EVALUATION OF THE BRACKE MOUNDER IN THE NORTHERN CLAY SECTION

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ABSTRACT

The Bräcke Mounder was evaluated on eight sites in Rowe's Northern Clay Section in Quebec that were characterized mainly by underlying compact clay-silt hardpan. Machine productivity ranged from 0.6 to 0.9 ha per productive machine hour. Of all patches, 27% had mineral soil capping on inverted LFH, 11% had mineral soil capping on mineral mounds, and 17% of the caps were deposited directly on the clay-silt mineral-soil base. Of the patches with caps (61%), a large proportion (89%) had a mineral soil volume between 0.3 and 8 L. Stumps and roots or slash interfered with spade penetration and resulted in poor mounding in 13-42% of the cases.

Of all patches, 15% had only a plantable spot created by the spade, 29% had the choice of plantable spots created by the spade and another source (i.e., the mattock wheel or the prime mover), 33% had only a plantable spot created by a source other than the spade and 23% had no plantable spot. The overall plantability was 80%, ranging from 50 to 90% among the site conditions.

The types and quantities of disturbances and the proportions of plantable microsites created by the Bräcke Mounder varied depending on site factors. The results generally became more acceptable as the depth of silty loam overtopping the hardpan increased. With the 17-tooth-gear setting selected in this trial, the addition of the spade produced more plantable spots than if the sites had been treated by the regular Bräcke two-row Cultivator alone. However, these plantable spots were often similar to those normally produced by the Bräcke mattock.

RÉSUMÉ

Le scarificateur Bräcke Mounder fut évalué sur huit conditions de terrain(s) dans la section des Argiles de Rowe au Nord du Québec characterisées par un horizon sousjacent d'argille-silt compact. La productivité variait de 0.6 à 0.9 ha par heure machine productive. De tous les poquets, les calottes de sol mineral étaient placées à 27% sur une LFH inversée, à 11% sur un monticule de sol minéral et à 17% directement sur la base de sol mineral originale. Parmi les poquets qui possédaient une calotte de sol mineral (61%), une portion importante (89%) avait un volume de sol mineral entre 0.3 et 8 L. Souches et racines ou debris ligneux gênèrent la pénétration de la pelle, résultant en de pauvres monticules dans 13-42% des cas.

De tous les poquets, 15% avaient seulement un microsite plantable créé par la pelle, 29% avaient un choix entre un microsite plantable

créé par la pelle ou par une autre source (roue à dents ou engin porteur), 33% avaient seulement un microsite plantable créé par une source autre que la pelle et 23% n'avaient aucun microsite plantable. Les possibilités de planter étaient de 80% et variaient de 50 à 90% entre les sites.

Le genre et la quantité de microsites créés par le Bräcke Mounder variaient dépendant des conditions de terrains. Les résultats étaient généralement plus acceptable à mesure que le loam limoneux couvrant la base de sol compact s'épaississait. Au montage de 17-pignons choisi dans cette étude, l'addition de la pelle produisit plus de microsites plantables que si seulement le Bräcke two-row Cultivator avait été utilisé. Cependant, ces microsites étaient souvent semblable à ceux produits normalement par la roue dentée du Bräcke.

TABLE OF CONTENTS

ACKNOWLEDGMENTS

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INTRODUCTION

The benefits of mounds as a planting microsite have been discussed by many authors (Pohtila 1977; Söderström 1977; Söderström et al. 1978; Berg 1980; McMinn 1982, 1983; Sutton 1983, 1984; Wood et al. 1988; and footnotes 1, 2, and 3). These reports covered different soil textures, tree species and climatic regions. They reported on **handmade mounds** placed on mineral or organic patches or furrows, and recommended that mechanized methods for producing mounds be developed. One such development is the Bräcke Mounder, a Swedish implement based on the Bräcke two-row Cultivator. The purpose of mounding rather than simply using the patch alone is, in part, to create a higher spot for planting, especially on sites prone to late or early frosts, and, in part, to produce a greater volume of mineral soil, which may help growth of the stock. Swedish studies of the Bräcke Mounder (Edlund 1980, Bäckström 1981, Edlund and Jönsson 1986, Adelsköld 1986) have been very encouraging. However, Canadian studies (Brewis 1984, Zroback 1985, Heidersdorf and Ryans 1986, Hedin 1987, Sutherland 1989, and footnote 4) indicate the need for modifications to the equipment to produce, with regularity, the type (mineral on mineral or mineral on inverted LFH) and size (15-20 L) of mound suggested by studies of manual mounding.

In 1984 and 1985 the Mechanization of Silviculture Unit of the Great Lakes Forestry Centre (GLFC), in cooperation with the Ministère de l'Énergie et des Ressources du Québec (MERQ), conducted an evaluation of the Bräcke Mounder. In Quebec the use of the Bräcke two-row Cultivator by MERQ had proven only partially successful on sites similar to those described in the present studies as a result of variations in the amount of mineral soil disturbed by the mattock wheel at each patch for the spacing required. The present study was designed to evaluate the ability of the Bräcke Mounder to produce plantable microsites in areas characterized by a deep, compact clay-silt hardpan overtopped by a silty

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[1] Draper, D., Binder, W., Fahlman, R. and Splittlehouse, D. 1985. Post-planting ecophysiology of interior spruce. Seminar on Interior Spruce Seedling Performance: State of the Art, 5-6 Feb. 1985. Northern Silvic. Comm. 19 p. unpublished.

[2] McMinn, R.G. 1985. Mechanical site preparation and spruce performance. Seminar on Interior Spruce Seedling Performance: State of the Art, 5-6 Feb. 1985. Northern Silvic. Comm. 5 p. unpublished.

[3] Reid, D.J. 1984. R_6 Yearly Report 1984 for the forestry research project mineral mound and humus mound planting in the boreal forest of Ontario. 26 p. file report.

[4] Parolin, R.W. 1986. Upper-halfway trials of Bräcke Mounder. Industrial For. Serv. Ltd., Prince George, B.C. 15 p. unpublished.

loam and duff layers. Expectations were that the spade behind the mattock would disturb additional mineral soil in each patch to produce a plantable spot more regularly or that the spade would produce a cap of mineral soil on inverted LFH to broaden the choice of plantable microsites and possibly increase the number of plantable spots per hectare.

METHODS

Location

The study area was located in Canton Noyelles 100 km northwest of Lebel-sur-Quévillon, Quebec (Fig. 1) in the Northern Clay Section (B.4) of the Boreal Forest Region (Rowe 1972).

Prior to harvest, the stands were almost pure black spruce (*Picea mariana* [Mill.] B.S.P.), 15 m tall and 60-80% stocked, with pockets of trembling aspen (*Populus tremuloides* Michx.). According to the Forest Ecosystem Classification for the Clay Belt (Jones et al. 1983), the stands were mainly OG5 (V8 vegetation type and S8 soil type) and others such as OG3 (V8 and S12), OG8 (V8 and S12) and OG9 (V9 and S12). Stand age was between 90 and 120 years. Full-tree harvesting was carried out in most of the area in 1982 and 1983, and a conventional tree-length cut-and-skid operation was conducted in the small, wet areas.

Scarifier and Prime Mover

A schematic of the Bräcke Mounder and the prime mover is shown in Figure 2. Additional specifications are listed in Appendix A. The Bräcke Mounder is similar in operation to the Bräcke two-row Cultivator (Smith et al. 1985), but has an added hydraulically operated spade behind each mattock wheel (Fig. 3). The Bräcke Mounder is a whole implement in itself, not an attachment.

Mounding is done in two stages. Immediately after the creation of a scalp and an inverted LFH by the mattock teeth, the spade is activated by the mattock wheel and digs into the scalp hole to bring up subsurface material onto either the patch shoulder or the inverted LFH. Patch length and number can be varied by manually changing the gear ratio in the chain drive. The unit has three sprocket combinations, each with four tines per mattock wheel: a 15-tooth gear (producing the longest scalp, approximately 2000 scalps/ha at an interfurrow spacing of 2 m), a 17-tooth gear (medium spacing, 2500 scalps/ha), and a 19-tooth gear (shortest spacing, 3000 scalps/ha). Only the 17-tooth setting was used in this trial. A diesel power unit mounted on the implement provided hydraulic power to operate the spades and to lift the mattocks for maneuvering. Both operations were controlled from the prime mover cab with a radio device. Technical data on the scarifier are provided in Appendix A.

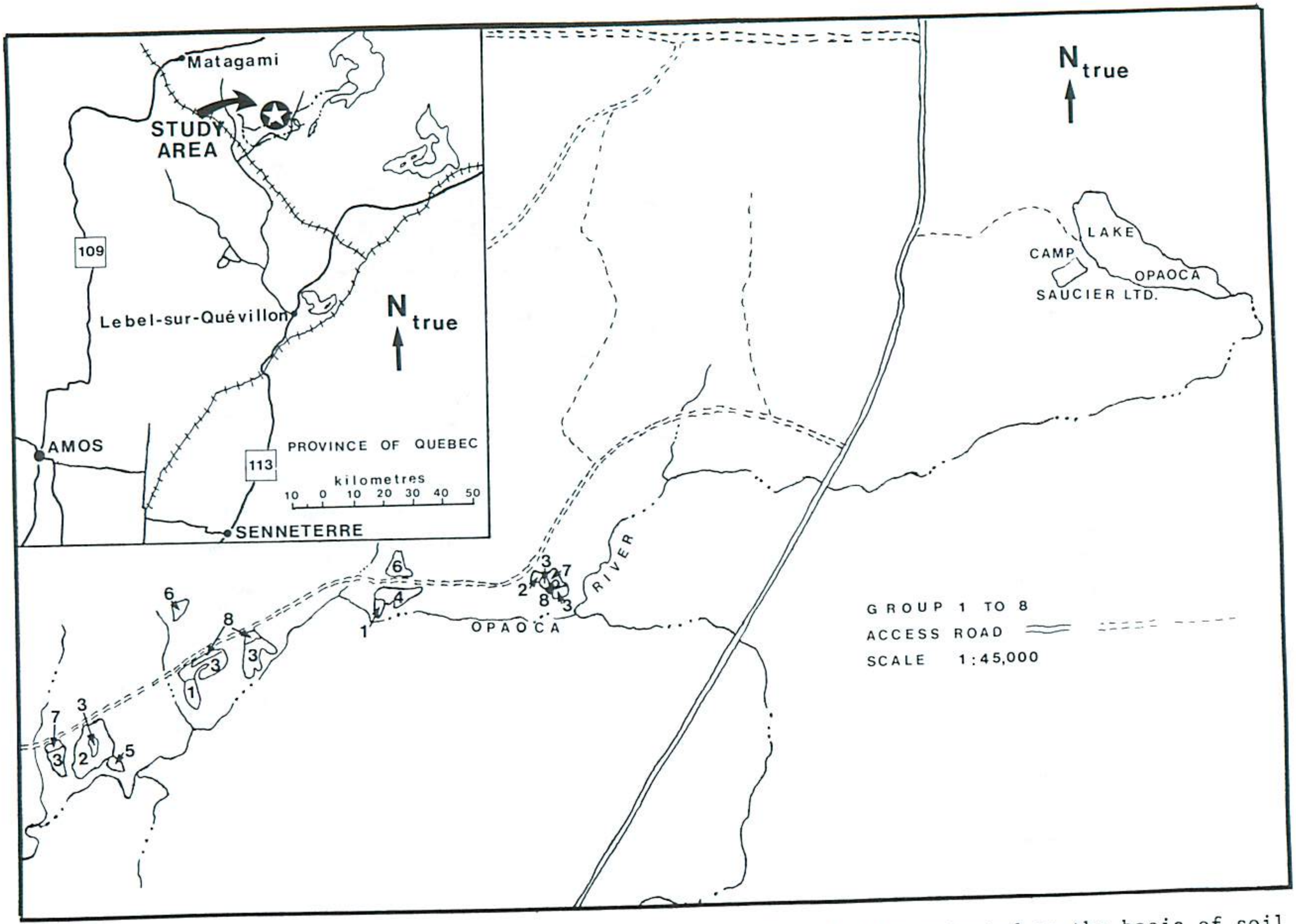


Figure 1. General location of study area and the eight groups of sites selected on the basis of soil characteristics.

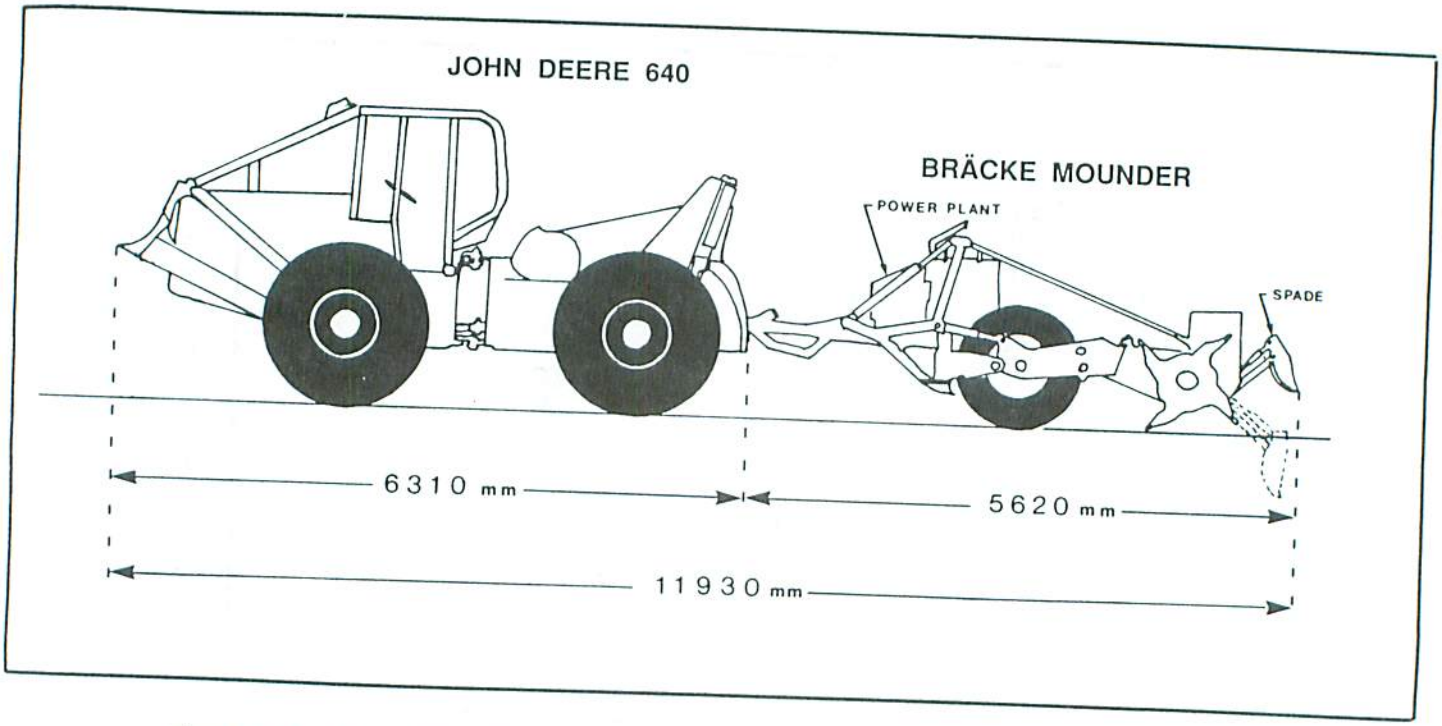


Figure 2. Overall dimensions, major components and working position of the Bräcke Mounder (implement redrawn from Wickström [1981]).

Figure 3. The hydraulically operated spade behind the mattock wheel.

The Bräcke Mounder was towed by a John Deere 640 cable skidder with an eight-speed forward direct-drive transmission. The prime mover was modified for site preparation by the addition of an enclosed cab, an additional transmission cooler and an increase in engine power from 82 to 93.3 kW (net, Society of Automotive Engineers [SAE]). Conventional tires (Firestone 74 x 30.5-32) were used. Ring-type tire chains were mounted on front and rear tires. A quick-disconnect "Bräcke-type" hitch was used for attachment to the prime mover.

Assessment Procedure

The procedures used for pretreatment assessment and time studies are described in Sutherland (1986). In summary, pretreatment sampling involved randomly located transects of 20 quadrats (each 2 x 2 m) scattered over the area to measure the site variables listed in Table 1. The resultant information was then regrouped into eight groups on the basis of duff layer thickness, depth of silty loam overtopping the clay-silt base, moisture regime and slope (see Table 1).

Continuous time studies were carried out during operation of the equipment to determine the distribution of time elements (defined in Appendix B), productivity per productive machine hour and average travel speed. Data for operational areas were summarized on the basis of moisture regimes (trafficability) and slope. The study was of relatively short duration (approximately 58 hours) and, therefore, only short-term information on the operating characteristics of the machine was reported.

For the post-treatment assessment, random transects of 10 quadrats (each 2 x 2 m) perpendicular to the direction of machine travel were used to assess disturbance in September 1984. The same transects were used to assess physical characteristics (see Fig. 6) such as cap (mineral soil heap created by the spade) depth (at the deepest point); the area of the mineral cap, the mineral mound (mineral soil heap created by the mattock wheel) and the inverted LFH; the reason for a poor mounding process; and the plantability of each patch that intersected the transect. The same microsites were assessed for plantability alone in May 1985 in order to observe the effect of weathering on the hard clay-silt caps produced by the mounder spade. Only the May 1985 plantability results are reported here, as the caps broke up over the winter.

In the plantability assessment, non-plantable microsites included disturbed or undisturbed duff thicker than 5 cm, open water, slash and mineral soil shallower than 3 cm over duff. Acceptable microsites included exposed mineral soil capable of being penetrated by the planting tool, penetrable capped or mounded mineral soil with a volume of at least 0.3 L (10 x 10 cm and 3 cm deep), a mix of loose mineral soil and duff over a penetrable mineral soil with a combined depth of more than 3 cm, duff of less than 5 cm depth over organic matter (Oh), organic matter over penetrable mineral soil with a combined depth of more than 3 cm, and loose mineral soil with a volume of at least 0.3 L over inverted or non-inverted duff (LFH) (see Table 7). Other criteria such as the stability of the cap on duff were also considered. The microrelief of a spot was considered not acceptable if it was anticipated that it would be under water during certain periods of the year.

To determine the usefulness of the spade, each patch was assessed for both the plantability that originated from the spade and the plantability that originated from one of the other sources (i.e., the mattock wheel or the prime mover during scarification, or logging/natural disturbance). There were four possibilities: 1) a plantable spot created by the spade and no plantable spot created by the other sources, 2) no plantable spot created by the spade and a plantable spot created by one of the other sources, 3) a plantable spot created by the spade and a plantable spot created by one of the other sources, and 4) no plantable spot from the spade or the other sources. The assessors did not have to determine if the plantable spot created by the spade was preferable to the one created by the other sources or vice versa.

Because of the mineral soil type (clay-silt and silty loam) that was exposed, loose, mounded, or capped by the spade or the other sources, the volume of soil was not always the primary criterion for selecting the best plantable spot or determining if the spot was plantable at all. For example, the insertion of a seedling in exposed clay-silt was often not acceptable whereas on other occasions the silt component was sufficient to permit that insertion. That forced the assessors to look at each plantable spot created by the spade (if there was one) in each patch and, using their judgment, to select the best. The same procedure was used for the plantable spots that originated from the other sources. The final number of patches per hectare was established on the basis of the furrow spacing multiplied by the number of patches along 50 m of furrow.

RESULTS AND DISCUSSION

Site Conditions

Soil and Ground Conditions

The eight soil-characteristic groups are described in Table 1. Five of the eight groups (1, 2, 3, 7 and 8) were underlain by a compact clay-silt hardpan at a depth between 5 and 15 cm. Groups 4 and 5 were also underlain by the clay-silt hardpan but this was reached only irregularly by the spade as a result of a deeper duff layer (30 cm) and silty loam or medium sand in group 5 and deep silty loam in group 4. Group 6 was located on an esker, with 30% slopes and a coarse, cobbly sand base topped by a medium depth (15 cm) of loamy fine sand; the stoniness covered 62% of the area. Group 8 was characterized by a medium depth (15 cm) of organic matter (Oh) sitting on the compact clay-silt hardpan.

Table 1. Pretreatment site conditions.

	Group							
	1	2	3	4	5	6	7	8
Avg depth of duff (LFH + moss) (cm)	5 (shallow)	15 (medium)	15 (medium)	5 (shallow)	30 (deep)	5 to 15 (shallow to medium)	15 (medium)	15 (medium)
Avg depth (cm) and texture of mineral soil or type of organic matter overtopping the clay-silt or sand mineral-soil base	5 (shallow) silty loam	5 (shallow) silty loam	15 (medium) silty loam	30^a (deep) silty loam/ loamy fine sand	15 (medium) silty loam/ medium sand	15 (medium) loamy fine sand	0	15 (medium) organic (Oh)
Texture of the mineral-soil base	hardpan clay-silt	hardpan clay-silt	hardpan clay-silt	hardpan clay-silt	hardpan clay-silt	cobbly coarse sand	hardpan clay-silt	hardpan clay-silt
Stoniness^b	-	-	-	-	-	62%	-	-
Ground moisture	fresh	fresh	fresh/moist	dry/fresh	moist	dry	moist/wet	moist/wet
Ground roughness^c	1	2[1]	2[1]	2[1]	1[2]	2[1]	2	2
Slope (%)	2	2	5	5	2	30	2	2
Ruts from logging	none	few	few	none	none	none	few	frequent
CPPA Terrain Classification^d	3.2.1	3.2.1	3.2.1	3.2.2	5.2.1	1.3.3	4.2.1	4.2.1
FEC Operational Group (OG) with vegetation and soil type^e	OG5 V8-S8	OG5 V8-S8	OG5 V8-S8	OG5 V8-S8	OG5 V8-S8	OG3 V4-S4	OG8 V8-S12	OG9 V9-S12

(cont'd)

Table 1. Pretreatment site conditions (concl.).

	Group							
	1	2	3	4	5	6	7	8
Slash:								
no. of pieces/2 m of lineaal tally								
diam. 1-5 cm	2.6	2.2	2.7	2.5	2.8	3.1	2.0	2.1
diam. >5 cm	0.7	0.6	0.5	0.5	0.5	0.5	0.4	0.3
volume (m^3/ha)								
diam. 1-5 cm	5.1	4.3	5.2	4.9	5.5	6.2	3.7	4.1
diam. >5 cm	38.2	33.4	24.1	32.8	36.6	40.8	13.3	15.7
total	43.3	37.7	29.3	37.7	42.1	47.0	17.0	19.8
quadratic mean diam. (cm) of pieces with diam. >5 cm	9.2	9.7	8.6	10.5	11.5	11.7	7.1	9.9
depth (cm)	4	5	6	4	4	8	6	4
Stumps: density (no./ha)	2125	1792	1455	1167	1312	750	1082	1200
diameter (cm)	17	20	18	22	21	26	15	20
height (cm)	13	22	19	17	15	22	16	21

[a] Soil depths > 31 cm were recorded as 35 cm. The reported average is for the zone between 0 and 35 cm.

[b] Stoniness was determined by inserting a steel rod into the soil every 2 m in each quadrat. The presence of stones was recorded if a stone or boulder was encountered within the first 35 cm of mineral soil.

[c] The Swedish terrain classification system (Anon. 1969) was used. Square brackets refer to a class that occurred in >10 % of the sample area. Ground roughness includes stumps as well as surface rocks, boulders, overturned stumps and depressions.

[d] Mellgren (1980)

[e] Jones et al. (1983)

Soil moisture was also an important factor affecting the type of microsites produced by the Bräcke Mounder in the different groups. Although the clay-silt hardpan made it virtually impossible for the equipment to bog down, logging had caused rutting under moist and wet site conditions. A summary of the soil and ground conditions is found in the fold-out page at the end of this report and it is recommended that this be unfolded for use while the report is being read.

Slash, Stumps and Vegetation

Loadings of slash (1-1.5 years old) were very light, and were comparable with the figures for a site logged by the full-tree method described by Smith et al. (1985) for the Bräcke two-row Cultivator. Such quantities of slash have not been shown to have an adverse affect the creation of microsites by the regular Bräcke. The same statement can be made with respect to the stump characteristics.

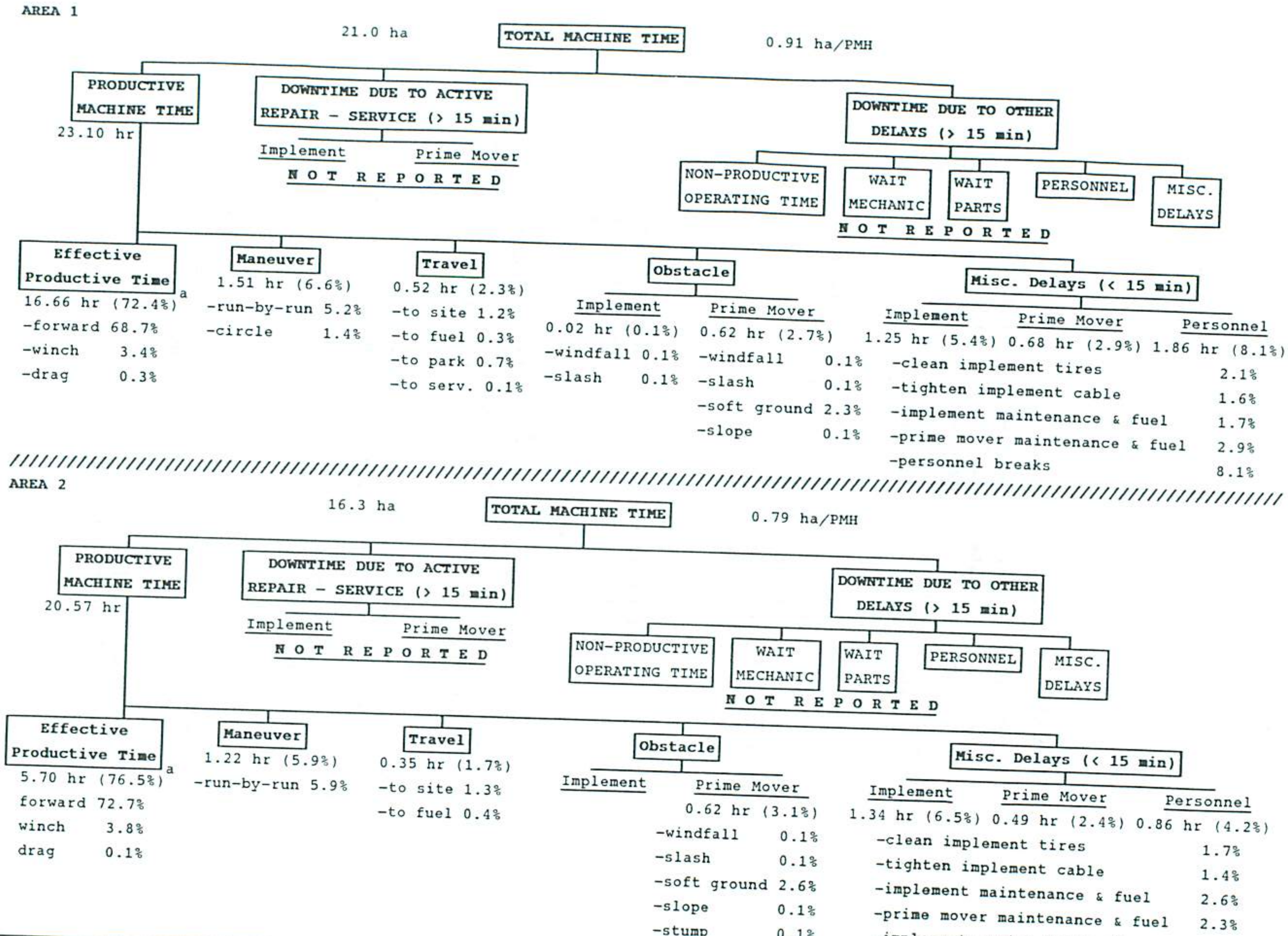
All the scarified soil-type groups were free of residual timber, and had only infrequent patches of black spruce advance growth. The minor vegetation, composed of Ericaceous shrubs, was not considered to be an obstacle in the creation of microsites.

Work Study

Because of their small size, individual groups could not be treated separately, nor could the scarifier be reset every time the machine crossed group boundaries; as a result, the time-study data were summarized by treatment areas. The first area, consisting of groups with a fresh moisture regime, covered portions of groups 1, 2, 3 and 4 and totaled 21.0 ha. The second area (16.3 ha) covered fresh, moist and wet portions of groups 1, 2, 3, 7 and 8. The third area (5.5 ha) was located on the moist-to-wet portions of groups 3 and 7. The last area (7.8 ha) covered group 6 (slope up to 30%).

In the first area, good support for the skidder and the tool plus the use of a concentric-circle treatment pattern gave the highest productivity, 0.91 ha/PMH (productive machine hour) (Fig. 4). For area 2, in which most of the soil-type groups were present (except slopes and large areas of wet ground), productivity averaged 0.79 ha/PMH (Fig. 4).

In area 3, moist-to-wet conditions reduced productivity to 0.63 ha/PMH. A high proportion (10.4%) of time was spent on winch scarification (i.e., a situation in which the implement had to be released by the skidder because of insufficient traction, for example, and was later pulled back to the skidder with the winch) and stopped as a result of obstacles such as soft ground (9.0%) (Fig. 5). High-flotation tires on the prime mover might have reduced these problems. In area 4, the effect



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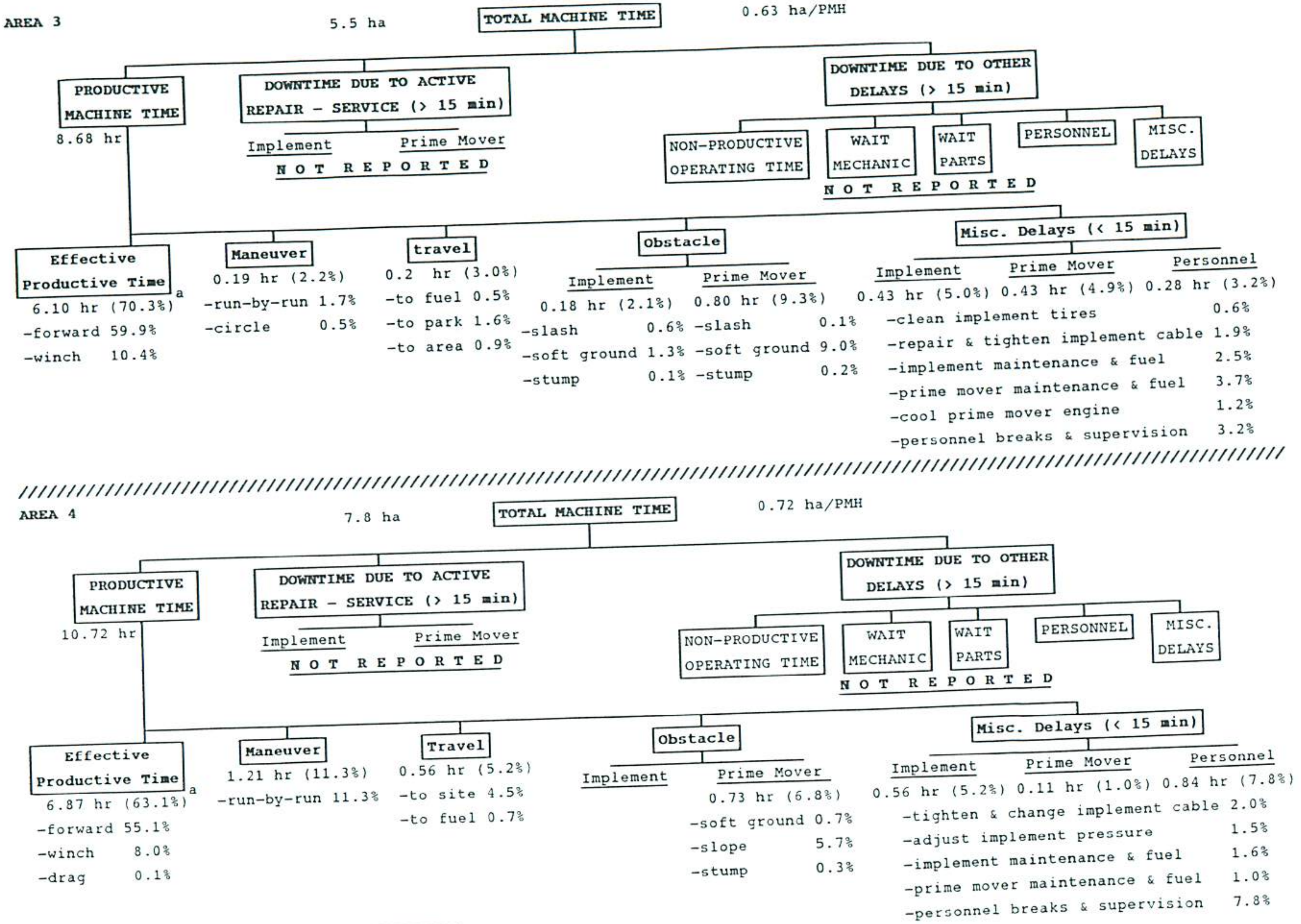
[a] Percentages are expressed in relation to productive machine time.

Figure 4. Results of the short-term continuous time study in areas 1 and 2.



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[a] Percentages are expressed in relation to productive machine time.

Figure 5. Results of the short-term continuous time study in areas 3 and 4.

of slopes reduced productivity to 0.72 ha/PMH. Again, winching was common (8%) (Fig. 5). The travel speeds achieved under fresh-to-moist ground conditions averaged 3.0 km/hr, whereas on moist-to-wet ground they averaged 2.3 km/hr. Such values did not exceed the speeds recommended for proper scarification with most scarification tools (Ryans 1986).

In the category of miscellaneous delays, cleaning of the implement tires accounted for 0.6 to 2.1% of productive machine time. The tire treads of the implement became clogged with the wet, fine-textured soil and could not shed the small debris (*Ledum groenlandicum* Retzius, small black spruce roots, etc.) that built up between the tire and the support frame of the mattock wheel. This caused momentary stoppage of the tires and subsequent ripping of the duff layer. Tire slippage on fresh-to-wet fine-textured soil may have an adverse effect on the mounding process as the spade, mattock wheel and tire are all connected in sequence of operation. As well, the diesel engine increased the weight of the tool (in comparison with that of the standard Bräcke) but the tire size was not increased to compensate; this resulted in reduced flotation and increased rutting under wet ground conditions.

Scarification

Overall Disturbance and Physical Characteristics of the Microsite

The surface coverages (2.5 to 5.6%) (Table 2 and Appendix C) of mineral soil produced by the Bräcke Mounder (17-tooth gear sprocket, 10.5 rows/20-m width) were higher than those recorded for the Bräcke two-row Cultivator by Smith et al. (1985) (2.3%, 17-tooth gear sprocket) and Leblanc and Sutherland (1987) (2.6%, 15-tooth gear sprocket); the two latter percentages were adjusted for row spacing.

The mean scalp width (48 cm) (Table 3) was similar to those obtained in studies of the Bräcke two-row Cultivator and the Bräcke Badger (Smith et al. 1985, Ryans 1986). However, the scalp length in the present study averaged 53 cm with the Bräcke Mounder versus 78 cm with the regular Bräcke (Smith et al. 1985). Part of the cap was placed in the scalp rather than being deposited on the shoulder of the patch (mineral mound) or the inverted LFH.

The production of plantable caps varied among the soil-type groups. Site factors that contributed to the occurrence of non-plantable caps include the variables selected for the grouping of sites (i.e., depth of duff and silty loam, moisture regime and the presence of the hardpan) and others (i.e., slash, stumps/roots, stones, scarification and logging ruts) (Table 4).

Table 2. Overall surface coverage of the types of soil disturbance[a] created by the Bräcke Mounder (September 1984).

	Group								Mean[b]
	1	2	3	4	5	6	7	8	
Exposed and loose mineral soil (%)	4.7	4.3	3.4	5.6	2.5	3.3	3.4	3.5	3.5
Acceptable (%)	7.8	7.1	6.5	8.2	5.1	5.9	7.4	6.6	6.2
Not acceptable (%)	16.6	16.2	21.2	17.4	19.8	19.0	22.0	34.3	20.3
Total (%)	24.4	23.7	27.7	25.6	24.9	24.9	29.5	40.9	26.5
No. of furrows/20 m	10.5	10.0	10.7	10.7	10.0	10.8	10.7	10.2	10.4

[a] Surface coverage and distribution of overall soil categories are detailed in Appendix C.

[b] weighted on the basis of the areas covered by each group

Table 3. Physical characteristics of the patches created by the Bräcke Mounder (September 1984).

	Group								Mean[a]
	1	2	3	4	5	6	7	8	
Scalp width (cm)	43	45	50	54	49	49	n.a	47	48
Scalp length (cm)	47	52	55	56	66	48	n.a	48	53
Scalp mound + inverted LFH width (cm)	n.a	59	59	66	n.a	68	n.a	54	58
Scalp mound + inverted LFH length (cm)	n.a	77	88	105	n.a	106	n.a	77	85
Total patch length (cm)	143	129	143	161	162	154	n.a	125	138
Scalp depth (cm)	16	20	24	26	38	19	n.a	19	22

[a] weighted on the basis of the area covered by each group

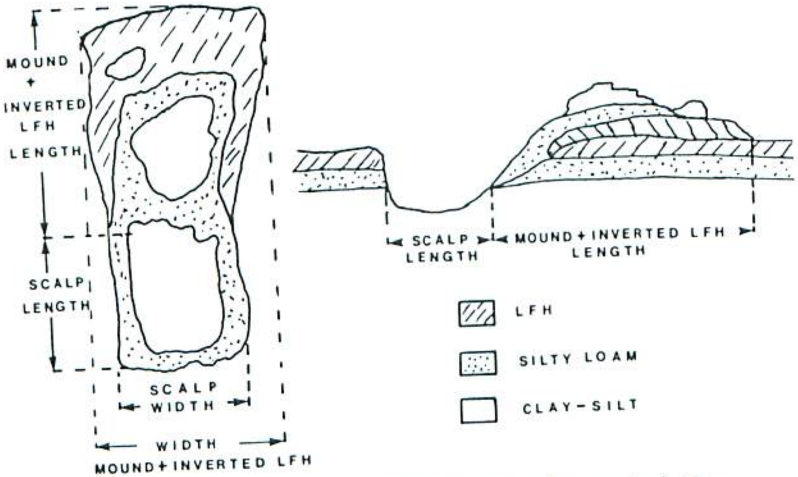

Figure 6. Physical measurements of the patches.

Table 4. Primary reasons for failure to achieve a plantable cap on inverted LFH or mineral mounds (September 1984 assessment).

Group	Plantable cap (%)	Hardpan clay-silt (%)	Stumps/ roots (%)	Slash (%)	Stone (%)	No minor vegetation root mat (%)	Excessive duff depth (%)	Cap rolled off on side of patch (%)	Scarification ruts (%)	Misc.[a] (%)
1	35	6	25	7	-	24	-	-	-	3
2	33	22	15	16	-	-	3	6	3	2
3	25	8	24	18	-	-	8	4	9	4
4	64	1	18	13	-	-	-	-	-	4
5	15	7	13	18	-	-	33	-	13	2
6	21	-	15	15	45	-	2	-	-	2
7	6	6	20	-	-	-	9	6	50	3
8	12	-	10	9	-	-	-	1	67	1

[a] Miscellaneous refers to brush, log skidding trail, ground roughness and unknown reasons.

Inversion of the LFH layer was not possible under all site conditions (Table 5). In shallow duff and silty loam with a poor minor-vegetation root mat (group 1), the "divot" of duff tended to break apart and not be inverted. Rutting during scarification was common because of the moist or wet conditions that resulted in poor ground bearing capacity and no inversion occurred when duff of medium depth lay directly atop the clay-silt hardpan (group 7) or the medium organic material (group 8). In deep duff and silty loam of medium depth or medium sand (group 5), rutting was one of the reasons the LFH was not inverted, but even in the absence of rutting, the scalp hole created by the mattock wheel was deep and the duff tended to break apart. When duff was shallow or of medium depth over silty loam or sand (groups 2, 3, 4 and 6) and soil was fresh, with a fairly well developed root mat in the duff and mineral soil, inversion of the LFH was possible.

The mattock could only penetrate the hardpan material very slightly even when this material was topped by shallow duff and silty loam (group 1). The main effect of the mattock was to break or invert the LFH and scrape the silty loam into a mineral mound at the end of the scalp (groups 1 to 6), or to scrape some clay-silt in mixture with bits of duff into small heaps when the upper few centimetres of the hardpan were softened as a result of moist-to-wet conditions (group 7). The size of the mineral mounds increased as the depth of silty loam increased and the duff depth decreased (groups 3, 4 and 6). However, a high degree of stoniness (20-cm-diameter stones) was an obstacle in group 6. Occasionally the mattock wheel placed silty loam or clay-silt on the inverted LFH.

Table 5. Cap plus mineral mound volume in patches with caps and inverted LFH surface area in patches with inverted LFH (September 1984 assessment).

	Patches with cap: volume of cap+mound (L)			Patches with inverted LFH: surface area inverted LFH (cm^2)				
Group^a	0.3-2 (%)	4-8 (%)	10-24 (%)	400 (%)	1600 (%)	2400 (%)	3200 (%)	3600 (%)
1	31	56	13	-	-	-	-	-
2	41	53	6	16	26	32	16	10
3	48	35	16	7	13	30	39	11
4	50	25	25	11	22	17	11	39
5	-	-	-	-	-	-	-	-
6	55	42	3	12	22	27	24	15
7	72	28	-	-	-	-	-	-
8	48	52	-	-	-	-	-	-
Mean^b	45	44	11	14	25	25	22	14

[a] LFH not inverted in groups 1, 5, 7 and 8

[b] weighted on the basis of the area in each group

The spade contacted the hardpan under most of the site conditions because the mattock scraped most of the duff and silty loam out of the way. This resulted in the deposition of a hard cap of clay-silt at the end of the scalp or on the non-inverted LFH in the presence of shallow duff and silty loam (group 1). The following spring, the cap was more penetrable. The caps were largest under these site conditions (Table 5). A relatively high proportion of smaller clay-silt caps was placed in the scalp hole when the duff was of medium depth and the silty loam was shallow (group 2). Some of these small caps were placed on the inverted LFH and sometimes rolled off on the side of the patch (Table 6). In duff of medium depth and silty loam of up to medium depth, most of the caps were still made of clay-silt and were placed on the inverted LFH (group 3). When the spade dug up material for a silty loam cap it was usually placed on top of the silty loam mound created by the mattock. When shallow duff was underlain by deep, silty loam or loamy, fine sand, the spade placed the cap of mineral soil just at the beginning of the inverted LFH (group 4). The silty and sandy material did not stick to the spade and part of it fell before the spade reached the inverted LFH.

The spade was unable to function when the duff was deep because the scalp hole created by the mattock wheel was too deep (group 5). The spade was affected more than the mattock wheel by cobbles (20 cm in diameter) and its penetration was virtually nil (group 6). When moist-to-wet conditions were treated and ruts were created (groups 7 and 8) the

Table 6. Occurrence of caps, mounds and inverted LFH over all patches (September 1984 assessment).

Disturbance category		Group 1	2	3	4	5	6	7	8	Mean[a]
(i) Mineral cap on LFH[b]	(%)	35	27	30	59	10	32	9	4	27 (4)
(ii) Mineral cap on mineral mound	(%)	9	12	14	9	3	17	13	4	11 (2)
(iii) Mineral cap on side of patch	(%)	-	12	5	3	-	2	6	8	6 (2)
Mineral cap on hardpan within scalp hole	(%)	44	21	7	9	10	-	16	34	17 (3)
Total cap	(%)	88	72	56	78	23	50	44	50	61 (4)
(iv) Inverted LFH only	(%)	-	7	17	6	-	25	-	-	10
(v) Mixed mound or mineral mound only	(%)	1	5	12	-	12	10	11	16	7
No cap, inverted LFH or mound[c]	(%)	11	16	15	16	66	15	45	34	22 (3)

[a] weighted on the basis of the area of each group (values in parentheses are confidence intervals at the 10% significance level)

[b] LFH not inverted in groups 1, 5, 7 and 8

[c] The total of (i) to (v) does not include mineral mounds in patches where there were caps on inverted LFH.

spade contacted the hardpan directly; however, the caps produced were small and were deposited in the ruts, in contrast with the situation for group 1. Stumps and roots or slash were the primary reasons for failure to achieve plantable caps on inverted LFH or mineral mounds in almost 30% of all patches assessed in the study because they prevented proper spade penetration or were in the way of the mattock wheel when it tried to produce a mineral mound or an inverted LFH (Table 4).

The implement produced many types of microsites, depending on the site conditions. Capping was unsuccessful, which is shown by the low and variable numbers (Table 6) and small size of the caps (89% of caps had an estimated volume of less than 8 L, Table 5). When within reach of the spade, the underlying hardpan inhibited penetration and thus reduced the spade's digging ability. The two-stage process and the product itself (cap on inverted LFH or mineral mound) were difficult to achieve because of the interference of stumps and roots or slash. Modifications such as increasing the size of the spade, its angle of attack, and the addition of teeth to the spade have been experimented with in British Columbia with some success (Parolin 1986). However, positioning of the block of clay-silt dug up by the spade on the inverted LFH was difficult to control in the present study and the creation of a larger block with the Bräcke Mounder would not solve the problem. A very large volume of hand-made or excavated mineral soil (Brunberg et al. 1986) might be necessary to accelerate decomposition of the inverted LFH (warmer temperature of the mineral soil and better compression of the inverted LFH (Sutton [1984]) and to assure that while the block dislocates, the amount of mineral soil exposure remains sufficient, even if two seasons might be needed to break apart the cap of clay-silt completely. This remains to be seen.

Digging with the spade produced additional disturbance, mainly similar to the disturbance produced by the Bräcke mattock. At least 30 cm of non-compact, relatively stone-free mineral soil with an average duff depth of 15 cm is preferable if the Bräcke Mounder is to be used with some success to produce capped mounds. The fine-textured mineral soil encountered in this trial is not very suitable for seeding; consequently, the additional disturbance of the mineral soil by the spade is not of much interest other than for describing the plantable microsites or the work done by the spade. Most studies have demonstrated that the Bräcke Mounder will disturb more mineral soil than the standard Bräcke, but it is important that the user question the usefulness of the disturbance for specific soil conditions if seeding is the objective.

Plantable Spots

To isolate the proportion of plantable spots per hectare added by the spade, Part A of Table 7 indicates the proportion of patches in which a plantable spot from one source only was available; Part B indicates the proportion of patches in which plantable spots from the spade and one of the other sources were available within the same patch. The actual number of plantable spots per hectare and the stocking potential at the prescribed spacing are presented in Appendix D. In Figure 7 the types of plantable spots and the most common situations in each soil-type group are presented.

In shallow duff and silty loam (group 1), 47% of the patches had only plantable spots produced by the spade, the highest proportion in all the groups. Most of these spots were on a cap of silt on non-inverted LFH and exposed mineral soil. When the patches had plantable spots from two sources (21%), the spot created by the spade usually consisted of exposed mineral soil combined with a spot of mixed or exposed mineral soil created by the mattock or with a spot of light duff on mineral soil created by the prime mover.

In duff of medium depth and shallow silty loam (group 2), 19% of the patches had only a plantable spot produced by the spade that consisted mainly of exposed mineral soil or a cap of silt on inverted LFH. The patches with two choices comprised 35% of the total. Silt on a mineral mound or on inverted LFH often originated in part from the spade and the mattock. In duff and silty loam of medium depth (group 3), 30% of the patches had only a plantable spot produced by the mattock wheel. Exposed mineral soil, light duff and silt on a silty-loam mound were the main types. The patches with two choices (33%) consisted mainly of a cap of silt on inverted LFH or a cap of silty loam on the mineral mound combined with a silty loam mound produced by the mattock.

Table 7. Proportion of patches in which plantable spots were created by the spade(s), mattock wheel(m), prime mover during scarification(p), and logging/natural(n). (May 1985)

	Group																															
	1				2				3				4				5				6				7				8			
Disturbance category source	s	m	p	n	s	m	p	n	s	m	p	n	s	m	p	n	s	m	p	n	s	m	p	n	s	m	p	n	s	m	p	n
A PROPORTION (%) OF PATCHES IN WHICH A PLANTABLE SPOT WAS AVAILABLE FROM ONE SOURCE ONLY																																
Exposed mineral soil	18	9	–	–	10	6	–	–	2	4	–	3	–	7	–	–	10	10	–	–	–	3	–	–	9	–	–	–	–	6	–	–
Capped or mound mineral soil	5	2	–	–	2	–	–	–	3	11	–	–	–	3	–	–	3	3	–	–	–	22	–	–	6	3	–	–	2	–	–	–
Mixed loose silt and duff	–	2	–	2	–	4	–	2	1	3	–	–	–	–	–	–	–	13	–	–	2	–	–	2	3	6	–	9	–	–	–	2
Duff 1-5 cm over silt or silty loam	–	5	–	–	–	3	–	2	–	11	4	1	–	3	–	6	–	18	–	–	–	11	–	3	–	–	–	–	–	–	2	4
Duff 1-5 cm over organic matter (Oh)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	4	16
Organic matter (Oh) over clay or silt	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	10	6	14
Loose silt[a] over duff	24	2	–	–	7	4	–	–	5	1	–	–	6	–	–	–	–	3	–	–	–	–	–	–	6	–	–	–	2	–	–	–
Loose silty loam[a] over duff	–	–	–	–	–	–	–	–	1	–	–	–	3	–	–	–	–	–	–	–	3	3	–	–	–	–	–	–	–	2	2	–
B PROPORTION (%) OF PATCHES IN WHICH PLANTABLE SPOTS WERE AVAILABLE FROM THE SPADE AND ONE OTHER SOURCE WITHIN SAME PATCH																																
Exposed mineral soil	17	5	2	–	2	–	–	–	2	2	1	–	6	3	3	–	–	4	–	–	–	2	–	–	–	–	–	–	8	–	–	–
Capped or mound mineral soil	2	–	–	–	10	13	–	–	12	18	–	–	9	44	–	–	–	3	–	–	2	9	–	–	9	6	–	–	8	–	–	–
Mixed loose silt and duff	–	4	–	–	–	4	–	–	2	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–
Duff 1-5 cm over silt or silty loam	–	–	5	5	–	8	–	–	1	5	3	1	–	3	–	3	–	3	–	–	–	–	–	–	–	3	–	–	–	–	–	–
Duff 1-5 cm over organic matter (Oh)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6	8
Organic matter (Oh) over clay or silt	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	4
Loose silt[a] over duff	2	–	–	–	23	10	–	–	12	1	–	–	3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Loose silty loam[a] over duff	–	–	–	–	–	–	–	–	4	–	–	–	41	3	–	–	10	–	–	–	9	–	–	–	–	–	–	–	–	–	–	–
source	s	m	p	n	s	m	p	n	s	m	p	n	s	m	p	n	s	m	p	n	s	m	p	n	s	m	p	n	s	m	p	n
Total **A**	47	20	–	2	19	17	–	4	12	30	4	4	9	13	–	6	13	47	–	–	5	39	–	5	24	9	–	9	4	18	14	36
B	21	9	7	5	35	35	–	–	33	28	4	1	59	53	3	3	10	10	–	–	11	11	–	–	9	9	–	–	18	–	6	12
Combined total[b]	90 (8)				75 (10)				83 (6)				87 (10)				70 (14)				60 (10)				51 (15)				90 (8)			

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[a] LFH not inverted in groups 1, 5, 7 and 8

[b] Combined total = Total A + Total B/2. Note that in Total B, s = m + p + n. Values in parentheses are confidence intervals at the 10% significance level.

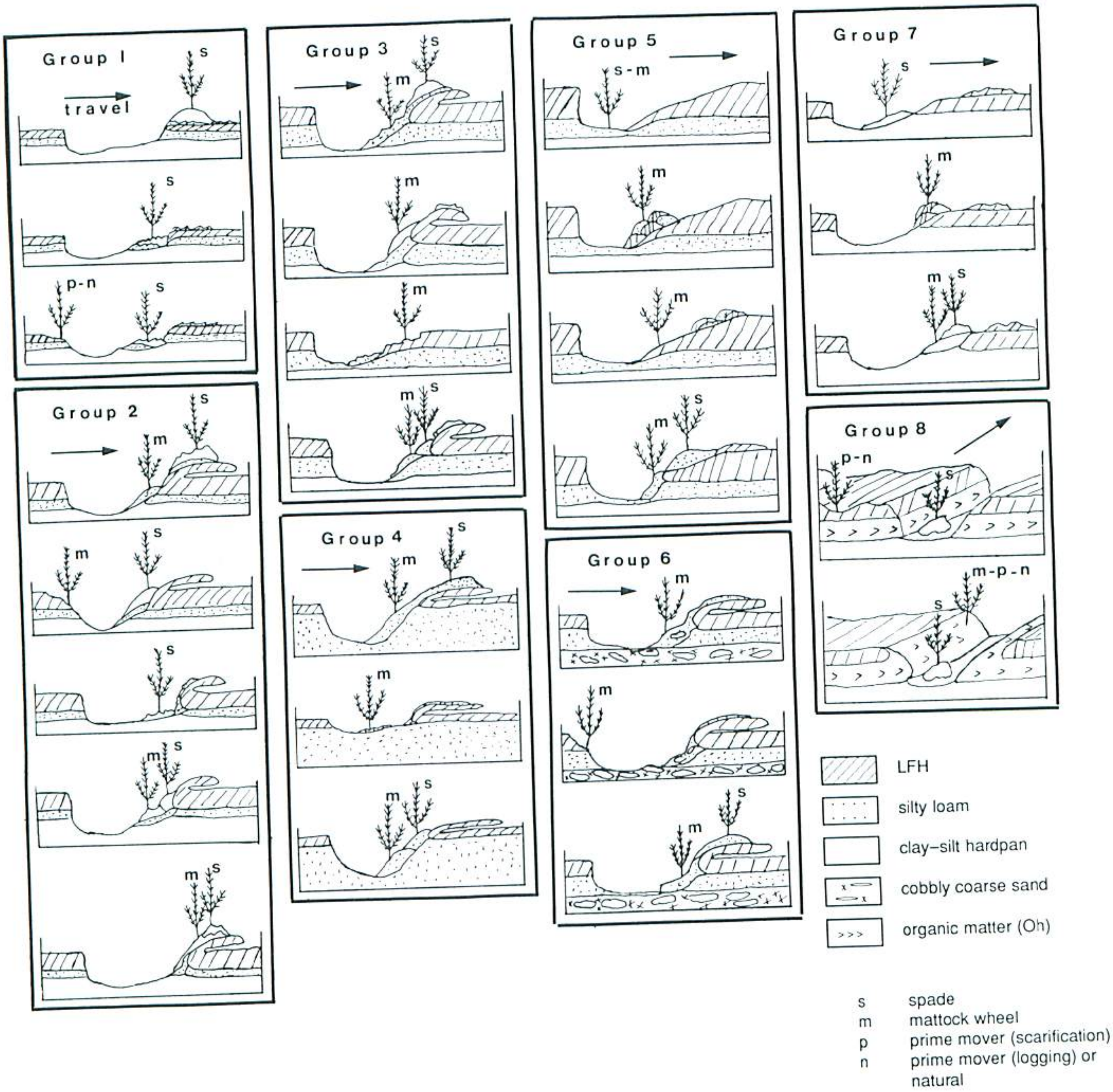

Figure 7. The most frequent types of plantable microsites in each soil-type group.

In shallow duff and deep silty loam (group 4), 59% of the patches had two choices of spot, which usually consisted of a silty loam mound produced by the mattock combined with a cap of silty loam on inverted LFH produced by the spade. In deep duff and silty loam or sand of medium depth (group 5) the mattock wheel created most of the plantable spots in patches with no other choices (47%) by exposing some mineral soil, mixing duff with mineral soil or partially removing the duff that overtopped the mineral soil. The spade did not contribute much because the scalp hole created in the deep duff was often too deep and vertical to permit the placement of mineral soil on the proper microrelief. The mattock wheel also produced the plantable spots in patches with no other choices (39%) in duff and fine sand of medium depth overtopping the cobbly, coarse sand (group 6) because the stones (20 cm diameter) prevented the spade from digging. Silty loam mounds and partially removed duff over mineral soil were the main types of spots produced.

Where duff of medium depth covered the hardpan directly (group 7), 24% of the patches had only plantable spots produced by the spade. Exposed mineral soil, capped silt over a silt mound or the non-inverted LFH, and a mixture of silt and duff all contributed to that total. In duff and organic matter (Oh) of medium depth (group 8), 50% of the plantable spots were Oh exposed by the prime mover's tires on the sides of the ruts during the logging or scarification operations.

It is clear that to achieve plantable spots of capped mineral soil almost exclusively on a mineral mound or on inverted LFH would be difficult under these site conditions. The addition of the spade permitted greater total plantability (approximately 80%, ranging from 50 to 90% among groups) but not markedly different types of plantable spots than if the sites had been treated by the regular Bräcke two-row Cultivator. As anticipated, the implement worked relatively well where the overlying layers of penetrable, silty loam or loamy, fine sand were sufficiently deep and where the duff was not excessively deep and permitted the scraping action of the mattock wheel. Although the spade added mineral soil (low volumes of clay-silt) to the microsites created by the mattock, it worked well only where it could dig into non-compact mineral soil topped by relatively shallow duff.

SUMMARY AND RECOMMENDATIONS

The Bräcke Mounder was assessed on an upland site in Rowe's (1972) Northern Clay Section in northwestern Quebec. Though uniform in appearance, the site consisted of a mosaic of site conditions. The site was divided into eight groups on the basis of combinations of duff and silty loam of various depths over a compact clay-silt hardpan and fresh-to-wet moisture regimes. Other site conditions were uniform and present in quantities that would normally be considered a minor impediment to light scarification equipment such as the Bräcke Cultivator. However, they affected the creation of capped mounds.

The mosaic of site conditions resulted in non-uniform creation of caps and mounds. The Bräcke Mounder produced a greater volume of mineral soil on mounds in comparison with the standard Bräcke but this was not a major improvement because the added soil tended to fall apart, disperse and not contribute greatly to increasing the number of mounds.

The Bräcke Mounder performed best when the duff was shallow (averaging 5 cm) and the silty loam or loamy fine sand were deep (averaging 30 cm). Under these conditions, the cap placed on the inverted LFH still averaged only 10 L because part of the mineral soil dug by the spade was placed on top of the mineral mound created by the mattock. Although not specifically assessed in this study, the same results should occur in deeper duff (averaging 15 cm) with a deep penetrable mineral soil instead of compact clay-silt hardpan. When the mineral soil was penetrable but averaged 15 cm or less in depth, the spade was of little help because the mattock wheel used most of the non-compacted soil to create the plantable microsites, which left the spade to try digging into the hardpan. The spade dug efficiently into the hardpan only when the overlying duff and the silty loam were shallow. However, although the caps of clay-silt were plantable, very little information is available on how seedlings will perform on these microsites. The addition of the spade did not improve results in deep duff.

This and other studies show that the Bräcke Mounder will rarely create mounds similar to the theoretical (i.e., 20-L hand-made) raised microsites. The two-step process used by the Bräcke Mounder for mounding is a major problem in achieving consistency. Stones (Bäcke et al. 1986) (diameter 20 cm), slash, or stumps and roots will impede the process of mounding by the Bräcke Mounder even if they are only present in relatively small quantities. If only an improvement to the microsites created by the Bräcke two-row Cultivator is desired, the Bräcke Mounder is definitely adequate. Use of a 15-tooth gear, although producing fewer mounding attempts, should achieve the largest capped mounds when the mineral soil is 30 cm or more in depth and penetrable by the spade, and the duff is 15 cm or less in depth. Again, the site and prescription will determine if that type of microsite is a valuable choice.

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APPENDIX A. TECHNICAL DATA FOR THE SCARIFIER

BRÄCKE MOUNDER

Engine:

Deutz - air cooled	
Model/cylinders	FL 511/2 cyl.
Max. power	19.5 kW (26 hp)
R.P.M.	2000
Displacement	1600 cm^3(98 $in.^3$)
Fuel tank capacity	20 L (4.4 imp. gal.)
Fuel consumption	2-3 L/hr (0.4-0.7 imp. gal./hr)

Electric system:

Generator	12 volt 33 amp A.C.
Battery	60 amp-hr
Fuse	one 16 amp/two 8 amp

Hydraulic system:

Pump	Gear type
Oil cooler	Tube type
Reservoir	80 L (17.6 imp. gal.)
Hydraulic oil type	SHS 32

Remote control:

Radio	27.180-27.210 MHz

General:

Weight	4500 kg
Length	5.85 m
Width	2.53 m
Ground clearance	0.80 m
Tire size	30.0 x 60.0 cm, 16-ply
Mattock wheels	2 mattock wheels with 4 pairs of tines per wheel
Tine & tooth: width	11 cm & 15 cm
length	24 cm & 67 cm
Drive sprocket	17 teeth/sprocket
Option	15- and 19-toothed sprockets for changing patch length
Hitch	Bräcke type

Manufacturer:

Robur Maskin AB
Gransgatan 42
S-840 60 Bräcke
SWEDEN

Distributors:

KBM Forestry Consult. Inc.
360 Mooney St.
Thunder Bay, Ontario
P7B 5R4

Woodlands Services Inc.
Box 257
Moose Lake, Minn.
55167 USA

KBM Forestry Consult. Inc.
Box 5462
Rome, GA
30162 USA

FORABI Inc.
221 rue Bolduc
Amos, Que.
J9T 3M4

APPENDIX B. DEFINITION OF TIME STUDY ELEMENTS[a]

Definition of long-term study time elements

TOTAL MACHINE TIME: The sum of Scheduled Machine Time and Overtime. It is the time associated with the machine for a given shift.

SCHEDULED MACHINE HOURS (SMH): A nominal statement of intent for regular machine activity (e.g., 8-hr shift). It is usually corresponds to the operator's paid on-job time.

PRODUCTIVE MACHINE TIME or HOURS (PMH): That part of total machine time during which the machine is performing its primary function.

ACTIVE REPAIR/SERVICE: Repair consists of mending or replacement of part(s) as a result of failure or malfunction. It includes modifications or improvements to the machine, and routine and preventive maintenance performed to ensure that the machine remains in satisfactory operating condition.

DELAY: That portion of total machine time during which the machine is not performing its primary function for reasons other than active repair and service. Delay time is divided into:

NON-PRODUCTIVE OPERATING TIME: The portion 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): The portion of in-shift time during which the machine is broken and is not under repair because of the unavailability of a mechanic(s).

WAITING FOR PART(S): The portion of in-shift time during which the machine is broken and is not under repair because parts are unavailable.

MISCELLANEOUS DELAY: The portion 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.

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[a] Definitions are based on those reported in Folkema et al. (1981) and Smith et al. (1985).

Definition of short-term time study elements

The PMHs recorded during continuous timing were broken down into the following elements.

EFFECTIVE PRODUCTIVE TIME (EPT) (SCARIFICATION): Begins when the implement is in the soil and the prime mover begins forward travel. The EPT can include winching (after being left behind because of soft ground or slopes, the implement is pulled back to the prime mover with the winch) if there is effective scarification during winching. Does not include delays.

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

OBSTACLE DELAY: Occurs from the time the scarifier stops (or scarifies over an area already scarified) because of an obstruction until scarification resumes.

TRAVEL: Is the time spent traveling a) in the block or to the roadside between breaks, and b) for repairs. It also includes traveling (if less than or equal to 15 min) between sites.

MISCELLANEOUS DELAYS (LESS THAN OR EQUAL TO 15 MIN): Same as delays (> 15 min) but includes those times ≤ 15 minutes. Short-term delays are part of productive machine time whereas delays > 15 minutes are not considered part of productive time.

APPENDIX C. OVERALL SOIL DISTURBANCE CREATED BY THE BRÄCKE MOUNDER.

Disturbance category	Surface coverage (%), by group								Distribution (%), by group[a]							
	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
Exposed mineral soil	2.9	3.1	2.1	3.9	2.0	2.2	2.6	2.8	88	88	77	93	60	75	66	74
Loose mineral soil	1.8	1.2	1.3	1.7	0.5	1.1	0.8	0.7	78	64	58	80	23	58	40	52
Mixed loose clay-silt & duff	0.5	0.4	0.4	-	0.7	-	2.4	0.1	15	16	12	-	34	-	25	10[b]
Mixed loose silty loam or loamy fine sand & duff	-	-	0.5	0.1	0.1	0.1	-	-	-	-	13	3	3	5	-	-
Mixed organic & duff	-	-	0.2	-	0.3	-	-	0.5	-	-	2	-	7	-	-	10
Duff 1-5 cm on clay	-	0.3	0.1	-	-	-	0.5	0.1	-	15	2	-	-	-	17	2
Duff 1-5 cm on silt or silty loam or loamy fine sand	1.2	0.2	0.5	0.2	1.0	0.6	0.3	0.1	33	18	19	10	43	28	7	6[c]
Organic matter on clay-silt	-	-	-	-	0.3	-	-	2.0	-	-	-	-	3	-	-	52
Loose clay-silt on duff or organic matter	1.1	1.8	0.7	0.2	0.1	-	0.3	0.1	43	54	29	10	7	-	20	8
Loose silty loam or loamy fine sand on duff	0.3	-	0.6	2.4	0.3	1.9	-	-	3	-	21	80	13	57	-	-
Acceptable	7.8	7.1	6.5	8.2	5.1	5.9	7.4	6.6								
Not acceptable	16.6	16.2	21.2	17.4	19.8	19.0	22.0	34.3								
Total	24.4	23.7	27.7	25.6	24.9	24.9	29.5	40.9								

[a] refers to the proportion of 2- x 2-m quadrats in which the indicated category of disturbance accounted for at least 1% of the area of the quadrat

[b] mixed loose clay-silt and organic matter

[c] duff 1-5 cm on organic matter

APPENDIX D. NUMBER OF PLANTABLE SPOTS PER HECTARE

Number of plantable spots per hectare created by the spade(s), mattock wheel(m), prime mover during scarification(p), and logging/natural(n).
(May 1985)

Disturbance category	Group 1				Group 2				Group 3				Group 4			
Source	s	m	p	n	s	m	p	n	s	m	p	n	s	m	p	n
A NUMBER OF PATCHES PER HECTARE IN WHICH A PLANTABLE SPOT WAS AVAILABLE FROM ONE SOURCE ONLY																
Exposed mineral soil	470	180	–	–	240	144	–	–	65	117	–	82	–	146	–	–
Capped or mound mineral soil	100	40	–	–	49	–	–	–	100	293	–	–	–	73	–	–
Mixed loose silt and duff	–	57	–	57	–	96	–	48	27	82	–	–	–	–	–	–
Duff 1–5 cm over silt or silty loam	–	114	–	–	–	96	–	48	–	300	109	27	–	73	–	146
Duff 1–5 cm over organic matter (Oh)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Organic matter (Oh) over clay or silt	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Loose silt[b] over duff	627	57	–	–	192	96	–	–	109	27	–	–	146	–	–	–
Loose silty loam[b] over duff	–	–	–	–	–	–	–	–	27	–	–	–	73	–	–	–
B NUMBER OF PATCHES PER HECTARE IN WHICH PLANTABLE SPOTS WERE AVAILABLE FROM THE SPADE AND ONE OTHER SOURCE WITHIN SAME PATCH																
Exposed mineral soil	408	114	57	–	48	–	–	–	54	54	27	–	146	73	73	–
Capped or mound mineral soil	48	–	–	–	240	337	–	–	328	492	–	–	206	1025	–	–
Mixed loose silt and duff	–	114	–	–	–	96	–	–	55	55	–	–	–	–	–	–
Duff 1–5 cm over silt or silty loam	–	–	114	114	–	192	–	–	27	136	82	27	–	73	–	73
Duff 1–5 cm over organic matter (Oh)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Organic matter (Oh) clay or silt	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Loose silt[b] over duff	57	–	–	–	577	240	–	–	328	27	–	–	73	–	–	–
Loose silty loam[b] over duff	–	–	–	–	–	–	–	–	109	–	–	–	949	73	–	–
source	s	m	p	n	s	m	p	n	s	m	p	n	s	m	p	n
Total A	1197	513	–	57	481	433	–	96	328	819	109	109	219	292	–	146
Total B	513	228	171	114	866	866	–	–	901	764	109	27	1387	1241	73	73
Combined total[c]	2280 (198)[d]				1876 (281)				2266 (82)				2044 (140)			
Number of patches/ha	2500				2500				2650				2332			
Stocking potential	90 %				75 %				91 %				82 %			

Disturbance category	Group 5				Group 6				Group 7				Group 8			
Source	s	m	p	n	s	m	p	n	s	m	p	n	s	m	p	n
A NUMBER OF PATCHES PER HECTARE IN WHICH A PLANTABLE SPOT WAS AVAILABLE FROM ONE SOURCE ONLY																
Exposed mineral soil	256	256	–	–	–	69	–	–	249	–	–	–	–	150	–	–
Capped or mound mineral soil	77	77	–	–	–	507	–	–	166	83	–	–	50	–	–	–
Mixed loose silt and duff	–	333	–	–	36	–	–	36	83	166	–	249	–	–	–	50
Duff 1–5 cm over silt or silty loam	–	416	–	–	–	288	–	72	–	–	–	–	–	–	50	100
Duff 1–5 cm over organic matter (Oh)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	100	400
Organic matter (Oh) over clay or silt	–	–	–	–	–	–	–	–	–	–	–	–	–	250	150	350
Loose silt[b] over duff	–	83	–	–	–	–	–	–	166	–	–	–	50	–	–	–
Loose silty loam[b] over duff	–	–	–	–	72	72	–	–	–	–	–	–	–	50	50	–
B NUMBER OF PATCHES PER HECTARE IN WHICH PLANTABLE SPOTS WERE AVAILABLE FROM THE SPADE AND ONE OTHER SOURCE WITHIN SAME PATCH																
Exposed mineral soil	–	83	–	–	–	46	–	–	–	–	–	–	200	–	–	–
Capped or mound mineral soil	–	83	–	–	36	206	–	–	249	166	–	–	200	–	–	–
Mixed loose silt and duff	–	–	–	–	–	–	–	–	–	–	–	–	50	–	–	–
Duff 1–5 cm over silt or silty loam	–	83	–	–	–	–	–	–	–	83	–	–	–	–	–	–
Duff 1–5 cm over organic matter (Oh)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	150	200
Organic matter (Oh) clay or silt	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	100
Loose silt[b] over duff	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Loose silty loam[b] over duff	250	–	–	–	216	–	–	–	–	–	–	–	–	–	–	–
source	s	m	p	n	s	m	p	n	s	m	p	n	s	m	p	n
Total A	333	1167	–	–	108	936	–	108	498	332	–	249	100	450	350	900
Total B	250	250	–	–	252	252	–	–	166	166	–	–	450	–	150	300
Combined total[c]	1750 (299)				1404 (151)				1245 (226)				2250 (229)			
Number of patches/ha	2500				2332				2650				3000			
Stocking potential	70 %				56 %				50 %				90 %			

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[a] The following abbreviations are used for the source of the planting spot: s = spade, m = mattock wheel, p = prime mover (during scarification), and n = logging/natural.

[b] LFH not inverted in groups 1, 5, 7 and 8.

[c] Combined total = Total A + Total B/2. Note that in Total B, s = m + p + n.

[d] Values in parentheses are confidence intervals at the 10% significance level.