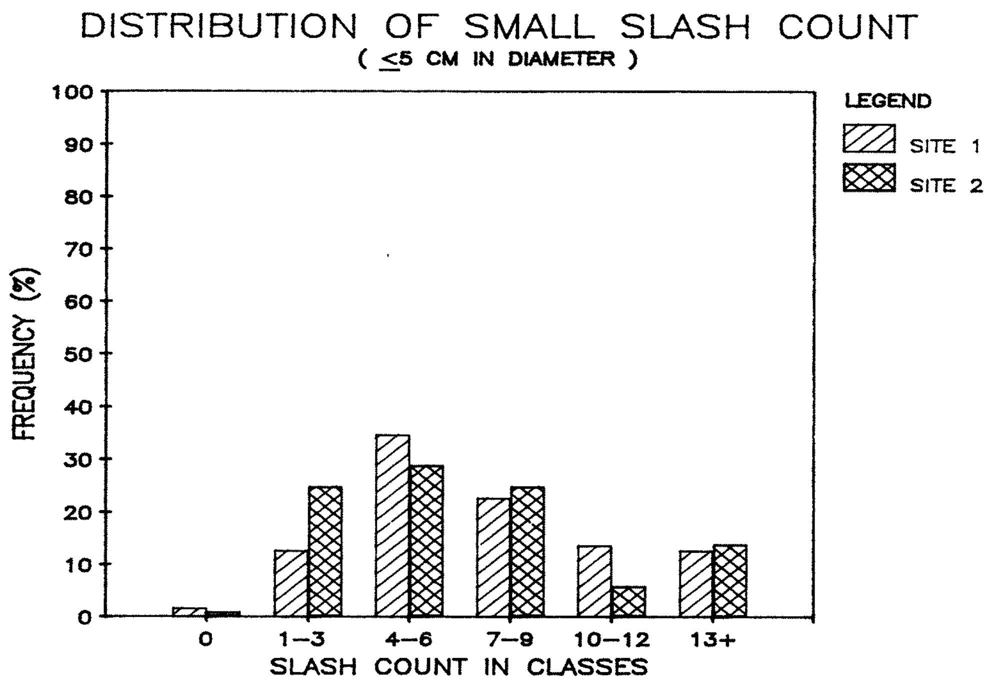


Figure 2. Distribution of Small Slash (≤ 5 cm in diameter)

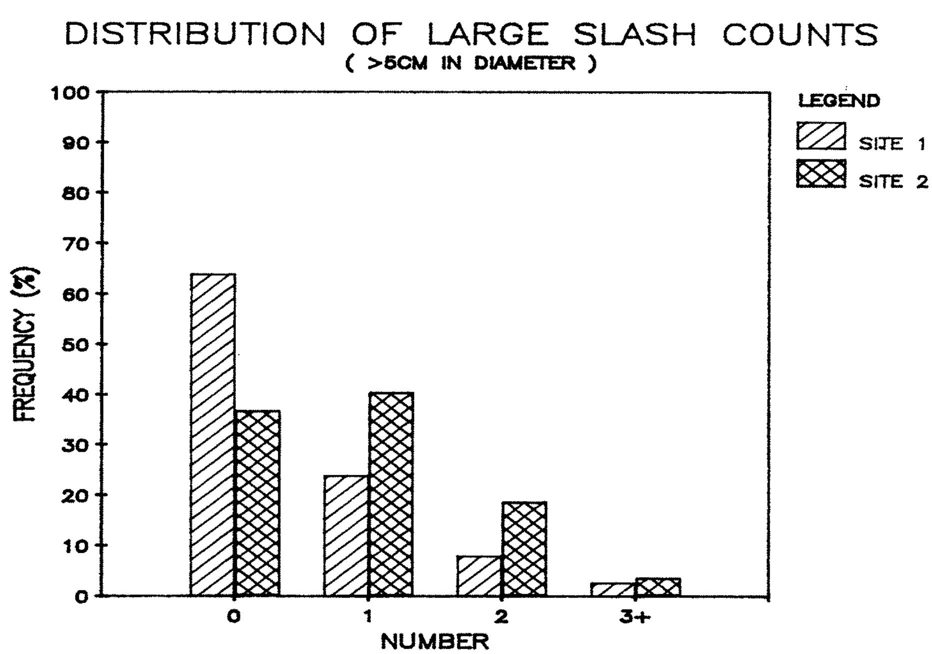


Figure 3. Distribution of Large Slash (> 5 cm in diameter)

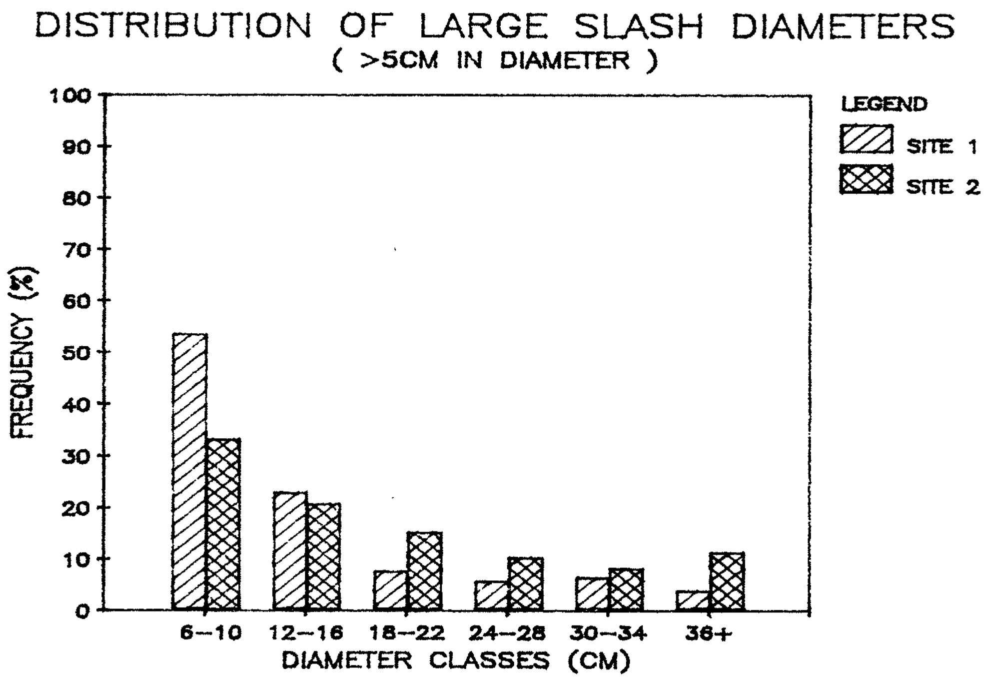


Figure 4. Distribution of Diameters > 5 cm.

Table 2 shows that Sites 1 and 2 were similar in volume of small slash pieces but radically different in volume of slash greater than 5 cm in diameter. A comparison of Figures 4 and 5 illustrates the effect larger slash diameter has on volume. The occurrence of very large slash pieces can increase volume signficantly. Figure 6 also emphasizes this by indicating a higher frequency in most volume classes on Site 2. Total average slash volume was 91.28 m^3/ha and 280.30 m^3/ha on Site 1 and 2 respectively.

Table 2. Average Slash Volume

Site	Slash Pieces 1-5 cm dia. (m^3/ha)	Slash Pieces > 5 cm dia. (m^3/ha)	Total Slash Volume (m^3/ha)	Major Slash Type Conifer (%)	Major Slash Type Hardwood (%)
1	14.50 *(1.48)*	86.45 *(21.43)*	91.28 *(21.58)*	100%	0%
2	14.27 *(1.55)*	271.38 *(60.40)*	280.30 *(60.27)*	100%	0%

[a] Proportion of quadrats with predominant species of slash.

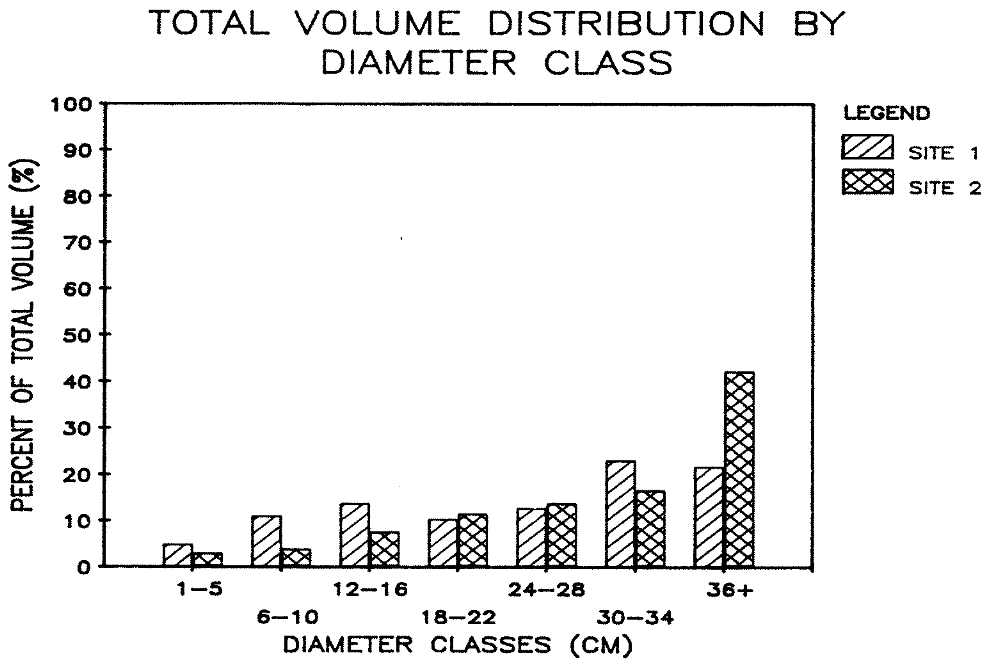


Figure 5. Volume Distribution in Diameter Classes

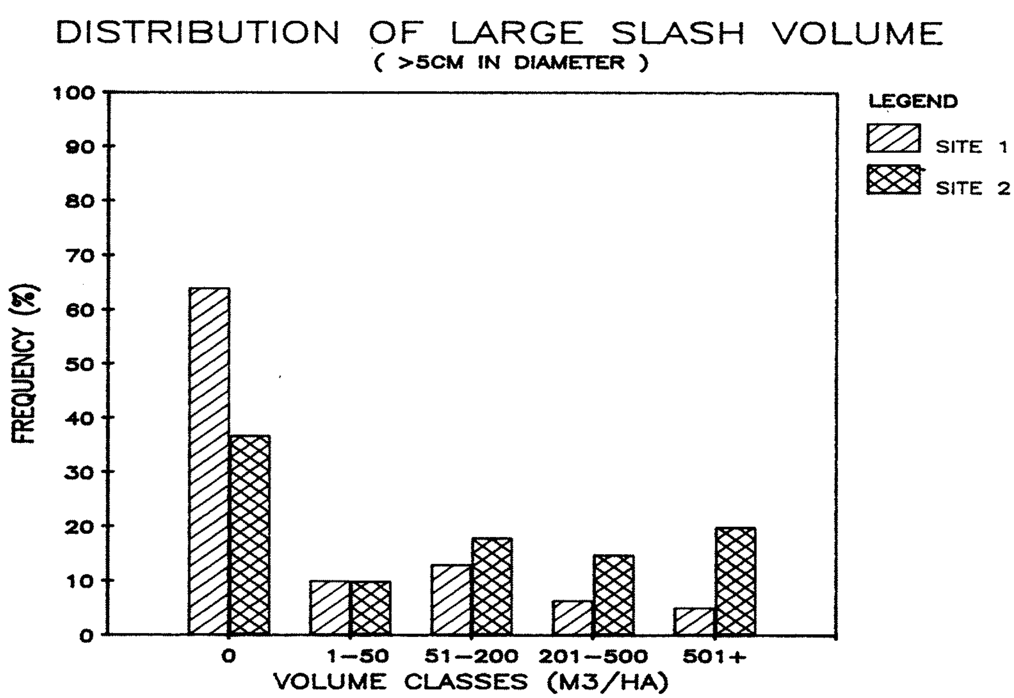


Figure 6. Distribution of Volume of Slash > 5 cm in diameter in each volume class

Average slash depth was much greater on Site 2 at 26.28 cm than Site 1 at 14.90 cm. Figure 7 illustrates a higher frequency (33% approx.) of slash depths greater than 30 cm on Site 2 compared to Site 1 (12% approx).

Slash lengths on both Sites 1 and 2 were similar at 3.57 m and 3.89 m respectively (Figure 8).

Stumps

The number of stumps per quadrat averaged 0.18 for Site 1 and 0.27 for Site 2 (Table 3). Extrapolation of stump data to a per hectare basis yields a low stump density for both sites. Stump height at 47.47 cm in Site 1 is significantly higher than in Site 2 at 37.77 cm.

Table 3. Average Stump Count, Diameter and Height

Site	Stumps per Quadrat[a] (No.)	Density[b] (No/ha)	Diameter (cm)	Height (cm)	Stump Species Composition (%)	
1	0.18 *(0.041)*	225	37.42 *(3.87)*	47.47 *(4.19)*	White Spruce	96.2
					Birch	3.8
2	0.27 *(0.066)*	338	35.54 *(3.90)*	37.77 *(3.94)*	White Spruce	60.5
					Balsam Fir	34.9
					Birch	4.7

[a] Due to a low stump density sample quadrat size was increased to 2 x 4 m.
[b] Density was extrapolated from average stump count per quadrat.

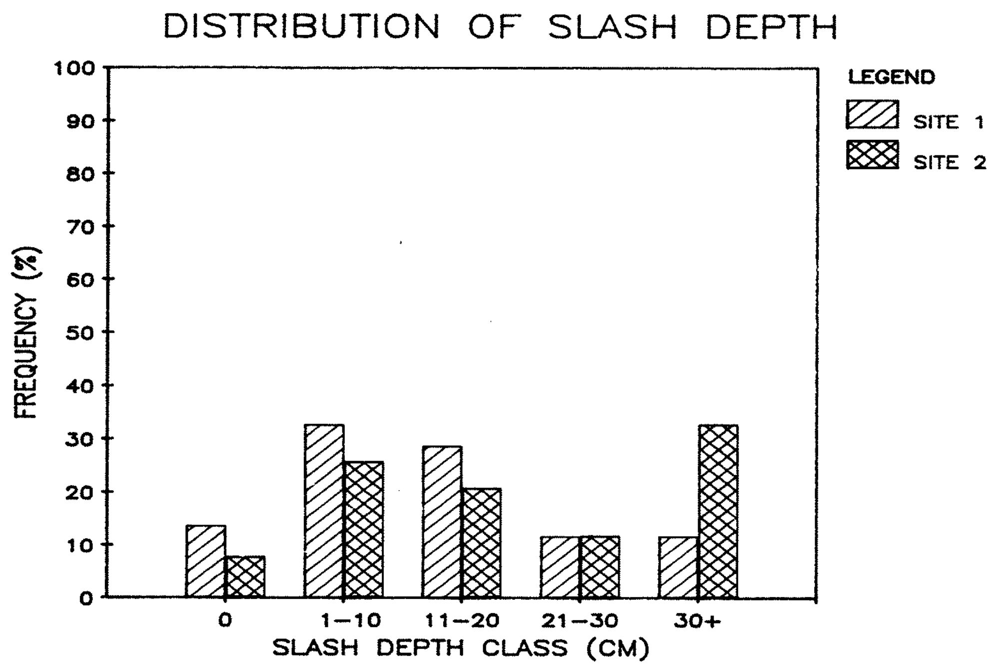


Figure 7. Distribution of Slash Depth in each Depth Class

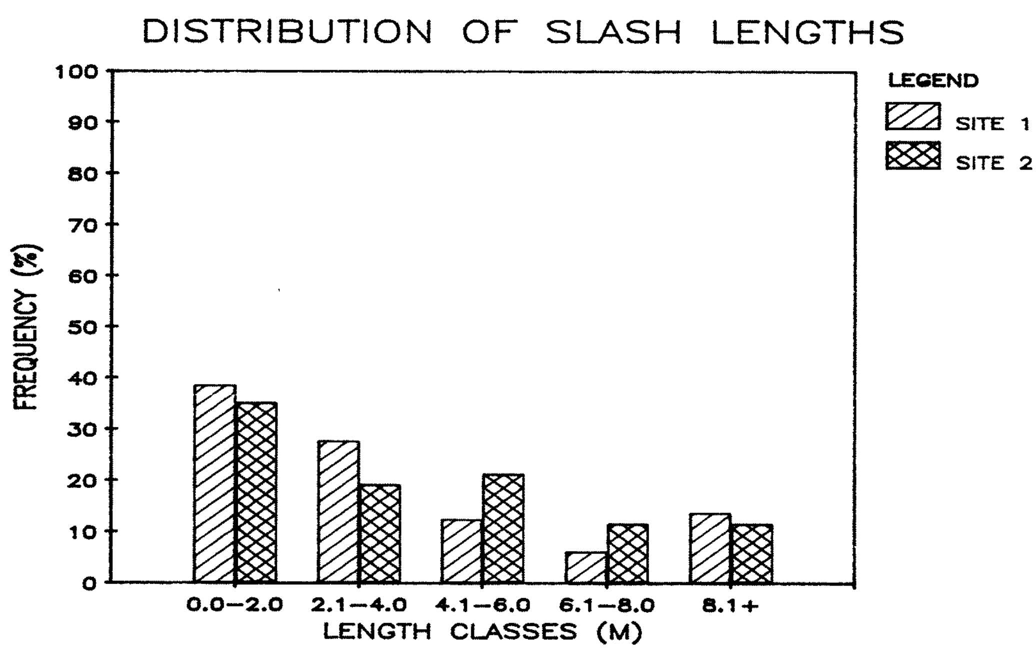


Figure 8. Distribution of Large Slash Lengths in Length Class

Soil and Ground Conditions

Sites 1 and 2, although stone free had average mineral soil depths of 25.8 cm and 29.5 cm respectively in the top 30 cm (Table 4). Depth soundings of less than 30 cm were attributable to tree roots. Soil depths greater than 30 cm occurred at a frequency of 76% on Site 1 and 98% on Site 2 (Figure 9).

Table 4. Average Soil & Ground Conditions

Site	Mineral Soil Depth (cm)	Duff Depth (cm)	Ground Roughness Class	Ground Conditions Texture	Moisture Class
1	25.82 *(2.19)*	22.82 *(2.45)*	1 [2]	Clay - Clay loam	4
2	29.50 *(0.84)*	23.11 *(2.76)*	2 [1]	Clay - Clay loam	4

[a] Depths are measured to a maximum of 30 cm from soil surface.

[b] Numbers in parenthesis indicate the ground roughness class with an occurrence greater than 10%.

Average duff depths were high at 22.82 cm and 23.11 cm for Sites 1 and 2 respectively. Figure 10 illustrates duff depth distribution for both sites. Excessive duff is one of the most important site variables restricting scarifier effectiveness. Disc trenchers characteristically produce furrows with cross sections having a combination of raised, side slope, level and deep microsites. Deep duff can limit disc penetration and reduce the proportion of side slope or level micro-reliefs in favour of hollow micro-reliefs which are more prone to flooding and associated frost problems. Furrows are deeper with steep sides and are thus less stable being prone to movement of side slope material. Disc trenched furrows in deep duff can contain more debris as the discs are less effective at clearing debris away from the furrows.

Ground roughness includes a composite measure of stumps, mounds and depressions measured on a scale from 1 to 5 where 5 is the most severe. Site 1 had an even ground roughness (class 1) and Site 2 had an intermediate ground roughness (class 2).

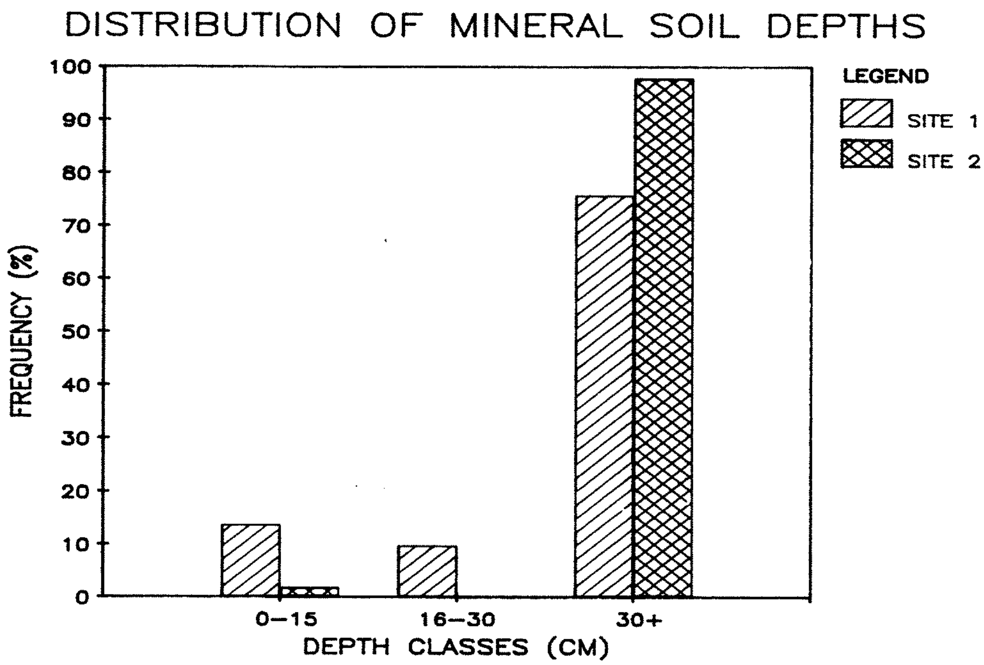


Figure 9. Distribution of Mineral Soil in each Depth Class

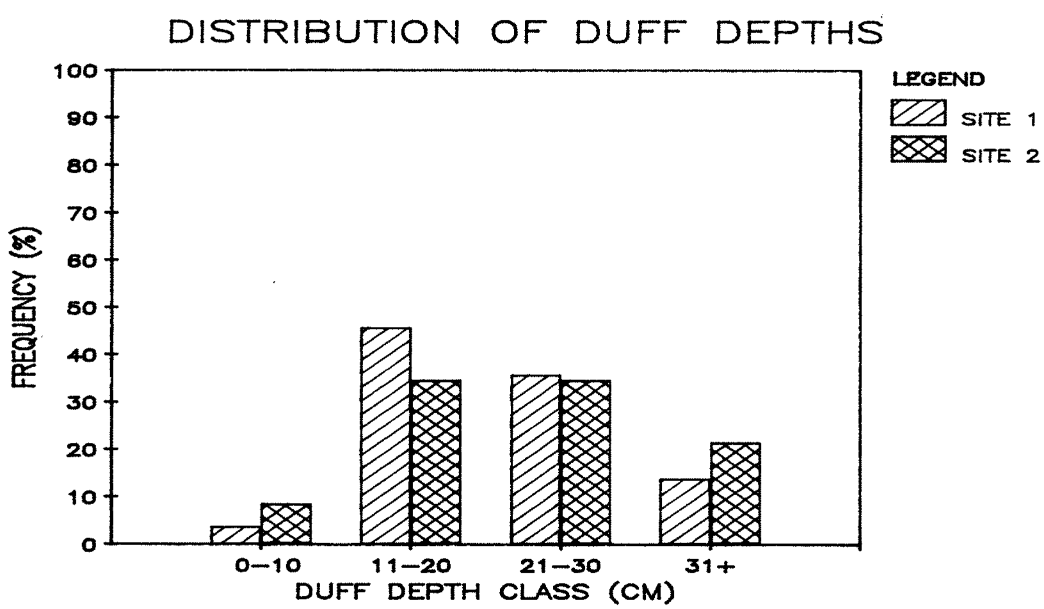


Figure 10. Distribution of Duff Depth in each Depth Class

Ground moisture is measured on a scale from 1 to 9 where 1 is the driest. Both sites averaged moderately moist (class 4) at the time of the pre-treatment assessment. After the pre-treatment assessment on Site 2, excessive rainfall (about 100 cm from July 1 to July 22) caused an increase to class 7 (moderately wet) at Site 2 during the time study. Distribution of pre-treatment soil moisture is shown in Figure 11.

Slope

Figure 12 shows the distribution of slope classes. On Site 1 slope never exceeded the 0-5 percent class. On Site 2 the majority of slope classes fell into the 6 to 20% range.

Residual Vegetation

Residual tree density was low averaging only 15-20 trees per hectare on both Sites 1 and 2. Such low densities had minimal effect on equipment operation.

Brush on Site 1 was virtually non-existant but Site 2 averaged 2055 stems per hectare at 20 percent stocking reflecting a slightly clumped nature. The low brush density also had little effect on equipment operation.

Vegetation coverage by minor plants was considerably less on Site 2 (13%) than on Site 1 (40%). Both sites were similar with a high occurrence of grasses and rose shrubs as the major species (Figure 13), but ground coverage between sites was significantly different (Figure 14). Dense coverage of minor vegetation can reduce the effectiveness of disc scarification due to the fiberous nature of root mats. Site 1 had a much higher coverage of minor vegetation than Site 2, however, the use of a powered disc trencher, in this case, would reduce the negative effect that vegetation root mats would have on disc penetration.

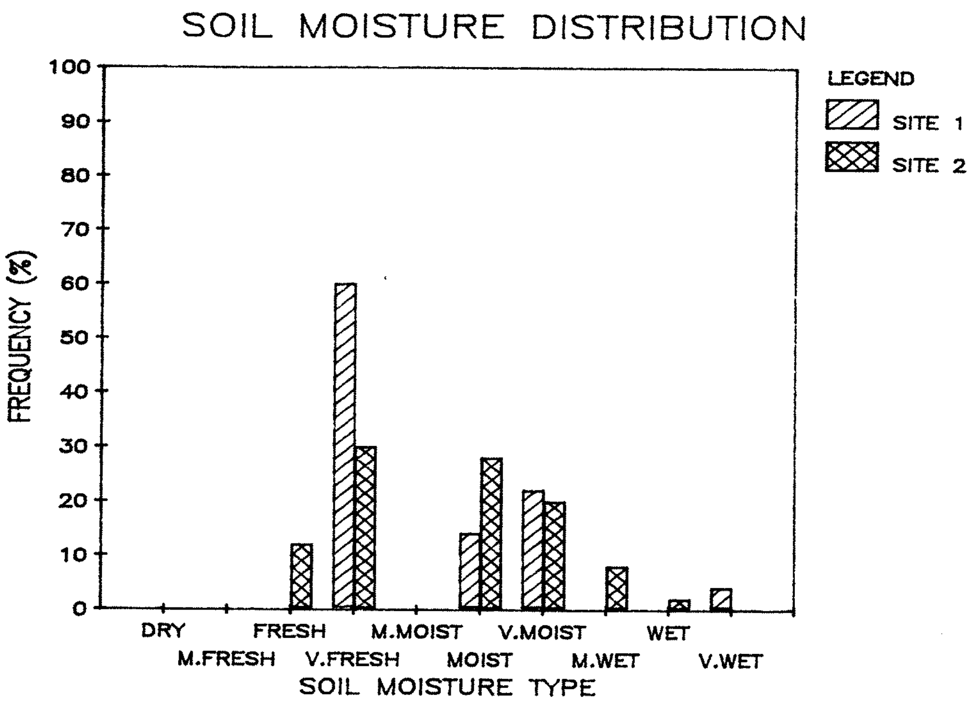


Figure 11. Distribution of Soil Moisture

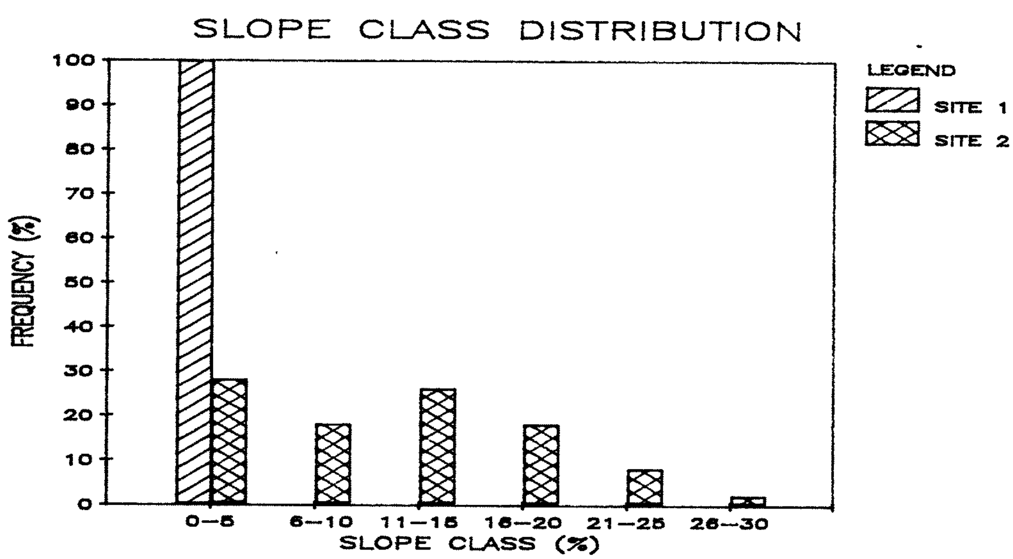


Figure 12. Distribution of Slope Classes

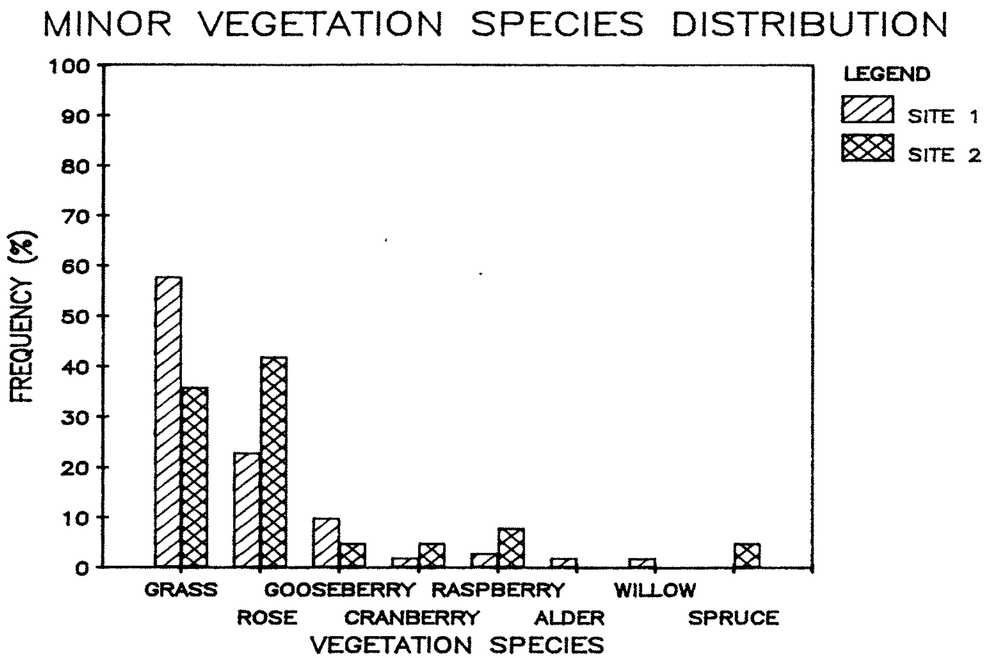


Figure 13. Distribution of Minor Vegetation Species

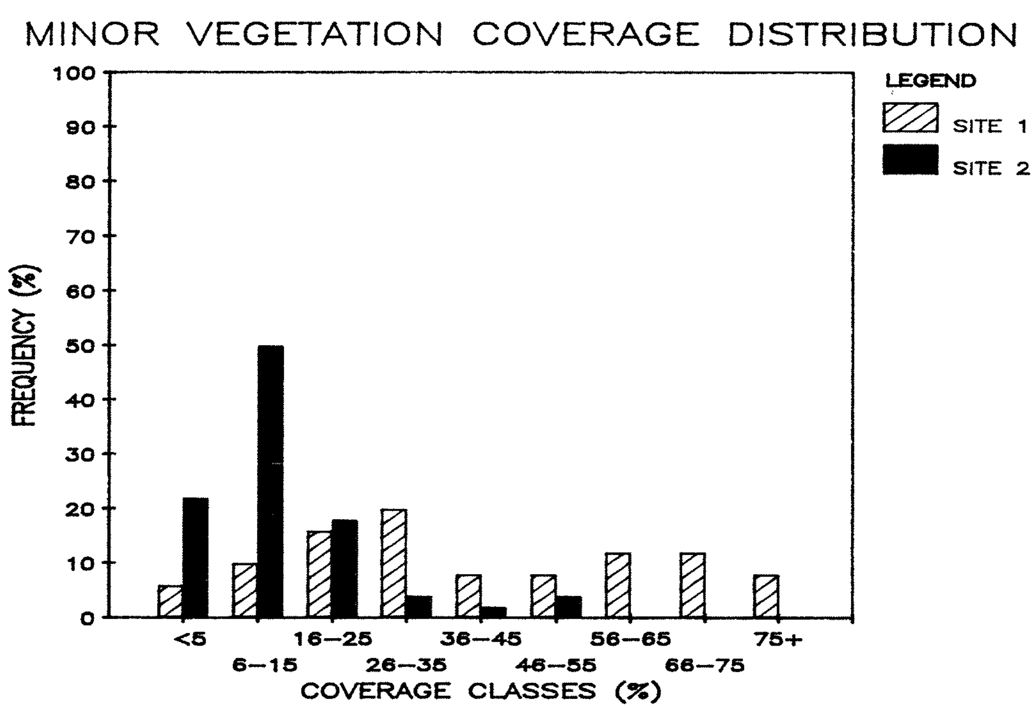


Figure 14. Distribution of Minor Vegetation Coverage

TIME STUDY

A short term time study of the Ardco/Donaren was conducted on both Sites 1 and 2. Scheduled machine time elements were analyzed to produce the productive summary in Table 5. Figure 15 and 16 illustrate machine time elements for Sites 1 and 2 respectively. See Appendix B for machine time formulas and definition of time elements.

Table 5. Productivity Summary

Site	Scheduled Machine Time (SMT) (min)	Productive Time (PMT) (min)	Travel Speed (km/hr)	Area (ha)	Productivity[a] Per EPT (ha/hr)	Per PMH (ha/hr)
1	324.73	300.77	2.79	5.6	1.50	1.12
2	1010.81	334.12	2.51	3.7	1.32	0.66

[a] EPT - Effective Productive Time: time machine is actually scarifying.
PMH - Productive Machine Hour (or time): includes EPT, obstacle time, manoeuvring time and delays $\leq$ 15 min.

Scarification was performed in first gear resulting in low travel speeds. Disk rotational speed was almost at maximum (28-30 rpm) resulting in fairly clean furrows. One factor which positively affected productive machine time was the operator who was well experienced with the Ardco carrier. Disk pressure on Site 1 was maintained at 0 bars and on Site 2, pressure varied up to 30 bars, but in general, was maintained at 25 bars as long as forward speed was not hampered.

Site 1

Productive machine hours (PMH or PMT) comprise 92.6% of schedule machine time (SMT) and downtime was 7.3%, caused by the prime mover being hung up on a high stump. The average travel speed, determined during effective productive time (EPT or EPH), was 2.79 km/hr. The overall average productive rate was 1.12 ha per PMH.

Utilization and availability were both very high as shown in Table 6.

Site 2

Productive machine time was considerably lower on Site 2 at 33.1% of scheduled machine time. A large part of the downtime at 59.6%, was due to active repairs to rear planetary gears of the Ardco.

The main factor affecting EPT was the size of large slash and number of pieces. Approximately 51.5% of obstacle time was due to slash.

Another significant factor was slope. A high amount of rainfall reduced traction causing the slope to become a major obstacle limiting scarification to one direction (downwards) on the steeper section of the block. This accounted for an additional 42.6% of obstacle time.

Travel speed averaged 2.51 km/hr downhill. Travel speed was not taken against the grade due to very short effective productive time intervals caused by slippery conditions and heavy slash impediments where uphill disking was done.

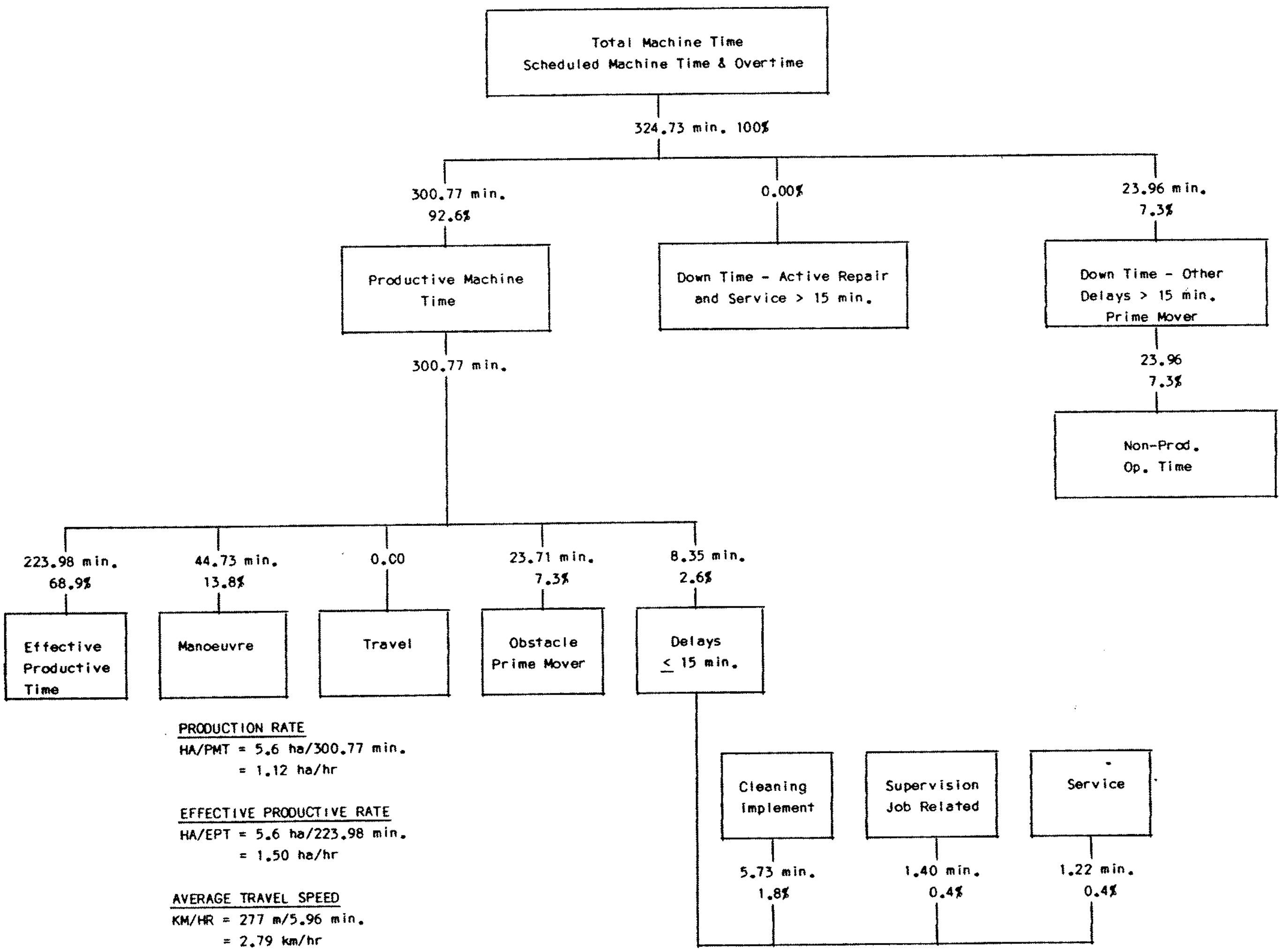
Utilization and availability were very low, on Site 2, as shown in Table 6. All the downtime during the test was attributed to the Ardco.

Table 6. Machine Availability and Utilization

SITE	MACHINE UTILIZATION	MACHINE AVAILABILITY		
		CPPA[a]	Implement & Prime Mover	Implement
1	92.6%	100.0%	100.0%	100.0%
2	33.1%	40.4%	35.7%	100.0%

[a] Canadian Pulp & Paper Association

SITE 1
SALVAGE PERMIT - MANNING
DONAREN 180 D DISK TRENCHER/ARDCO K 4 x 4
SHORT-TERM MACHINE TIME STUDY



PRODUCTION RATE
HA/PMT = 5.6 ha/300.77 min.
= 1.12 ha/hr

EFFECTIVE PRODUCTIVE RATE
HA/EPT = 5.6 ha/223.98 min.
= 1.50 ha/hr

AVERAGE TRAVEL SPEED
KM/HR = 277 m/5.96 min.
= 2.79 km/hr

[1] Manoeuvre time includes turning time as well as repositioning for no reason other than to scarify unprepared ground (no obstacles involved).
[2] Obstacle time includes manoeuvres for wet ground, slash, blading and stopping for obstacles.
[3] Service time is fixing a loose winch cable.
[4] Delays > 15 min is single occurrence of prime mover hang up on stump.

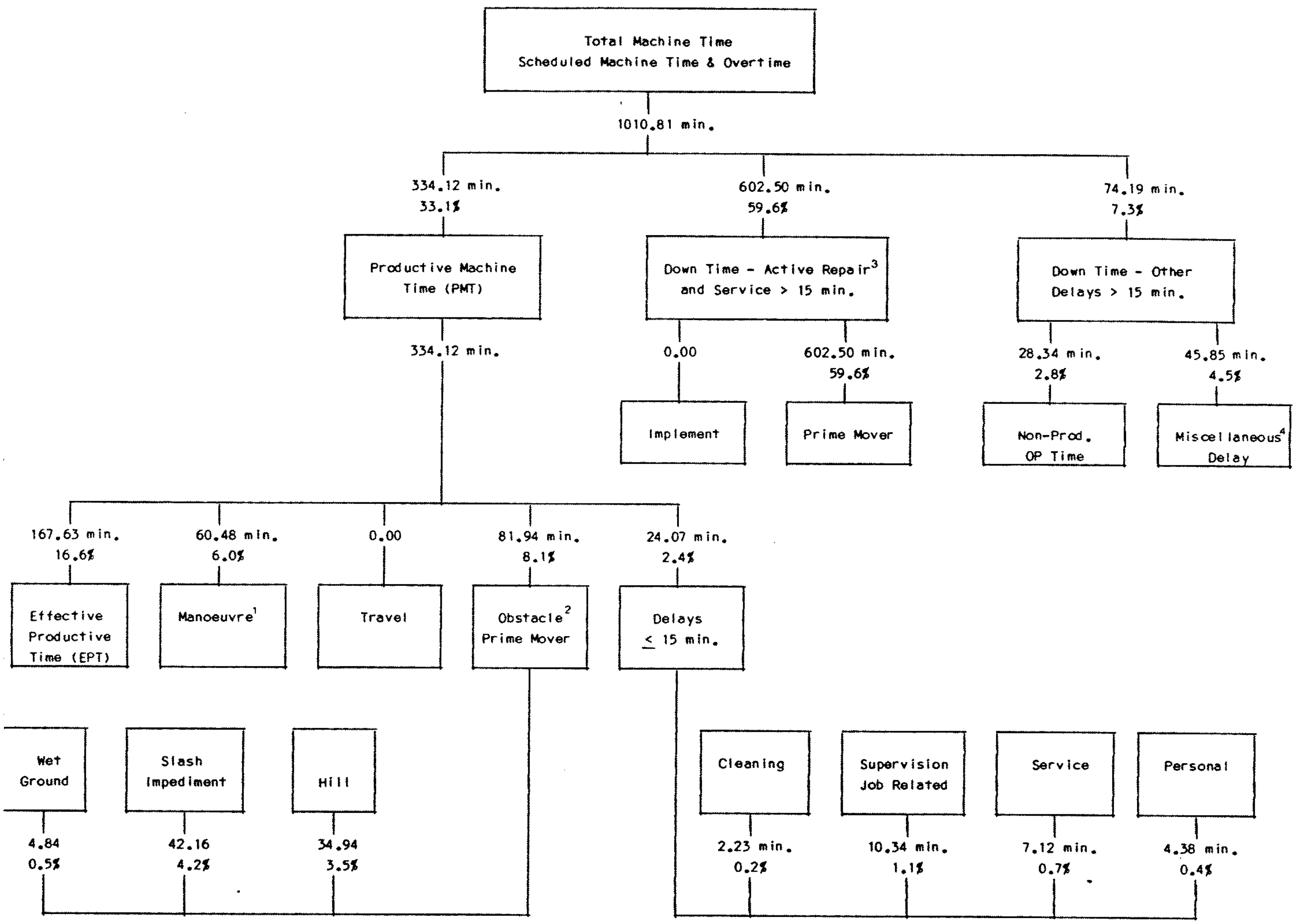
Figure 15. Results of Time Study - Site 1

SITE 2

CANADIAN FOREST PRODUCTS FMA - GRANDE PRAIRIE

DONAREN 180 D DISK TRENCHER/ARDCO K 4 x 4

SHORT-TERM MACHINE TIME STUDY



PRODUCTION RATE
HA/PMT = 3.7 ha/334.12 min.
= 0.66 ha/hr

EFFECTIVE PRODUCTION RATE
HA/EPT = 3.7 ha/167.63 min.
= 1.32 ha/hr

AVERAGE TRAVEL SPEED
KM/HR = 94 m/2.25 min.
= 2.51 km/hr

1 Manoeuvre time includes turning time as well as repositioning for no reason other than to scarify unprepared ground.
2 Obstacle time includes manoeuvres for wet ground, slash, blading, hills (one directional passes) and stopping due to obstacles.
3 Downtime due to active repair includes one major breakdown (planetary gears) and one minor breakdown (hydraulic oil tank breather).
4 Miscellaneous delay is operator's personal breaks (coffee, lunch, etc.).

Figure 16. Results of Time Study - Site 2

On both Sites 1 and 2 the time elements attributed to manoeuvering and obstacles were with the scarifying discs in the raised position. The frequent occurrence of these helped reduce the need for seperate disk cleaning with the result that cleaning comprised only 1.9% of PMT for Site 1 and 0.7% of PMT for Site 2 (not stated on Figures 15 and 16).

Post-Treatment Assessment

The post-treatment assessment measured soil disturbance, width and spacing of scarification and plantability.

SOIL DISTURBANCE

Disturbance was determined by the type and amount of soil/duff modification resulting from scarification. Soil/Duff Modification categories are based upon the amount and thickness of disturbed or compressed duff, soil/duff mixture and mineral soil exposure. Table 7 gives the averages for acceptable and unacceptable disturbance while Figure 17 shows the percentage of total area contained in each soil/duff modification category (undisturbed are not illustrated). Exposed mineral soil makes up the highest percentage of acceptable disturbance created by the Donaren.

Table 7. Averages for Disturbance

Site	Acceptable Disturbance (%)	Unacceptable Disturbance (%)	Total Disturbance (%)
1	9.3	13.8	23.1
2	16.3	8.0	24.1

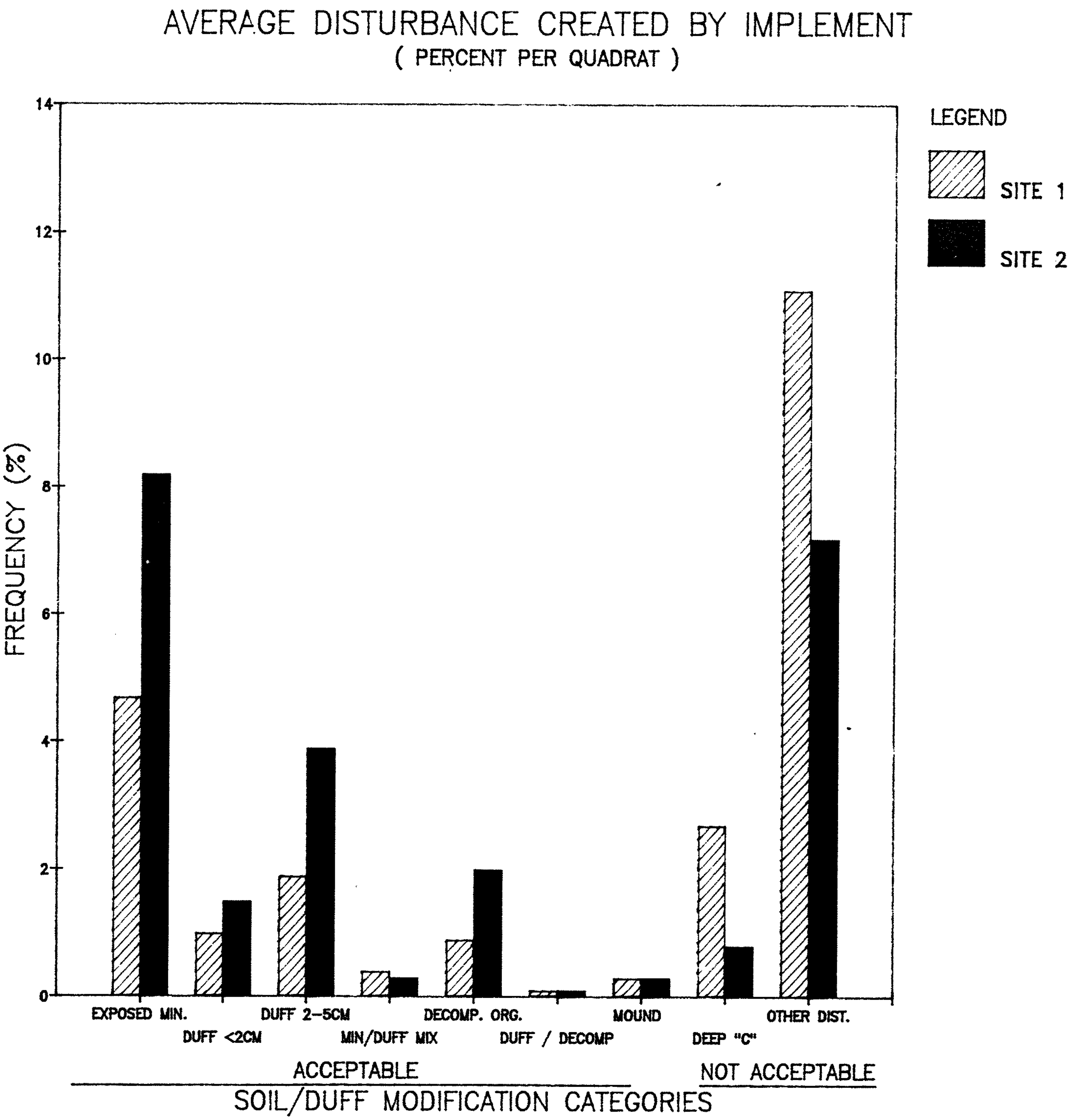


Figure 17. Distribution of Soil/Duff Modification Categories

The difference, of 9.3 and 16.3%, in proportion of acceptable disturbance between sites 1 and 2, can be explained by differences in site conditions and in machine setting. Of primary importance was the higher down- pressure setting of the discs on Site 2, 25 bars versus a setting of 0 bars or a float position on Site 1. Positive downpressure is effective in penetrating through duff and debris. On Site 1 approximately 15% of the quadrats had depth soundings of less than 15 cm of mineral soil while only 2% were limited on Site 2 (Figure 8). Shallow depths soundings were attributed primarily to the presence of subsurface stump roots which can inhibit full penetration of the discs and explain in part the reduced mineral soil exposure.

WIDTH AND SPACING OF SCARIFICATION

Average furrow spacing perpendicular to travel was 2.7 m for both Sites 1 and 2. Average spacing and widths of furrow elements are listed in Table 8.

Table 8. Width and Spacing of Scarification.

Site	Inter - Pass[a] (m)	1st Furrow Berm (m)	1st Furrow Furrow (m)	1st Furrow Gross (m)	Inter - Row[b] (m)	2nd Furrow Furrow (m)	2nd Furrow Berm (m)	2nd Furrow Gross (m)
1	1.1	0.8	0.7	1.5	1.3	0.8	0.7	1.5
2	0.9	0.8	0.7	1.5	1.5	0.8	0.7	1.5

[a] Inter-Pass: spacing between consecutive passes.
[b] Inter-Row: spacing between furrows of the same pass.

PLANTABILITY

Planting spots were assessed as plantable or non-plantable at a prescribed inter-tree spacing of 2.5 m plus or minus 10% along a row. The Donaren's disks were set to facilitate planting at a 2.5 m furrow spacing for a maximum of 1600 spots/ha. (Site 2 will be aerially seeded but plantability was assessed to compare sites). Plantable spots were described based on soil penetration, debris, micro-relief, micro-disturbance type and presence of competing vegetation. The same soil/duff modification categories used in the disturbance assessment were used for micro-disturbance. Non- plantable spots were described in terms of soil/duff modification categories and reason.

Table 9. Plantability Assessment

SITE	SPOTS PLANTABLE (No/Ha)	(%)[a]	SPOTS NOT PLANTABLE (No/Ha)	(%)[b]	TOTAL SPOTS PRESCRIBED (No/Ha)	(%)
1	1058	66	542	34	1600	100
2	1195	75	348	21	1600	100

[a] Percent plantable are based on an actual inter-furrow spacing of 2.7 m and a spot spacing along the furrow of 3.5 m and 3.1 m for Site 1 and 2, respectively.

[b] Percent not-plantable = percent total number of attempts/ha (not exceeding 100) minus percent of plantable.

The average stocking of plantable spots along the furrows, based on the ratio of prescribed to actual spacing, was 71% for Site 1 and 81% for Site 2. The average spacing of plantable spots within trenches was 3.5 m and 3.1 m for Sites 1 and 2, respectively. The total number of spots or attempts assessed along the row exceeded the prescribed spacing of 2.5 m resulting in stocking of 109% and 104% for sites 1 and 2, respectively.

The spacing of plantable spots along the furrow combined with an average spacing between furrows of 2.7 m provides a measure of density and overall stocking. Site 1 contains 1058 plantable spots/ha and Site 2 contains 1195 plantable spots/ha for respective plantability stocking levels of 66% and 75% (Table 9).

Table 10 shows the description of plantable spots. Penetration was high on both sites with only a minor occurrence of roots impeding penetration in Site 2. Roots on Site 1 were shallower than Site 2 and were often exposed when the duff was removed. Although the roots may have inhibited penetrating by the disks on Site 1, penetrating of the planting tool was not affected. Limitations to penetration caused by hidden roots occurred at a frequency of 3.5% on Site 2.

Micro-relief of plantable spots was quite variable. Plantable micro-sites on the raised relief (berms) were rare but other relief including level, sideslope and hollow were fairly evenly distributed. Level relief occurred most often with Site 1 at 37.2% and Site 2 at 38.6%. Hollow spots (trench bottom) were considered plantable if they were not exposed C-horizon soil or floodable.

Vegetative competition on plantable spots was low on both sites due to effective removal by the disks. Only 14.5% and 3.6% of plantable spots on Sites 1 and 2 respectively had any competition.

Plantable and non-plantable spot distribution based on soil/duff modification types are illustrated in Figure 18. Exposed mineral soil comprised 31.2% of all spots described for Site 1 and disturbed duff less than 2 cm thick was the most common plantable spot in Site 2 with 29.5% of all spots. The most common soil/duff modification categories for non-plantable spots consisted of either less than adequate (disturbed) or non scarified (undisturbed) area. These two categories totalled 27% and 18% on Sites 1 and 2 respectively.

Table 10. Planting Spot Description

SITE	PENETRATION OF SOIL Good (%)	Restricted (%)	MICRO-RELIEF Level (%)	Raised (%)	Side (%)	Hollow (%)	DEBRIS None (%)	Light (%)	Moder. (%)	VEGETATION COMPETITION (%)
1	100.0	0.0	37.2	2.8	31.0	29.0	89.0	10.3	0.7	14.5
2	96.5	3.5	38.6	2.4	30.1	28.9	80.5	18.3	1.2	3.6

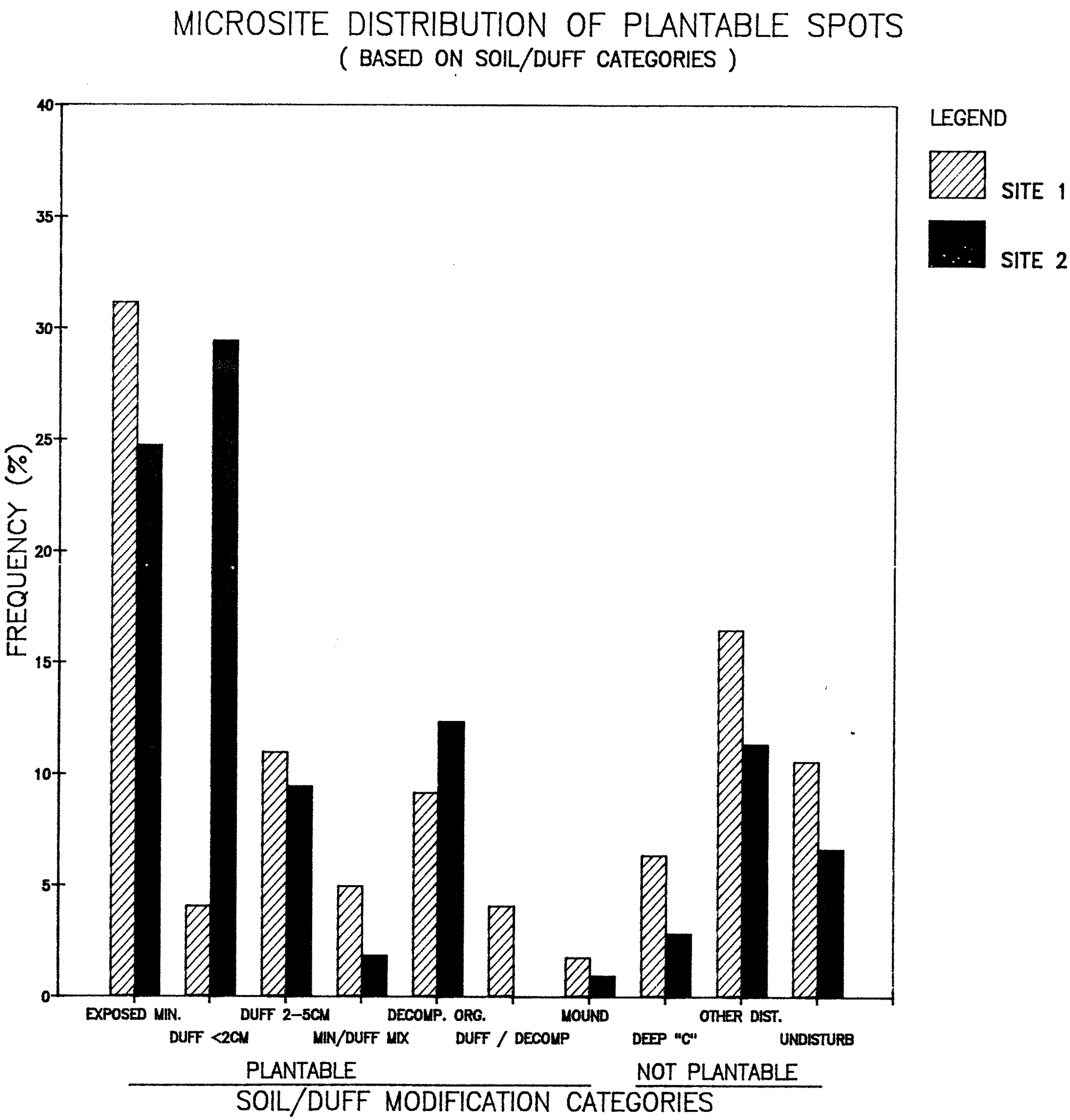


Figure 18. Distribution of Planting Spots Based on Soil/Duff Modification Categories

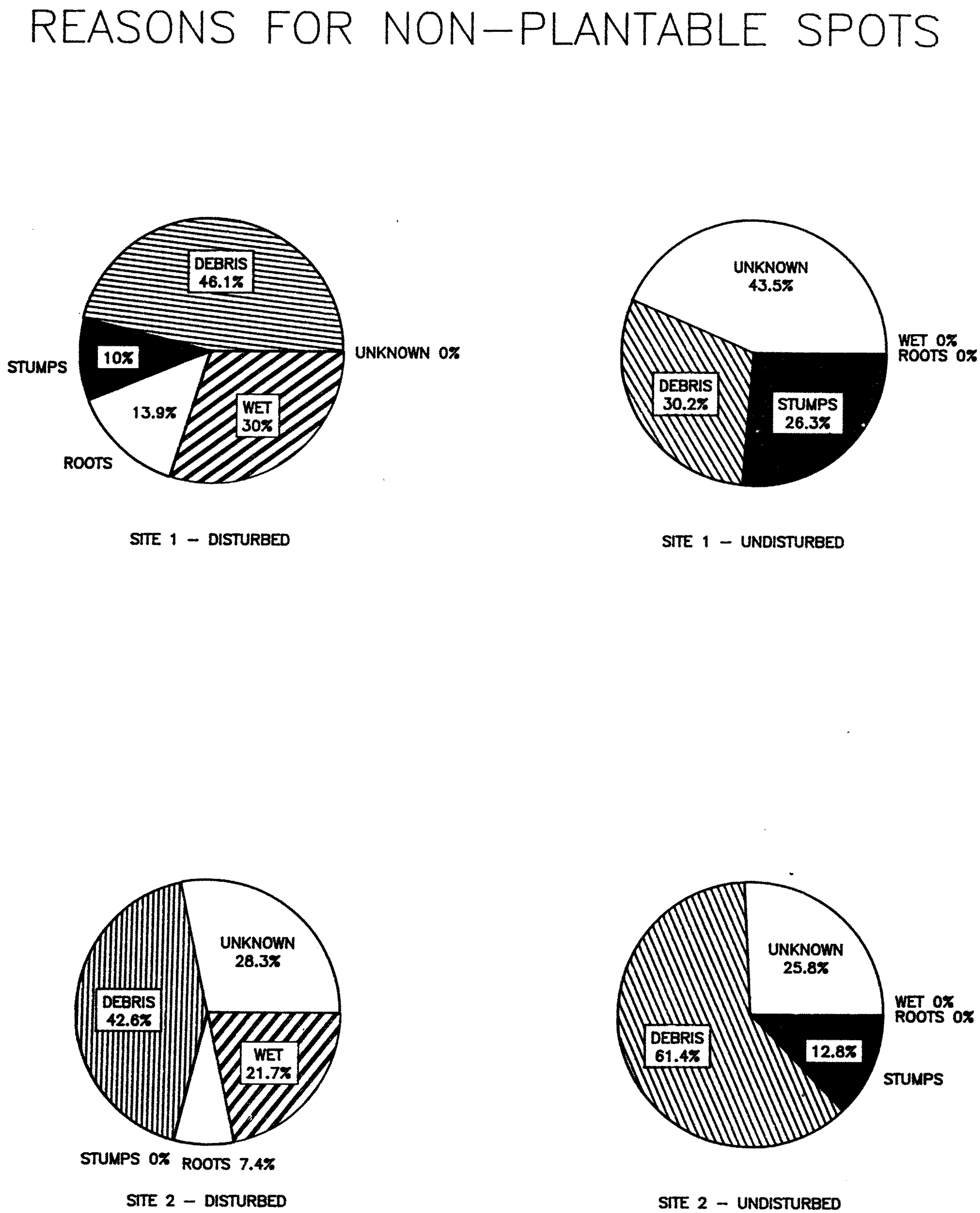


Figure 19. Reasons for Non-plantable Disturbed and Undisturbed Planting Spots.

The reason for non-plantable spots, both disturbed and undisturbed, are presented in Figure 19. Debris in the form of slash greater than 5 cm in diameter was the most common reason attributed to all non-plantable spots with the exception of Site 1, undisturbed. Of the disturbed non-plantable spots on Sites 1 and 2, 46.1% and 42.6% respectively, resulted from a debris influence.

SUMMARY AND DISCUSSION

The success of site treatment can be determined by how well objectives were met. Based on a spacing prescription of 2.5 m by 2.5 m (1600 plantable spots). Sites 1 and 2 ultimately yielded 1058 and 1195 plantable spots per hectare, respectively, or a plantability stocking of 66% and 75%, respectively. The resulting average spacing for Site 1 was 2.7 m by 3.5 m and for Site 2 was 2.7 m by 3.1 m.

Duff depths averaging 23 cm and slash greater than 5 cm in diameter appear to be the most important factors affecting scarification by the Donaren on these sites. Slash up to 10 or 12 cm in diameter broke under disk pressure and was easily transmitted away. If larger slash, laying perpendicular to travel was not re-aligned by the prime mover, it sometimes caught disk teeth preventing disturbance. Quick, responsive measures by the operator usually remedied the situation but on occasion, slash was dragged before breaking or being knocked free by a stump. Disks usually rode over large slash and stumps then returned immediately to scarifying. The operator raised disks occasionally while negotiating over larger slash. Stump density was low on both sites so their effect on the scarification produced was considered minimal. Duff and mineral soil were seldom mixed, as microsites were predominantly mineral soil covered by less than 2 cm of duff. The majority of micro-relief positions were either level, side slope or hollow.

Several possible changes in settings or operating techniques could improve the stocking of plantable spots. The most obvious one is reducing the 2.7 m average spacing between rows by making passes closer together. However, this will only improve stocking slightly. Increasing the down pressure or reducing travel speed could result in deeper penetration and increase the proportion of hollow and side slope micro-sites. However, there is a possible negative effect of this in that the proportion of microsites in the deep C-horizon or floodable hollow may increase and in deep duff conditions, side slope positions may be unstable if steep sided.

Changing the disk angle[1] such that a wider furrow is produced may be beneficial in increasing the proportion of microsites in the level or hollow position and at the same time reduce the proportion in the deep C-horizon or floodable hollows. The choice of operating technique and machine setting will also depend on whether disturbance is being produced for aerial seeding or for plantable spots.

Productivity expressed as acceptable disturbance or plantable microsites created per productive machine hour (PMH) is called silvicultural productivity (Puttock and Smith, 1986). The average silvicultural productivity rate was 1185 spots or 1042 m^2 acceptable disturbance per PMH for Site 1 and 789 spots or 1076 m^2 acceptable disturbance per PMH for Site 2.

Topography, slash and weather played important roles in machine productivity on Site 2. Almost 25% of productive machine time was spent dealing with obstacles and an additional 18% manoeuvring for the next pass. Excessive rainfall increased soil moisture to moderately wet (class 7) for the time study. This combined with steeper slopes made uphill travel difficult. Approximately 10.5% of productive machine time was spent negotiating the hill. Large slash average diameter of 18.72 cm combined with an average slash volume of 280.30 m^3/ha further reduced machine productivity. Effective productive time (EPT) was only 50.2% of productive machine time.

Site 1 with better ground conditions including an even ground surface and moderately moist soil moisture (class 4) which remained constant, combined with a lower average slash volume of 91.28 m^3/ha and an average diameter of large slash of 13.64 cm, was less restrictive to machine productivity. Effective productive time was 74.4% of productive machine time.

[1] Disk angle with respect to each arm is fixed and thus is a function of the spacing between arms.

Downtime on both sites was recorded against the prime mover. The only delay time charged to the Donaren was cleaning which was insignificant. Downtime charges to the Donaren are absent partly due to the shortness of the time study and partly due to time study scheduling which allowed faulty hydraulic hoses to be replaced before each time study commenced. Outside short-term study areas, numerous hydraulic hoses and fittings had to be replaced as a result of damage from large slash pieces and pinching by the arms when disks were raised.

The Ardco K-HSP was an effective prime mover during the time study for Site 1 but persistant breakdowns were common on Site 2. Operations off the test sites were also hampered by continual breakdowns. The lightness of the Ardco was advantageous on wet spots but proved to its detriment in its ability to withstand the stress and abuse which site preparation imposes on equipment. Despite numerous problems with the drive train the Ardco with hydrostatic drive had ample power, hydraulic flow and pressure to operate the Donaren at low travel speeds.

CONCLUSION

The Donaren 180D, mounted on an Ardco K-HSP prime mover, was tested among five participants under the Canada/Alberta Forest Resource Development Agreement from May to November, 1986. Formal assessment was performed on 2 sites which comprised a small portion of total area tested.

While stocking of plantable spots achieved on both Sites 1 and 2 was less than optimum, it is clear that the Donaren was effective in penetrating duff layers averaging 23 cm while contending with heavy slash. Increased down pressure on the disks increased acceptable disturbance in moderately severe site conditions. The powered disks transmitted debris away leaving consistantly clean furrows. When obstacles such as large slash and stumps were encountered, disks rode over smoothly and returned to the ground immediately afterwards.

Raised microsites or berms were infrequent and were mostly non-plantable being airy and intermixed with slash. Plantable spots on other micro-relief types were fairly evenly distributed. If a higher portion of raised microsites and higher stocking are desireable, measures must be taken to modify operating characteristics of the Donaren.

Comparability between productivity, disturbances and plantability results was not possible between Sites 1 and 2 due to variation in site parameters such as slash, slope, soil moisture and depth. Ironically, Site 2 with more-difficult pre-treatment conditions and poorer productivity had a higher percentage of acceptable disturbance and plantable spots. The use of positive down pressure on the discs on Site 2 helps to demonstrate the Donaren's ability to penetrate slash and duff to create plantable spots and acceptable seedbeds. The poorer productivity, though, increased scarification costs proportionately.

While the Donaren was well suited to both moderate and severe conditions the Ardco prime mover was better suited to Site 1 with a moderately light slash loading and even ground surface. Productivity on this site was approximately 1 hectare per hour. The excessive frequency of repairs experienced on the Ardco outside the test areas increased on more severe sites. Utilization and availability were generally low but improved by the season's end.

The Ardco K-HSP prime mover failed to achieve the level of mechanical availability presently expected from conventional log skidders doing site preparation work. Unless mechanical availability improves the Ardco will not be adopted over skidders as a prime mover even though the unit was a good match for the Donaren and did offer the advantage of a higher power to weight ratio than skidders of equivalent size class. On sites where wet conditions limit site preparation to winter operations the Ardco/Donaren combination offers the potential for lower cost summer treatment.

SINKKILA HMF SCARIFIER MOUNDER

The Sinkkila was brought into Alberta from extensive performance trials in British Columbia and given a short term test to evaluate its ability to treat clay type soils for planting. The machine experienced severe hydraulic problems with the right lock/release valve. These problems were not easily correctable and eventually lead to overheating of electrical sensors which further degraded performance.

The malfunction resulted in a high percentage of missed attempts where neither scalps nor mounds were created. Of the mounds created, very few (8.6%) were considered plantable. Plantable spots, including both scalps and mounds, averaged approximately 950 per hectare. Of the mound attempts made 40.0% had been dragged an average distance of one metre beyond the scalp by the right mattocks, and 32% by the left mattocks. Some mounds were also spiralled (rolled-up like a carpet) but were still hinged to the scalp.

Although, desirable results were not achieved with the Sinkkila HMF scarifier due to malfunctions and a hard soil (solonetzic), there is promise that it may perform well on more penetrable moist sites. More extensive testing on Alberta clay soils in a variety of site conditions is needed to further evaluate its potential.

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APPENDIX A

DONAREN 180D POWERED DISK TRENCHER*

TECHNICAL DATA:

Measurement:

Disc diameter	950 mm (37.4")
or	1050 mm (41.3")
Outer measurement, tooth edge	1250 mm (49.2")
or	1350 mm (53.1")
Track spacing	1500-2750 mm (59.0"--108.2")
Track width	600-800 mm (23.6"--31.5")
Maximum movement up:	1200 mm (47.2") above horizontal position
down:	1250 mm (49.2") below horizontal position

Weight:

Gross weight: 2300 kg (5070 lbs.)

Discs:

Number of replaceable teeth/disc 10

Discs and teeth are designed for automatic slash removal.

Arms:

The arms have three (3) work positions:
- Work position with stepless loading pressure 0-40 bar (0-580 psi)
- Floating position with 0-pressure.
- Transport position.

The arms ad disc bearings are strongly built and are designed to give extensive moveability both upwards and to the side.

Hydraulic System:

Required hydraulic pressure:	Max. 170 bars (2470 psi)
Required flow	70 l/min. (19 gals/min)
Variable disc rotation (driven version):	Between 15-30 rpm

Hydraulic motors for the driven discs can be driven in three ways:
1. directly from the tractor's pump.
2. from a separate pump mounted on the shaft from the power take-off.
3. from a separate diesel motor with a pump.

Electrical System:

Current - 24 or 12 V

Electrical control panel conveniently placed in the driver's cab for desired working positions.

Power Requirement:

Engine power required is approximately 90-115 kw.

*Extracted from Donaren Brochure

APPENDIX A

ARDCO K-4 x 4

ENGINE 4-53 Detroit Diesel 130 HP @ 2800
Optional - 300 Ford Industrial Gas 120 BHP @ 2800
- 6v-53 Detroit Diesel 210HP*
- 3150 Caterpiller Diesel

TRANS. New Process 5 speed manual transmission
Optional - Clark 285V 5 speed manual
- Allison MT 653 5 speed automatic
- Sunstrande Full Hydrostatic Drive*

AXLES Rockwell Model 204 planetary drive no-spin front and conventional rear
Optional - Rockwell Model PR 120 planetary drive

TIRES 66 x 43:00 - 25,6 or 10 ply Goodyear Terra Tire*
Optional - 23.1 x 26,8 or 10 Ply Power Torque
- 67 x 34:00 - 25 Goodyear Flo-Grips

FRAME Heavy duty steel frame with articulated centre joint and trunnion ±40 degree turn and ± 20 degree roll. (K-HSP was shortened and adapted for mounting Donaren 180D).

BRAKES Hydraulic driveline disc brake with mechanical actuated park brake
Optional - Rockwell in wheel air/hydraulic enclosed wet disc brake

WINCH 15,000 lb. Ramsey Model 700L, front mounted, P.T.O. driven complete with 125' of 5/8" cable tailchain and hook

CAB 3 man cab, centre mounted, steel welded construction, fully insulated
Optional - 5 man centre mounted
- 2 or 4 man front mounted (with automatic trans only)
- 12 man front mounted
- 1 man cab with forestry brush guarding.*

ELECT. 12 volt system, 85 amp. alternator, 8D heavy duty battery, lighted gauges
Optional - highway lighting, beacon and spotlight

MISC. Brush guard and bumper, skid plate, 60 gal. fuel tank, 8' wide x 10' long cargo carrier, radiator shutters, optional color, blade

OPERATING CHARACTERISTICS:

Maximum Speed	25 mph	35 km/h
Turning Radius - Inside	10 ft.	3,000 mm
- Outside	18 ft.	5,500 mm
Ground Clearance	22 1/2 in.	572 mm
Vehicle Weight	13,000 lb.	6,000 kg
Payload	10,000 lb.	4,500 kg
Gross Weight	23,000 lb.	10,500 kg

*NOTE: A special model called **K-HSP** has been designed to accommodate the special requirements of silvicultural contractors.

APPENDIX A

JOHN DEERE 740 A
740 A SKIDDER SPECIFICATIONS

Rated Power @ 2200 rpm: SAE
Net . . . . 152 hp (113 kW)
Gross . . . . 167 hp (125 kW)

Engine: John Deere 6-466A
Type . . . . 4-stroke cycle turbocharged and intercooled diesel
Bore and stroke . . . . 4.56 x 4.75 in. (116 x 121 mm)
No. of cylinders 6
Displacement . . . . 466 cu. in(7.638 L)
Maximum net torque @ 1200 rpm . . . . . 507 lb-ft (687Nm) (70.1 kg-m)
Cooling fan . . . . Blower
Compresion ratio . . . . 15.5 to 5
Lubrication . . . . Pressure system w/full flow filter
Air cleaner w/restriction indicator . . . . Dry
Electrical system . . . . 12-volt w/alternator
Batteries (two) . . . . Reserve capacity: 180 minutes each

Differentials:
Front and rear . . . . Full differentials w/hydraulic look

Engine Clutch Disconnect:
Hand-operated, spring-loaded, dry-disk. Single plate, 12.88 in. (327 mm).

Transmission:
Power Shift with planetary gears, hydraulically actuated wet-disk clutches and brakes; provides 8 speeds forward -- 4 reverse. Controlled by single lever. Pressurized lubrication.

Travel Speeds (2200 engine rpm, no tire slip):

	Km/h
Forward	2.6-30.0
Reverse	3.2-9.3

Drive Axles:
Four-wheel drive with inboard planetary gears on all axles. Fron axle oscillates 15 degrees above and below horitonatl. (632 mm) total travel at tire center line at narrrowest tread.

Steering: Power
Articulated frame hydraulically actuated by dual cylinders. Steering system had hydraulic pressure priority.
Turning radius . . . . 17 ft. 5 in. (5.31 m)
Turning clearance circle . . . . 37 ft. 1 in (11.30 m)
Wheel rotation, max. left to max. right . . . . 3 turns

APPENDIX A

JOHN DEERE 740 A
740 A SKIDDER SPECIFICATIONS (Cont'd.)

Brakes:
Service . . . . Wet-disk brakes
Winching . . . . Manually locked service brakes
Parking . . . . Foot-operated mechanical

Hydraulic System:
Closed center, constant presure. Variable-displacement pump driven from crankshaft . . . . 34 gpm (2.14L/s), 2000 psi (13 790 KPa) (140.6 kg/cm^2) at 2200 engine rpm.
Externally mounted transmission driven gear pump . . . . 20 gpm (1.26 L/s) @ 2200 engine rpm provides charge oil to main hydraulic pump.

Tire:
24.5-32, 16-PR, Kevlar, LS-2
30.5-32, 12-PR, logging, double bead, LS-2
30.5-32, 16-PR, steel ply, double bead, LS-2
30.5-32, 16-PR, Kevlar, LS-2

Capacities:	Liters
Fuel tank	204.4
Cooling system	45.4
Engine lubrication, including filter	18.9
Transmission and winch	91.6
Front differential	24.6
Rear differential	24.6
Hydraulic sump tank	68

SAE Operating Weight. . . . . 30,200 lb. (13 698 kg)

APPENDIX B*

MACHINE TIME FORMULAS

The following formulas were used to calculate utilization and mechanical availability (Folkema et al. 1981):

Utilization $= \frac{\text{PMH (in shift)}}{\text{SMH}} \times 100\%$

Mechanical Availability $= \frac{\text{PMH}}{\text{PMH + repairs + service}} \times 100$

(PMH, repairs and service include both in- and out-of-shift activities)

CPPA Availability $= \frac{\text{SMH-(repairs + service + wait [parts+mechanic]) x 100}}{\text{SMH}}$

(Repairs and service include only in-shift)

PMH = productive machine hours
SMH = scheduled machine hours
CPPA= Canadian Pulp and Paper Association

DEFINITION OF TIME ELEMENTS

The productive machine hours (PMH) recorded in the continuous time study were broken down into the following elements. Note that the time study data are separated into shift level availability and productivity elements for reference to day-to-day operations as well as short-term study elements for more detailed analyses.

Shift level availability and productivity elements

Scheduled machine hours (SMH): Nominal statement of intent for regular machine activity (e.g., 8-hr shift). It usually correspondes to operator's paid on-job time.

Productive machine time or productive machine hours (PMH): That part of total machine time during which the machine is performing its function.

Active repair: Repair consists of mending or replacement of part(s) in consequence of failure or malfunction. It also includes modifications or improvements to the machine.

Service: Service is routine and preventive maintenance performed to maintain the machine in satisfactory operational condition.

Delay (greater than 15 min.): That portion of SMH during which the machine is not performing its primary function for reasons other than active repair and service. Delay time is divided into:

*Appendix B is extracted from Puttock and Smith, 1986.

Nonproductive operating time: Period of in-shift time during which the machine's engine is running but the machine is doing something other than performing its primary function.

Waiting for mechanic(s): That in-shift time during which the machine is broken and is not under repair because of the unavailability of mechanics(s).

Waiting for part(s): Period of in-shift time during which the machine is broken and is not under repair because of the unavailability of mechanics(s).

Miscellaneous delay: Period of in-shift time during which the machine engine is not running for reasons other than for active repairs and service and/or waiting for repairs and service.

Short-term Study Elements

Effective productive time (scarify): Begins when the implement is in the soil and the prime mover begins forward travel. Does not include delays.

Maneuver (turn): Occurs from the time the scarifier has finished a pass until the scarifier begins the next pass. This element may include raising the implement from the ground, turning and then lowering the implement.

Obstacle delay: Occurs from the time the scarifier stops because of an obstruction until scarification resumes.

Travel: Is the time spent a) travelling in the block or to the roadside between breaks, and b) on repairs. It also includes travelling (if under 15 min.) between sites.

Delays (less than 15 min.): Same as delays (greater than 15 min.) but includes those times less than or equal to 15 minutes. Short-term delays are part of tota productive machine time whereas delays over 15 minutes are not considered part of productive time.