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EVALUATION OF MECHANICAL SITE PREPARATION ON PHYSICAL SOIL PROPERTIES OF THREE BOREAL MIXEDWOOD SITES

BY ©

JORGE ALCAZAR MONTERO

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of Master of Science.

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled EVALUATION OF MECHANICAL SITE PREPARATION ON PHYSICAL SOIL PROPERTIES OF THREE BOREAL MIXEDWOOD SITES submitted by JORGE ALCAZAR MONTERO in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE.

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November 2, 1993

To my parents

Abstract

Physical soil properties created by three mechanical site preparation treatments (ripper ploughing, disc trenching, and blading) were evaluated to determine which was best at creating plantable microsites on wet soil conditions on three mixedwood boreal sites. The objectives of the study were: 1) to look at the success of the different mechanical site preparation treatments in creating plantable microsites in quantity and quality; 2) to analyze selected microsites in terms of water content and bulk density to determine the most favourable treatment; and 3) to estimate potential soil erosion created by each treatment.

Three locations near Whitecourt, Alberta, with fine textured soils, high water contents, and similar topographic characteristics were selected for study. Four site preparation treatments (including a control) were applied at each location, running up and down slopes. Each treatment was repeated twice per location and located randomly. Microsites created were surveyed on two 10 x 10m plots in each treatment area (upper and lower slopes). Number of microsites and soil disturbance were recorded for each plot. Undisturbed and disturbed soil samples were taken from the ground surface for laboratory analyses.

Soil analyses revealed ripper ploughing as the best site preparation treatment in this study, using the hinge microsite as the preferred planting spot. All three treatments resulted in an improvement of physical soil conditions compared to the control, although the differences among treatments were not as big as expected. More hinge than berm or trench microsites were created by ripper ploughing and disc trenching. Hinge were superior microsites compared to the others and they were characterized by a thin organic layer with a good mixture with mineral soil. Hinge microsites in ripper ploughing had faster drainage and better bulk density conditions than those in disc trenching. Berm microsites had a poor mixture organic matter and mineral soil, resulting in low bulk density, fast drainage, and low

water retention capacity. Trench microsites were located on exposed mineral soil and had slow drainage and sometimes high bulk density values, and were frequently waterlogged after heavy rainfalls, especially those created by ripper ploughing. Blading produced drier microsites than the other treatments and wasted plantable space creating the piles. Furthermore, it is not an easy treatment to perform and mineral soil is often exposed with high risk of soil erosion and frost heaving.

More research is needed to relate changes in soil properties due to site preparation treatments to seedling survival, root growth, and supply of water and nutrients in both, short- and long-term periods.

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TABLE OF CONTENTS

1. INTRODUCTION 1
    1.1 Introduction 1
    1.2 The ideal microsite 3
    1.3 Objectives 5

2. STUDY AREA 7
    2.1 Location 7
    2.2 Geology and Soils 8
    2.3 Climate 9
    2.4 Physiography and topography 9
    2.5 Drainage basins 11
    2.6 Vegetation 11

3. SITE PREPARATION TREATMENTS AND MICROSITES 12
    3.1 Disc Trenching 12
        3.1.1 Description 12
        3.1.2 Machinery 13
        3.1.3 Microsites created 13
    3.2 Ripper ploughing 16
        3.2.1 Description 16
        3.2.2 Machinery 17
        3.2.3 Microsites created 17
    3.3 Blading 19
        3.3.1 Description 19
        3.3.2 Machinery 19
        3.3.3 Microsites created 20
    3.4 Control 21

4. METHODOLOGY 24
    4.1 Layout 24

4.2 Sampling 25
- Sample set no.1 25
- Sample set no.2 28
4.3 Laboratory analysis 29
4.3.1 Bulk density 29
4.3.2 Soil moisture content 30
4.3.3 Soil structure 30
4.3.4 Organic matter content 31
4.3.5 Particle size analysis 34
4.3.6 Water retention capacity 34
4.3.7 Drainage 35
4.3.8 Potential soil erosion 36

5. RESULTS 38
5.1 Number of microsites and soil disturbance 38
5.2 Organic matter content 40
5.3 Drainage 41
5.4 Bulk density 42
5.5 Water retention 43
5.6 Potential soil erosion 45
5.7 Bulk density and moisture content for selected microsites 47

6. DISCUSSION 60
6.1 Optimal range of soil properties 60
6.2 Control conditions 65
6.3 Ripper ploughing 66
6.4 Disc trenching 67
6.5 Blading 68
6.6 Microsite summary 69

7. CONCLUSIONS AND RECOMMENDATIONS 72

LITERATURE CITED 76

APPENDICES 82

Appendix 1.1 Statistical analysis 83
Appendix 1.2 Number of microsites per hectare created by each treatment .. 85
Appendix 1.3 Depth of the organic layer above the mineral soil 87
Appendix 1.4 Soil disturbance 89
Appendix 1.5 Organic matter content 91
Appendix 1.6 Drainage 94
Appendix 1.7 Bulk density 97
Appendix 1.8 Soil-moisture desorption curves 100
Appendix 1.9 Organic matter content of mineral layers for the K factor of the U.S.L.E. 108
Appendix 1.10 Soil texture 110
Appendix 1.11 Potential soil erosion: K*C factor 116
Appendix 1.12 Bulk density of selected microsites 118
Appendix 1.13 Soil moisture content of selected microsites 120

LIST OF TABLES

Table 2.1. Geographic situation of the study sites 8

Table 2.2. Topographic characteristics of the study sites 10

Table 3.1. Summary of the different microsites and their characteristics 23

Table 4.1. Types of soil samples taken from the different microsites 29

Table 4.2. Cropping-management factor (C) of the Universal Soil Loss Equation for pasture, rangeland, and idle land. Ground cover at surface is grass, decaying compacted duff, or litter at least 5 cm deep. (From U.S. Soil Conservation Service, 1975) 37

Table 5.1. Soil texture of the different locations 57

Table 5.2. Soil texture for the different microsites 57

Table 6.1. Optimal range of mineral soil properties for seedling establishment and growth 64

Table 6.2. Physical conditions of the different microsites. 1 = very poor, 2 = poor, 3 = fair, 4 = good, and 5 = very good 71

LIST OF FIGURES

Figure 1.1. Environmental conditions that affect and define microsites 4

Figure 2.1. Location of the study sites 7

Figure 2.2. Slope shape of Judy Creek (a), Fox Creek (b), and Ante Creek (c) study sites 10

Figure 3.1. Potential plantable microsites created by Disc Trenching 15

Figure 3.2. Potential plantable microsites created by Ripper Ploughing 18

Figure 3.3. Potential plantable microsites created by Blading 21

Figure 3.4. Potential plantable microsites defined at the control area 22

Figure 4.1. Layout 24

Figure 4.2. Soil samples taken from the different microsites 28

Figure 4.3. Calibration curve used to estimate organic matter content in mineral samples 33

Figure 5.1. Number of microsites per hectare created by the treatments 49

Figure 5.2. Depth of the organic layer above the mineral soil layer 49

Figure 5.3. Percent soil disturbance on randomly located 10 x 10 m plots within each treatment 50

Figure 5.4. Relationship between soil disturbance and the number of microsites created by each treatment. Dotted line represents confidence limits (95%) ... 50

Figure 5.5. Organic matter content. Standard error shown are the result of a balanced design used in the analysis of the data (Appendix 1.5). Standard errors of the actual data for thin and trench microsites are smaller than shown 51

Figure 5.6. Drainage index values for deep-mineral and ground surface-organic samples 51

Figure 5.7. Bulk density of the different treatments and microsites 52

Figure 5.8. Soil-moisture desorption curves for the different treatments and microsites. Filled circles represent samples from mineral layers and hollow circles represent samples from organic and mixed (organic matter and mineral soil) layers. Standard errors for pressures of -15 bars are sometimes big or do not exist because sample size for this pressure is very low (2 or sometimes 1) 53

Figure 5.9. Available water-storage capacity of the different microsites 54

Figure 5.10. Organic matter content in the mineral layer of the microsites sampled 54

Figure 5.11. Frequency distribution of permeability levels (U.S.L.E.) for the different microsites. 1=rapid, 2=moderate to rapid, 3=moderate, 4=slow to moderate, 5=slow, and 6=very slow 55

Figure 5.12. Frequency distribution of structure levels (U.S.L.E.) for the different microsites. 1=very fine granular, 2=fine granular, 3=medium or coarse granular, and 4=massive or blocky 56

Figure 5.13. Potential soil erosion (K*C factor of the Universal Soil Loss Equation) created by the different treatments 58

Figure 5.14. Bulk density at surface layers for selected microsites 58

Figure 5.15. Volumetric moisture content at surface layers for selected microsites 59

Figure 6.1. Hypothetical relationship between drainage and seedling growth 61

CHAPTER ONE

INTRODUCTION

1.1 Introduction

Some of the most common problems affecting seedling establishment and growth in harvested areas are water stress as a result of poor root-soil contact, frost damage, change in light regime, high soil moisture, grass competition and insects. Many of these problems can be reduced by site preparation practices (Örlander et al., 1990). Mechanical site preparation is a standard practice for establishment of conifer plantations across Canada. Seventy percent of the area reforested by the Alberta Forest Service and Forest Industry (428,634 ha) for the period 1966-90 received some kind of mechanical site preparation (Reforestation Statistics 1990/91). In 1990/91 97% of the coniferous cutover area in Alberta (34,497 ha) was scarified. The largest amount of scarification was in the Whitecourt Forest (7,658 ha, or 23% of the total in Alberta).

The main goals of mechanical site preparation, which exposes, mixes, and elevates mineral soils, are to increase soil temperatures (Sims, 1975), to increase the rate of mineralization and nutrient mobilization, to reduce the effects of soil compaction (Örlander et al., 1990), to produce better and more uniform water conditions, to control or reduce competitive plant species, and to improve planter access (McMinn and Hedin, 1990).

It is clear that mechanical site preparation can be beneficial to tree survival and growth (McMinn and Hedin, 1990; Örlander et al., 1990). Lantagne and Burger (1983) found tillage treatments improved loblolly pine survival and growth in South Carolina and Georgia

Piedmont by 26 and 50 percent respectively compared to chemical and control treatments. Outcalt (1983) found disking significantly increased average tree diameter and tree height, and total volume production by 60 percent over that on control plots. However, on many sites seedling survival and growth were not improved by mechanical site preparation (Drew, 1988). The success of site preparation is dependent on matching site conditions and site preparation methods together (Derr and Mann, 1977, cited by Outcalt, 1982).

Mechanical site preparation can have detrimental effects on soil fertility and structure. Nutrients can be exported from a site by erosion in solution or mass transport. The most important soil variables affecting soil erosion are: soil cover, slope, texture, and slope length, though the effect of slope can be strongly mitigated by organic matter cover (Moon, 1988). So, when mineral soil is exposed by mechanical site preparation, the risk of soil erosion is increased.

Three mechanical site preparation treatments commonly used in Alberta are ripper ploughing, disc trenching, and blading. Ripper ploughing is frequently used in wet sites which have problems of summer accessibility. Ploughing is usually done in winter when the soil is frozen and machines can easily access cutblocks and prepare the soil. It is a drastic treatment that produces great soil disturbance by exposing mineral soil in continuous trenches and berms offering a range of planting spots.

Disc trenching is a popular treatment used by forest industry. It also creates continuous trenches and berms, but it is a less severe treatment than ripper ploughing. When applied in mixedwoods, competing vegetation is not always controled and it can become a problem.

Blading, on the other hand, exposes mineral soil extensively by removing and piling the slash and part of the forest floor. It is currently used less than in the past because 1) it reduces the area available for reforestation as slash piles can cover up to 25% of a cutblock, and 2) it requires trained operators to avoid detrimental soil effects (loss of soil, erosion problems, etc.).

Mechanical site preparation is an expensive silvicultural practice. Average costs per hectare for blading, ripper ploughing, and disc trenching are $275.00, $250.00, and $156.65 respectively (Daryl D'Amico, personal communication). These costs can become a very significant part of budgets for reforestation.

Different site preparation treatments have different effects on soil properties. Even the same treatment can have different results depending on the conditions under which it is done, such as slope, season, soil characteristics, and equipment and equipment operator. As site preparation is costly, it is important to choose the most appropriate treatment for each particular forest type and soil condition. This is important and necessary to create a good environment for the establishment and growth of seedlings.

The purpose of this study was to evaluate three site preparation treatments (ripper ploughing, disc trenching, and blading) to determine which one was best in the first growing season after treatment is done for wet soil conditions in the Lower Boreal Cordilleran ecoregion (Corns and Annas, 1986).

1.2 The ideal microsite

Stathers et al. (1990) defined a microsite as "a portion of a site that is uniform in microtopography and surface soil materials that can range in size from less than 1 m^2 to occasionally over 5 m^2." On any given site, several types of microsites can be found, with some being more suitable for planting than others (Stathers et al., 1990). Identification and selection of plantable microsites can be a difficult task.

The "ideal microsite" can be defined as the optimum environmental conditions for the establishment and growth of plants. It is very difficult to describe because it is relative and dependent on many biotic and abiotic factors (Margolis and Brand, 1990). The main environmental conditions defining and affecting microsites are climate factors, soil properties, topography, and biotic factors (Figure 1.1). These factors can be either "limiting factors" that prevent seedling establishment and growth, or factors that positively or negatively affect seedling performance. All these environmental conditions or factors are interrelated, and their

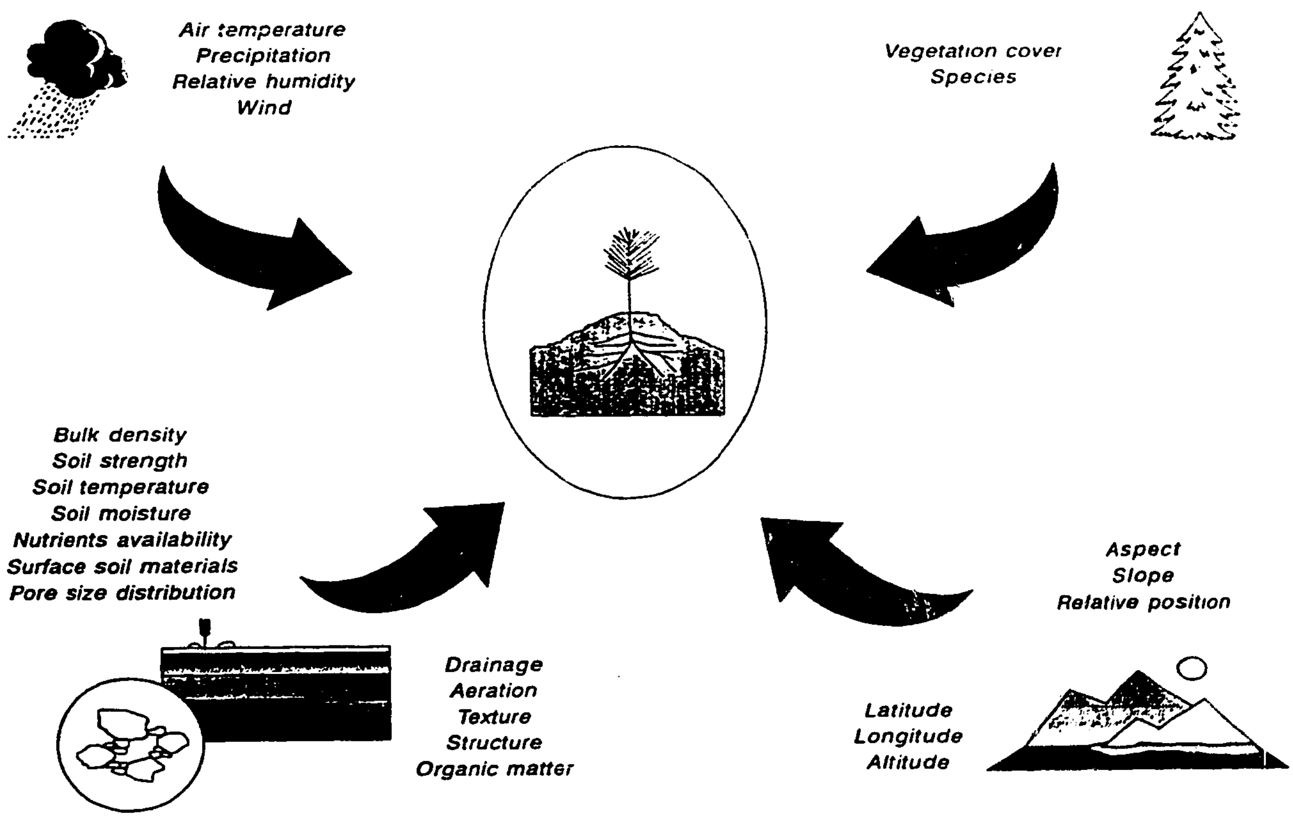


Figure 1.1. Environmental conditions that affect and define microsites.

effects can be increased or decreased by the presence or absence of other factors. In some situations a factor can be both positive and negative to seedling establishment and growth. For example, a coarse-textured soil will be more suitable for planting on lower slopes with north aspect than on upper slopes with south aspect (Corns, 1985).

The combination of all of these factors makes the concept of the "ideal microsite" very site- and plant-specific.

1.3 Objectives

The response of planted trees to different silvicultural treatments, such as site preparation, has been the focus of most silvicultural research. Little research however has been conducted on the changes in the environment that have caused trees to grow and respond to site preparation (Margolis and Brand, 1990). There is not much information on the effect of intensive management practices on physical soil properties other than bulk density (Gent et al., 1984). There is not much information either that quantifies erosion caused by mechanical site preparation (Ballard, 1988). This study attempts to describe the effects of three mechanical site preparation treatments on a wide range of physical soil properties for a better understanding of tree responses to these practices.

The three main objectives in this study were closely related, but they involved differences in sampling and laboratory analysis. The three objectives were:

1.- To analyze the success of the different mechanical site preparation treatments in creating plantable microsites. Basically, an evaluation of the quantity and quality of microsites was conducted in terms of:

- Number of microsites created.
- Soil exposure.
- Organic material on soil (slash and litter layer).
- Mixing of organic material and mineral soil.
- Drainage of microsites.

Microsites in each treatment were also described in terms of soil moisture, bulk density, and soil texture. These data were used to understand how effective the treatments were in creating plantable microsites, if slope position influenced the effectiveness of the treatments and the quality of the microsites (i.e. mesic-upper slope microsites versus hydric-lower slope microsites), and if there was any relation between soil exposure and effectiveness of site preparation.

2.- To analyze selected microsites in each treatment (microsites cconsidered most favourable within each treatment from objective 1) in terms of water content and bulk density to determine the most favourable treatment for seedling establishment in the study area.

3.- To estimate potential soil erosion for each treatment based on the K (soil erodibility) and C (cropping management) factors of the Universal Soil Loss Equation (USLE). These results will show which treatment produces lower potential soil erosion and therefore is more appropriate for the study area, and will help to provide recommendations for soil protection and conservation.

CHAPTER TWO

STUDY AREA

2.1 Location

Three sites (Judy Creek, Fox Creek, and Ante Creek) situated in the Whitecourt Forest in west-central Alberta, Canada, were selected for study (Figure 2.1). The geographic location of each site is shown in Table 2.1.

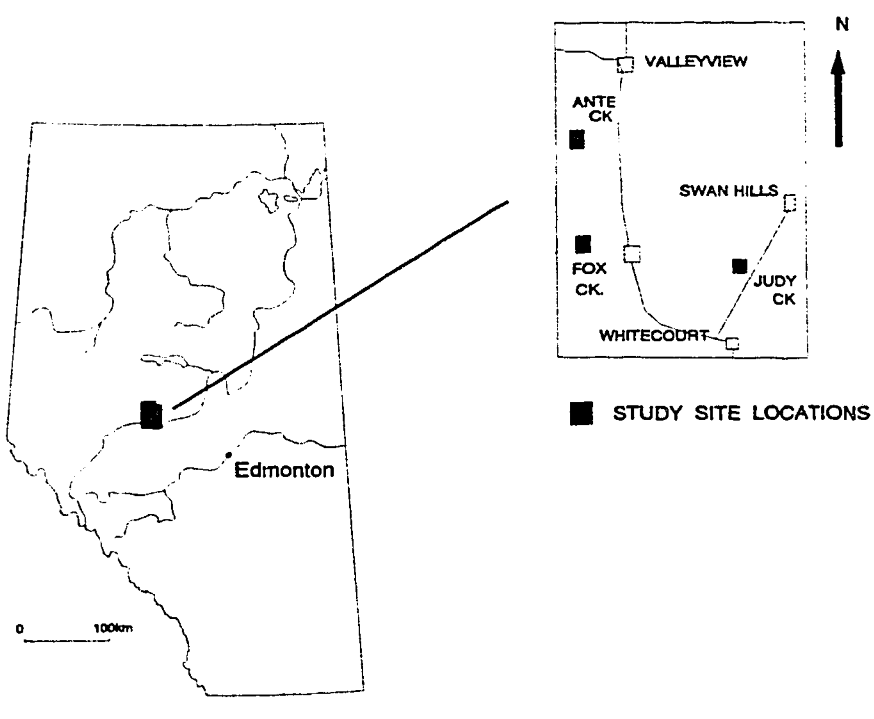


Figure 2.1. Location of the study sites.

Table 2.1. Geographic situation of the study sites.

	Judy Creek	Fox Creek	Ante Creek
Geographic coordinates			
Latitude	54° 24' 49" N	54° 15' 16" N	54° 29' 10" N
Longitude	115° 40' 58" W	116° 49' 54" W	117° 29' 41" W
Alberta township syst.			
Meridian	W 5th	W 5th	W 5th
Township	62 -- 63	61	63
Range	12	19	24
Section	35 NE -- 1 S½	7 SE	36 SW, 26 NE, 25 NW

2.2 Geology and Soils

Structurally, the area is part of the broad Alberta Syncline. The bedrock strata are described under the Paskapoo Formation (Judy and Fox Creek) and its transition to the Wapiti Group (Ante Creek) (Knapik and Lindsay, 1983; Wynnyk et al 1969). They are a succession of upper Cretaceous- and Tertiary (Paleocene)-aged, nonmarine deposits consisting of thick, pale gray, crossbedded sandstones interbedded with gray siltstone, silty mudstone, and local coal seams.

The entire area was covered with glacial Laurentide ice during the Pleistocene that originated in the Keewatin area, which eroded and smoothed the landscape. The surficial deposits are morainal materials, with some glaciolacustrine sediments in the Ante Creek area. Morainal materials consist mostly of till deposited directly from glacial ice onto the landscape. Till is a heterogeneous material usually clay loam textured, free of salts, with dark brown color, and a thickness varying from less than 1 m to several meters. The glaciolacustrine sediments are dominantly clay and silt-sized and usually contain scattered pebbles.

Soil landscapes in Ante and Fox Creek are dominated by Orthic Gray Luvisols (>40% of the area) developed on clay loam textured till, with inclusions of poorly drained Gleysolic soils (20-40% of the area) in the depressional areas. Till is moderately stony and moderately to slowly permeable. In Judy Creek moderately well drained Orthic Grey Wooded soils developed on fine textured materials originating from the Paskapoo Formation. Orthic Gray Wooded (Orthic Gray Luvisol) soils have a general profile with organic surface horizons (L-H), light-colored illuvial horizons (Ae), and illuvial horizons with accumulations of clay (Bt) (Canada Soil Survey Committee, Subcommittee on Soil Classification, 1974).

2.3 Climate

The climate of this area is humid continental, with long cold winters and cool summers. Mean annual precipitation is 550 to 600 mm, with 350 to 400 mm during the period May to September. Snowfall averages 150 to 200 cm. The mean annual temperature is 0 °C. Mean daily temperature for the warmest month (July) is 15 °C, and the coldest (January) -14 °C. The frost-free period lasts generally less than 75 days. Annual potential evapotranspiration ranges from 350 to 450 mm.

2.4 Physiography and topography

The three study sites are situated at elevations between 855 and 1010 m (Table 2.2). Ante Creek is located on the geomorphological element of the Simonette benchland, Fox Creek on the Fox Creek benchland, and Judy Creek on the Swan Hills upland. The three sites are characterized by a complex, rolling topography, with slopes varying from 3.7% to 20% (Table 2.2). Judy Creek has a sigmoid shaped relief with clear differences between upper and lower slopes (Figure 2.2). Fox and Ante Creek have a more uniform slope. Predominant aspects of the sites are showed in Table 2.2.

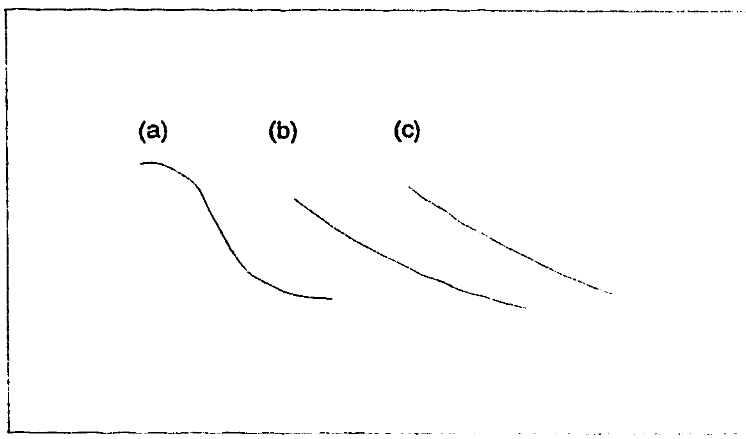


Figure 2.2. *Slope shape of Judy Creek (a), Fox Creek (b), and Ante Creek (c) study sites.*

Table 2.2. Topographic characteristics of the study sites.

		Slope	Altitude (m)	Aspect
Judy Creek	Upper	20%	1010	300°
	Lower	3.9%		
Fox Creek	Upper	8.9%	975	270°
	Lower	3.7%		
Ante Creek	Upper	7.6%	855	100°
	Lower	7.1%		

2.5 Drainage basins

Judy Creek drains to Carson Creek and the Sakwatamau River, which are tributaries of the Athabasca River. Fox Creek drains to Smoke Lake and Ante Creek to Waskakigan River, with both eventually draining to the Little Smoky river which is a tributary of the Peace River.

2.6 Vegetation

The three study sites are located in the Lower Boreal Cordilleran forest ecosystem association (Corns and Annas, 1986). This ecoregion is a transition zone between the primarily deciduous Boreal Mixedwood and the coniferous Upper Boreal Cordilleran ecoregions. The principal trees of the area are aspen (*Populus tremuloides* Michx.), balsam poplar (*Populus balsamifera* L.), white spruce (*Picea glauca* (Moench) Voss), and lodgepole pine (*Pinus contorta* Loudon var. *latifolia* Engelm.). Other species present in the area are black spruce (*Picea mariana* (Mill.) B.S.P.) and fir (*Abies balsamea* (L) Mill.). The stand density of the surrounding area is 51 - 70%, with a site index class "good" (20 m + in height for white spruce, pine, aspen, and balsam poplar, and 12 m + for black spruce) (Forest inventory 1985). Other characteristic non-arboreal species of the area are *Viburnum edule, Lonicera involucrata, Rosa acicularis, Cornus canadensis*, and *Calamagrostis canadensis*. When the trees are logged, competing vegetation, especially *Calamagrostis canadensis* and aspen suckers, can became a serious problem for planted conifer seedlings (Corns and Annas, 1986).

CHAPTER THREE

SITE PREPARATION TREATMENTS AND MICROSITES

The site preparation methods selected for study were: disc trenching, ripper ploughing, and blading. These methods commonly used in the region were compared to a harvested, untreated control.

3.1 Disc Trenching

3.1.1 Description

The Disc Trencher uses a rotating toothed disc to create two parallel trenches each approximately 60 cm wide by 20 cm deep. Surface organic material and mineral soil are mixed and turned into berms.

The objectives of this treatment are to create a range of planting spots, and to provide better foot access for planters (Coates and Haeussler, 1987). Planting spots vary from depressed in mineral soil trenches to elevated in partially overturned and mixed berms (Hunt and McMinn, 1988). The long, continuous parallel rows minimize machine turning time and offers planters numerous planting spots within tolerance limits for a desired spacing (McMinn and Hedin, 1990).

Disc trenchers are very effective in a wide range of situations, either for natural regeneration or planting. The effectiveness of this method varies depending on site factors (slope, amount of slash, etc.) and the type of disc trencher and settings used (Von der Gönna, 1992).

3.1.2 Machinery

Disc trenching was done with a Donaren 180D powered disc trencher mounted on a John Deere 640 skidder. It consisted of two toothed disks mounted on two separate, articulating arms hydraulically activated to vary downward pressure at an angle to the direction of travel. When the disks turn, the soil surface is ripped and mineral soil is exposed in a trench bordered on the upper side by a berm (Hunt and McMinn, 1988).

The depth and width of the trench can be adjusted by changing the angle of the disks, the downward pressure, and the travel speed (Von der Gönna, 1992). As the angle of the disks and the direction of travel increases, the trench is shallower and wider. With lower speeds and higher downward pressure, the trench is deeper.

Advantages (Bamsey, 1985; Coates and Haeussler, 1987) of disc trenching include: it is easy to attach and to transport from block to block; it is a simple, rugged machine; it creates good planting opportunities within prepared soils, particularly on lighter-textured soils; it is relatively inexpensive to operate.

Disadvantages (Bamsey, 1985) include: heavy slash (>7.5 cm diameter) reduces effectiveness; it can cause erosion problems on sloped sites. On sites with heavy slash and deep organic layers, powered trenchers are required. To minimize erosion, trenching should be intermittent (i.e. avoid long continuous trenches).

3.1.3 Microsites created

Disc trenching was expected to create three plantable microsites: Berm, Hinge, and Trench (Figure 3.1).

The ***berm*** is an elevated planting spot with irregular organic material turned over and partially mixed with mineral soil. Characteristics of this microsite can include:

- higher soil temperatures that enhance seedling growth and speed mineralization and therefore nutrient availability (McMinn, 1985);
- lower bulk density, higher porosity and better drainage, which is positive in wet sites and negative in dry sites (McMinn and Hedin, 1990);
- high fertility since it retains the available nutrients from the surface organic matter;
- control of competing vegetation by the soil disturbance and inverted layers (McMinn, 1985) or enhancement of competing vegetation by increase in fertility; and
- logging debris that limits microsite creation.

The ***hinge*** is a level planting spot usually located at the junction of the mineral soil exposed at the furrow and the surface organic layer or edge of the berm. The hinge can be either a mixture of organic matter and mineral soil or just mineral soil, depending on the degree of disturbance. Characteristics of this microsite are:

- lower bulk density, higher porosity and good drainage;
- higher soil temperatures with exposure and mixing of organic matter and mineral soil;
- control of not very aggressive competing vegetation if the disturbance is intense (McMinn, 1985); and
- high fertility.

The hinge is a preferred planting spot in fine-textured soils and sites with intermediate moisture regimes because of its micro relief that creates intermediate moisture retention and the high organic matter content which makes soils less compact.

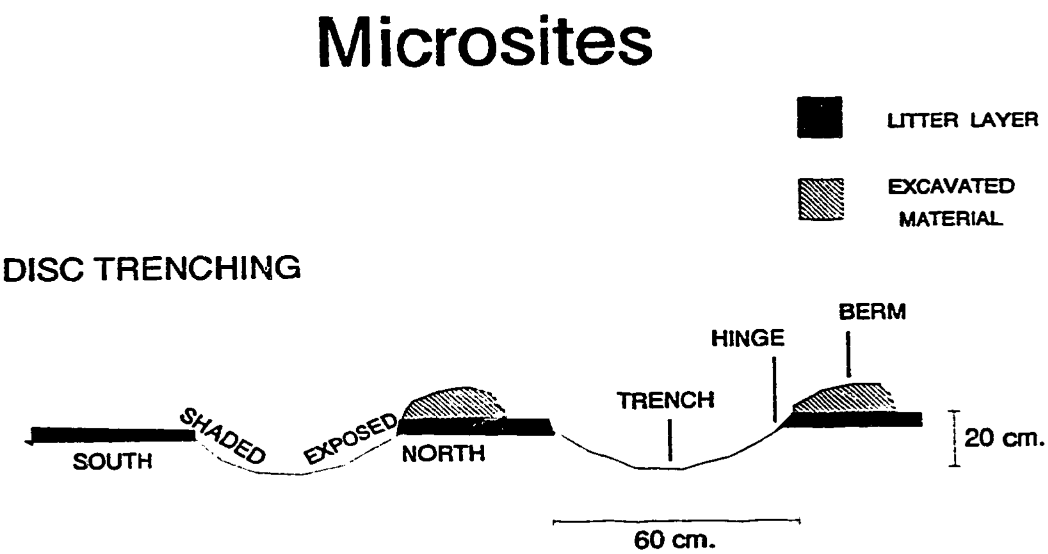


***Figure** 3.1. Potential plantable microsites created by Disc Trenching.*

The ***Trench*** is a depressed planting spot located in the bottom of the furrow. Characteristics of this microsite are:

- higher soil temperatures due to the exposure of mineral soil and removal of shading vegetation (McMinn, 1985);

- poor drainage and risk of flooding or waterlogging and frost heaving, especially in fine-textured soils;

- compaction, especially in fine-textured soils; we can find inhibition to root growth due to soil compaction.

- decrease of evaporation, especially in dry climates, due to the shade provided by the berms; and
- risk of erosion in sloped sites.

High soil temperatures can speed root growth and roots can reach available nutrients located far away (McMinn, 1985). On the other hand, soil compaction can inhibit root growth.

The trench is a recommended planting spot on well-drained and dry sites with medium-textured soils, where moisture conservation is required (McMinn and Hedin, 1990).

3.2 Ripper Ploughing

3.2.1 Description

Ripper ploughing is a drastic mechanical site preparation treatment which can affect not only the long- and short-term growth of seedlings, but also the flora and fauna of the area (Örlander et al. 1990). The purpose of this treatment is to create a continuous trench of bare mineral soil and berm offering a range of planting spots, and to provide improved microsite drainage.

A ripper tooth with wings mounted on the rear of a tracked tractor creates a trench 80 cm wide by 30 cm deep, and a berm 40 cm tall. In general, the depth and height of trenches and berms are greater than those produced by disc trenching. As in disc trenching, the scarification pattern is a long, continuous row to improve planter access, and to provide a greater selection of plantable spots.

3.2.2 Machinery

Ripper ploughing was done with a modified standard ripper tooth mounted on the back of a tractor or prime mover used to remove vegetation and organic layers. Ripper ploughing created extensive soil disturbance forming a deep trench and an overturned berm. Ripper ploughs are recommended for use in sites with thick duff layers or in wet sites when the soil is frozen (Von der Gönna, 1992). The ripper tooth digs into the frozen ground and the plough or wings displace blocks of frozen soil laterally and partially turn them over creating a berm (Coates and Haeussler, 1987).

Advantages of the ripper plough are (Coates and Haeussler, 1987): it has simple attachment; it has low maintenance and investment costs; if the treatment is applied on frozen ground, soil damage will be minimized; and it provides good planter access. Disadvantages (Bamsey, 1985) are: depth control is difficult; the treatment does not work very well on dry or nutrient-poor sites (with thin humus layers); and risk of erosion on sloped sites especially with fine-textured soils. In this case, the treatment should be applied intermittently by lifting the ripper occasionally.

3.2.3 Microsites created

Microsites expected from ripper ploughing are similar to those of disc trenching: Berm, Hinge, and Trench (Figure 3.2), but topograghic elevations are more extreme.

The ***berm*** is an elevated planting spot with inverted humus partially mixed with mineral soil. Sometimes a clearly defined berm is not produced (Von der Gönna, 1992) or it has too much debris or slash and it is not suitable for planting. Characteristics of this microsite are:

- high soil temperatures;
- high fertility since nutrients are rapidly liberated from slash and humus;
- low bulk density, higher porosity and aeration, and better drainage; and
- competing vegetation can be either controlled or enhanced depending on the severity of the soil disturbance.

The ***hinge*** is a level planting spot at the interphase between the mineral soil and the humus layer. It is similar to the hinge microsite defined in disc trenching. A potential problem in this microsite is that as the trench is deeper, roots sometimes cannot cross to the other side of the furrow and seedlings can develop asymmetrical root systems (Von der Gönna, 1992).

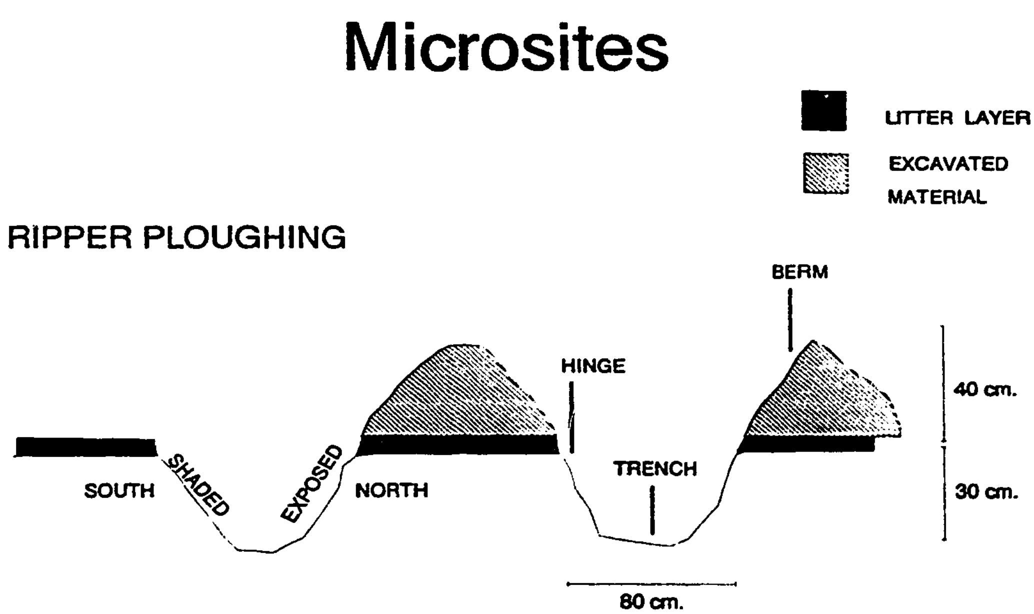


Figure 3.2. Potential plantable microsites created by Ripper Ploughing

The ***trench*** is a depressed planting spot located at the trench or furrow created. It is defined by mineral soil exposed, and it is similar to that defined in disc trenching but deeper. Characteristics of this microsite are:

- high soil temperatures, though temperatures may be cooler in some sites where shading from berms or aspect occur, or moisture collects;
- risk of flooding and frost heaving;
- risk of land erosion on sloped, wet sites; and
- good microsite in dry sites where moisture accumulation is required.

3.3 Blading

3.3.1 Description

Blading removes surface organic material by pushing it into piles using a tracked tractor. The microsite produced is a level or depressed, scalped spot. The objectives of this treatment are to expose mineral soil, to suppress grass competition, and to improve planter access (Bamsey, 1985). Blading is usually a very effective method, but some area is lost for reforestation since the piles created are not suitable for planting. Piles are located along contours in windrows, and they are 2 m wide by 20-25 m long by 1.5-2 m tall (Figure 3.3).

This treatment is generally applied in combination with other treatments as a first-pass treatment to improve their effectiveness (McMinn and Hedin, 1990).

3.3.2 Machinery

The machinery used to remove slash and surface organic material was a front-mounted straight blade. It should work deep enough to remove unfavourable litter and duff layers, but not too deep because nutrients can be removed from planting spots and lost in slash piles. Advantages of blading are (Bamsey, 1985): it can deal with heavy slash; competing vegetation is controlled effectively; equipment is easily available and relatively cheap; and it is very effective in exposing mineral soil. Disadvantages are (Bamsey, 1985): risk of soil erosion, especially on wet sites with fine-textured soils; nutrients are removed from planting spots and concentrated in slash piles, so seedlings planted in this areas may show poor growth; slash piles reduce available planting area; and roots can be placed in an poor-oxygenated environment on wet sites with fine-textured soils.

3.3.3 Microsites created

Microsites created by blading were defined as thick or thin, as a function of the surface organic material remaining after treatment (Figure 3.3).

The ***thin*** is a depressed planting spot with an organic layer <5 cm deep, which corresponds with a well-decomposed organic horizon or humus layer, or mineral soil exposed in at least a 0.16 m^2 area (40 x 40 cm). In general, removing vegetation and roots, and reducing surface layer thickness provide increased soil temperatures, more secure moisture availability, and reduced vegetation competition. There is a high risk of soil erosion and frost heaving on these microsites, especially in fine-textured soils.

The ***thick*** is a level or depressed planting spot with an organic layer ≥5 cm deep at least 0.16 m^2 in area, where some reduction of the surface organic layer occurred. It has characteristics similar to the thin microsite but is less extreme because of protection from the thick organic layer. This microsite also has higher fertility than the thin.

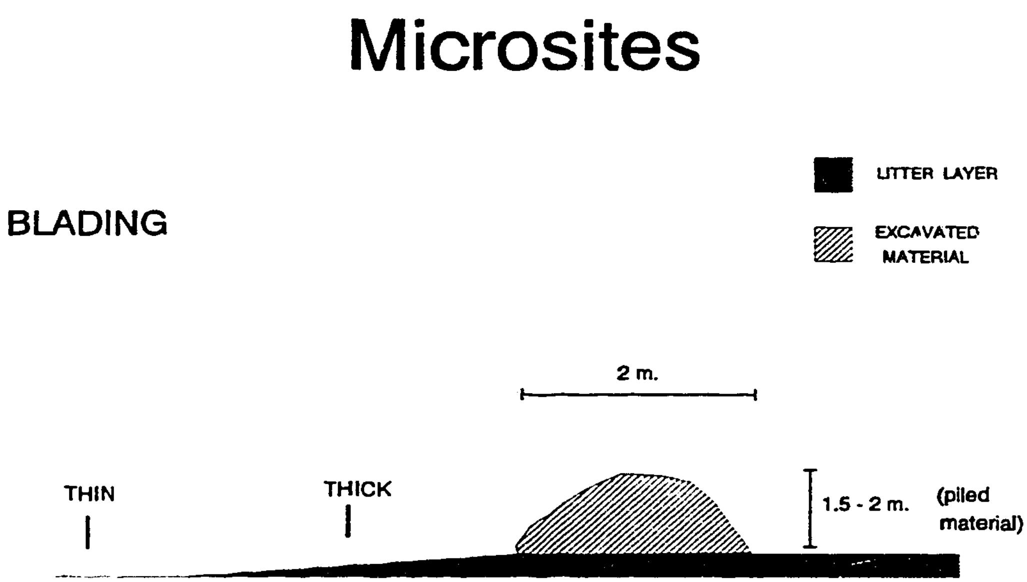


Figure 3.3. Potential plantable microsites created by Blading.

3.4 Control

A harvested untreated area was used as a control in this study. The harvesting method used was tree length harvesting and delimbing at roadside. Ground conditions after harvesting were good. Soil disturbance was minimum and no spots of exposed mineral soil were created. Two microsites were defined: control and screef (Figure 3.4).

The ***control*** is a planting spot with undisturbed conditions. Well drained elevated or level spots were considered favourable planting microsites. Low poorly drained spots or locations very close to stones or with too much slash so the seedlings would not perform (i.e. survive and grow) were avoided.

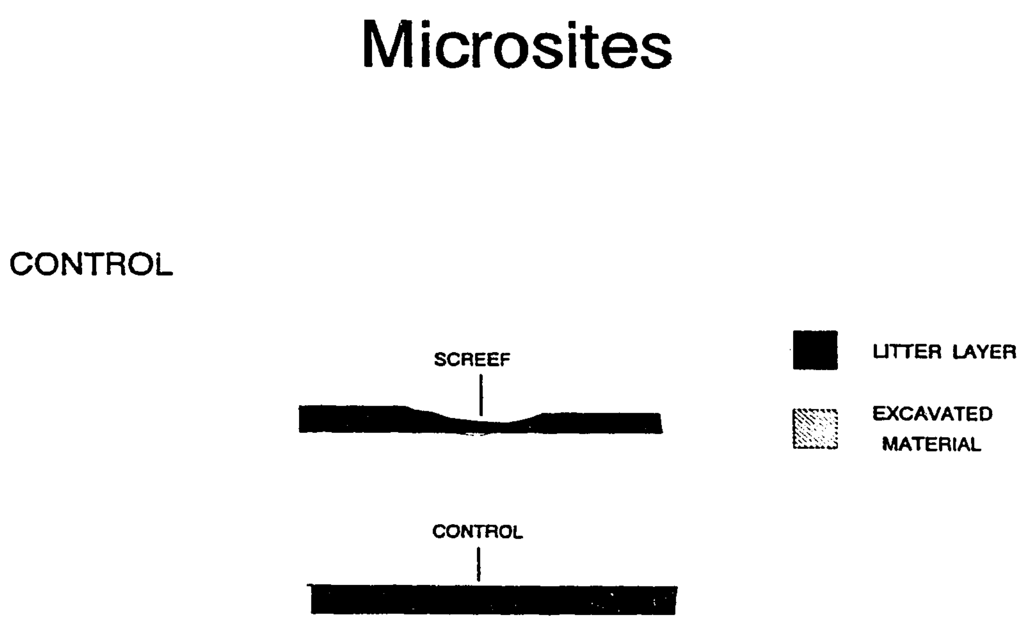


Figure 3.4. *Potential plantable microsites defined at the control area.*

The ***screef*** is essentially the same planting spot as the control microsite where the surface litter was removed by the planter dragging his boot back and forth across the ground surface. The screef was a shallow depression which was more moist and dense than the control.

A summary of the different microsites and their characteristics is shown in Table 3.1.

Table 3.1. Summary of the different microsites and their characteristics.

Treatment	Microsite	Relative pos.	Composition	Characteristics	
Disc Trenching	Berm	elevated	mixture / mineral soil inverted	- High soil temperature - Low bulk density - High fertility	- Control of competing vegetation - Excessive debris - Good drainage
	Hinge	level / depressed	mixture / mineral soil	- High soil temperature - Low bulk density - High fertility	- Control of comp. veg.
	Trench	depressed	mineral soil	- High soil temperature - Poor drainage - Compaction	- Risk of erosion
Ripper Ploughing	Berm	elevated	mixture / mineral soil inverted	- High soil temperature - Poor drainage - Compaction	- Control / enhancement of competing vegetation - Good drainage
	Hinge	level / depressed	mixture / mineral soil	- High soil temperature - Low bulk density - High fertility	- Control of competing vegetation
	Trench	depressed	mineral soil	- High soil temperature - Poor drainage - Risk of erosion	- Compaction
Blading	Thin	depressed	mineral soil / mixture	- High soil temperature - Risk of erosion - Control of comp. veg.	
	Thick	depressed	organic matter / mixture	- High fertility - High soil temperature - Control of comp. veg.	
Control	Control	level	organic matter	- Undisturbed	
	Screef	depressed	organic matter	- Moister and denser than control	

CHAPTER FOUR

METHODOLOGY

4.1 Layout

Three sites in the Whitecourt Forest with similar topography, soils, and stand types were selected as the study area. They were clearcut, and four site preparation treatments were applied at each site (ripper ploughing, disc trenching, blading and control or undisturbed). Harvesting was done in fall-winter 1990. All treatments were completed in the winter and spring of 1990-91. Each treatment was repeated twice per site, and located randomly within each block. Treatment areas were about 20 m wide to ensure that microsites were characteristic for each treatment. The blocks were located side by side so they would have the same physical characteristics (aspect, similar slope, moisture, etc) (Figure 4.1).

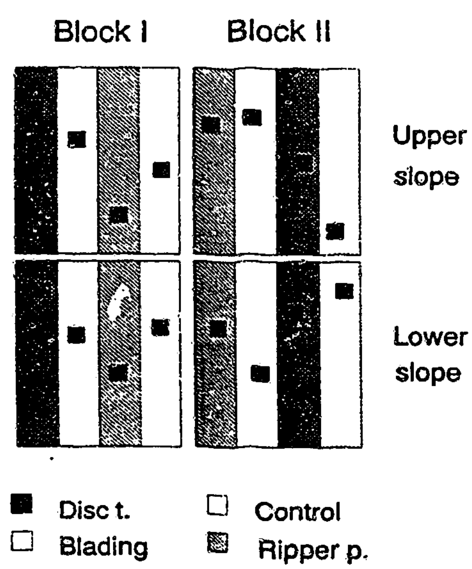


Figure 4.1. Layout.

Disc trenching and ripper ploughing were applied running up and down slopes. Blading was applied by piling slash and surface litter along the contour, creating a pile approximately every 20 m.

4.2 Sampling

Two sets of samples were taken during the summer of 1991. The first one was used to describe the success of the treatments in creating plantable microsites, the physical soil characteristics of the different microsites, and the potential soil erodibility created by the treatments. The second one was used to compare physical soil properties of selected microsites among treatments. All samples were taken at least two days after rainfall to allow soils to drain from saturation and reach field capacity (soils did not contain gravitational water). Sampling at each site was accomplished in one day to avoid the confounding effects of precipitation and associated differences in soil moisture. The average precipitation in the summer of 1991 was 367 mm.

Sample set no. 1

The success of the treatments in creating plantable microsites was evaluated by a survey. Two plots 10 x 10 m were established randomly in each treatment area, one at the upper slope and one at the bottom of the slope. This provided 16 plots at each location, for a total of 48 plots among all the study sites.

The following data were recorded from these plots:

- General data: location, block, treatment, slope position, and plot number.

- Maximum slope.

- Aspect in the direction of the maximum slope.

- Spatial distribution of mineral soil exposed. Three categories were visually identified:

  * Continuous: continuous areas occupying > 25 m^2.

  * Discontinuous: patches of 4-25 m^2 in area.

  * Spots: discrete, continuous areas of < 4 m^2.

- Amount and type of slash. They were classified in the following categories by means of visual identification and the help of a measuring tape when needed:

  * Heavy: most logs with diameter ≥ 7 cm.

  * Light: most logs with diameter < 7 cm.

  * Abundant: area covered with slash ≥ 50%.

  * Scarce: area covered with slash < 50%.

A 2 x 2 m spacing for planted seedlings was assumed as a basis for evaluating and sampling the number of microsites created (i.e. a minimum of at least 2500 microsites per hectare). Therefore, each 10 x 10 m plot was subdivided into 25, 2 x 2 m subplots which were surveyed for the following:

- Absence or presence of all plantable microsites created by each treatment (Figures 3.1, 3.2, and 3.3). Therefore, a minimum of 25 microsites of each type were expected in each 10 x 10 m plot. 1 microsite of each type was randomly selected in each 10 x 10 m plot and physically marked by metal pins for later sampling and description.

- Depth to mineral soil was defined as the depth of the litter layer above the mineral soil. Measurement was done by inserting a long metal pin into the forest floor at each microsite until the mineral soil was reached, and then recording the depth of penetration of the pin.

- Soil disturbance. The percent of the total area (4 m^2) occupied by exposed mineral soil, by mixed mineral soil with organic matter, and by undisturbed forest floor (organic layer) was visually estimated. Soil disturbance was defined as the sum of the first two components.

The physical soil properties for each microsite were described. Disturbed and undisturbed soil samples were randomly taken for each type of microsite in each 10 x 10 m plot. Undisturbed samples were taken with a brass ring (5.4 cm in diameter x 2.9 cm in height = 66.42 cm^3) with the help of a hammer and bulk density soil sampler. Disturbed samples were excavated with a small shovel.

Sampling was restricted to the surface 0 - 10 cm of the soil, where seedlings were planted and expected to survive and grow. Substrates sampled varied from mineral soil, mixed organic matter and mineral soil, to undisturbed forest floor depending on treatment and microsite (Table 4.1 and Figure 4.2). Undisturbed samples were always taken from the surface 2 - 7 cm depth, and from the first mineral soil horizon below the ground surface to evaluate treatment effects and microsite locations in the soil profile. Disturbed samples were always taken in mineral soil at either the ground surface or first mineral horizon depending on whether or not there was a surface organic layer. This set of soil samples were taken in June and July 1991 and were used to describe the soil texture, particle size distribution, structure, organic matter content, drainage, soil water retention capacity, and bulk density of each microsite. Microsites sampled were:

- Ripper ploughing: trench, hinge, and berm.
- Disc trenching: trench, hinge, and berm.
- Blading: thin and thick.

- Control: control.

Sample set no. 2

A second set of soil samples were taken in August 1991 to quantify microsite bulk density and soil moisture content (Figures 5.14 and 5.15). Microsites selected for sampling were:

- Ripper ploughing and disc trenching: hinge, which was stratified by aspect for shaded and exposed locations.
- Blading: thin and thick.
- Control: control and boot screef.

Three randomly located, undisturbed samples were taken for each microsite on the upper and lower slopes of each treatment area. Microsites were sampled once in the growing season.

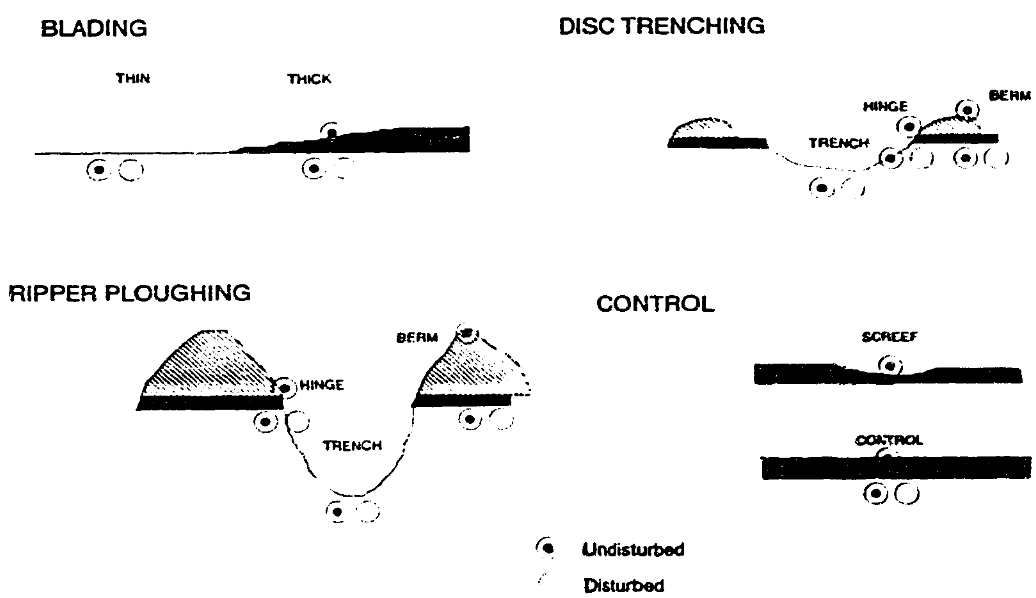


Figure 4.2. Soil samples taken from the different microsites.

Table 4.1. Types of soil samples take from the different microsites.

Treatments	Microsites	Bulk density samples	Disturbed samples
Disc Trenching	Berm	- mineral soil - mixture[1]	- mineral soil
	Hinge	- mineral soil - mixture[2]	- mineral soil
	Trench	- mineral soil	- mineral soil
Ripper Ploughing	Berm	- mineral soil - mixture	- mineral soil
	Hinge	- mineral soil - mixture[2]	- mineral soil
	Trench	- mineral soil	- mineral soil
Blading	Thin	- mineral soil	- mineral soil
	Thick	- mineral soil - mixture	- mineral soil
Control	Control	- mineral soil - forest floor	- mineral soil
	Screef	- forest floor	

[1] Mixture of organic matter and mineral soil.
[2] If it is created.

4.3 Laboratory Analysis

4.3.1. Bulk density

Bulk density was determined from undisturbed soil samples obtained in sample rings 2.7 x 2.9 cm. Samples were dried in an oven at 105-110° C for at least 48 hours and weighed. Bulk density was calculated as (Hillel, 1980):

$$\text{Bulk density: } \rho_b = \frac{\text{ovendry weight}}{\text{volume}} \qquad [4.1]$$

4.3.2. Soil moisture content

Soil moisture content of the 2-7 cm layer of each microsite was gravimetrically sampled at least 48 hours after precipitation to allow for drainage and on expression of any differences in soil water storage between microsites.

Undisturbed soil samples were weighed before and after drying in an oven at 105-110° C for at least 48 hours. Gravimetric and volumetric soil moisture contents were calculated

$$\text{Gravimetric water content: } \theta_g = \frac{(\text{wet weight}) - (\text{dry weight})}{\text{dry weight}} \qquad [4.2]$$

$$\text{Volumetric water content: } \theta_v = \theta_g * \left(\frac{\rho_b}{\rho_w}\right) \qquad [4.3]$$

as follows (Hillel, 1980):

where:

ρ_w: density of water. It is usually close to 1 Mg/m^3.

4.3.3. Soil structure

Soil structure is "the arrangement and organization of the particles in the soil" (Hillel, 1980). Soil structure was determined visually and by resistance to compression by fingers. The following structural classes were defined (Larionov, 1982):

I. Very fine granular*. Particles are loose.

II. Fine granular*. Bonds between grains are weak. Easily crushed by fingers under low pressure.

III. Medium or coarse granular*. Bonds between grains are stronger. Soil sample crushed under high pressure (sometimes crushing is not possible).

IV. Massive or blocky*. Bonds between particles have high strength. Soil samples can be crushed only by hammer blow.

* These structural classes correspond with those used in the nomograph for determining the soil erodibility factor (K) in the Universal Soil Loss Equation (Wischmeier, 1971).

4.3.4. Organic matter content

Organic matter content was determined by a simple ashing procedure. Soil samples from the forest floor and mixed substrates had such high organic matter contents that the loss in weight after burning in a muffle furnace was large enough to be expressed as a gravimetric percent of organic matter with acceptable accuracy (Storer, 1984). Organic matter of mineral soil samples was considerably lower, and therefore it was determined by using a calibration curve relating LECO induction furnace estimates to muffle furnace estimates. Fifty paired samples were used to develop the calibration curve. Calibration curve was used to economize on the cost of LECO measurements.

*** LECO.**

After mechanical fragmentation of the samples, they were introduced into the LECO furnace for combustion at 1300° C. Percentage of total carbon was obtained from the amount of CO_2 volatilized in the combustion quantified by a gas chromatograph fitted with a flame ionization detector (Nelson and Sommers, 1982). Organic matter content was calculated as follows:

$$\%\ O.M. = \%\ total\ C * Walksman\ coefficient \qquad [4.4]$$

*** Simple ashing procedure.**

After mechanical fractionation of the samples, they were dried in an oven at 105-110° C overnight, cooled, and weighed. Then, samples were ashed in crucibles in a muffle furnace at 950° C for 7 min. Weight of the samples were recorded after burning. Organic matter content was calculated as follows:

$$\%\ O.M. = \frac{(dry\ weight\ at\ 105^{o}\ C) - (dry\ weight\ at\ 950^{o}\ C)}{dry\ weight\ at\ 105^{o}\ C} \times 100 \qquad [4.5]$$

*** Calibration curve.**

The calibration curve (Figure 4.3) was derived by regression of ashing results on LECO observations.

The organic matter contents of the samples that were not analyzed by the Leco were obtained by ashing the samples in the muffle furnace and calculated by the equation:

$$\%O.M.\ furnace = 1.28\ (\%O.M.\ LECO) + 1.01 \qquad [4.6]$$

with a coefficient of determination r^2 = 0.73. Loss of accuracy produced by using this calibration curve was acceptable.

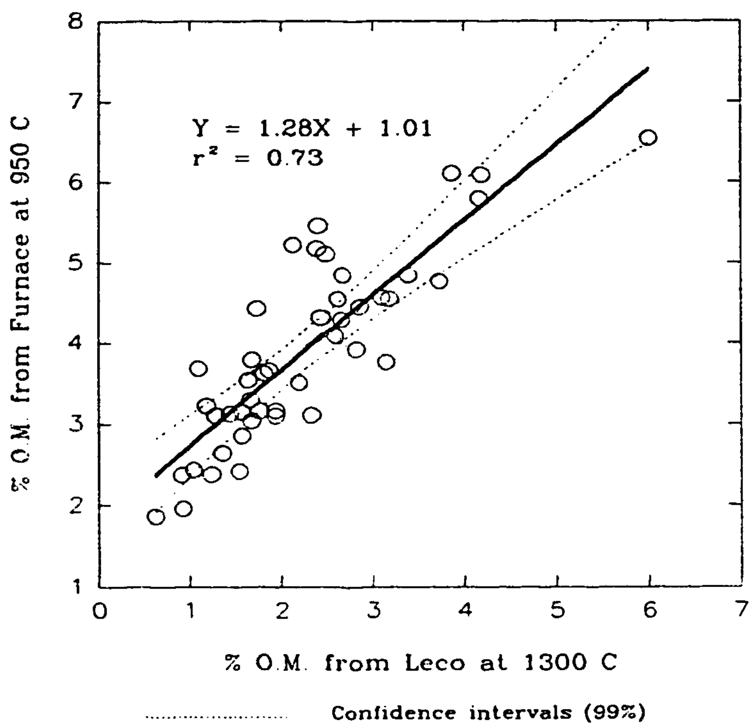


Figure 4.3. *Calibration curve used to estimate organic matter content in mineral samples.*

Soil samples were tested for carbonates by adding HCl to them. No signs of soluble salts content were found.

4.3.5. Particle size analysis

Particle size analysis was done using the hydrometer method (McKeague, 1978). Large particles (>0.05 mm) were separated by passing the soil sample in suspension through a sieve with the help of running water.

Pretreatment dispersion was necessary to break down the aggregates into single particles. The dispersion of the particles was done by the addition of Calgon solution (50 g/L) and homogenization with an electric mixer (McKeague, 1978).

The soils of this of this area were free of carbonates and iron oxides, so no chemical pretreatment was necessary for these compounds. Since organic matter content was lower than 5%, its removal was not necessary (Kalra and Maynard, 1991).

Particle-size distribution curves were described with data from the sieving and sedimentation procedures. They were used to calculate the soil erodibility factor and the texture of the different microsites.

4.3.6. Water retention capacity

Water retention capacity was expressed as matric potential obtained by constructing soil water desorption curves using a ceramic pressure plate system (McKeague, 1978). With the use of pressure-plate apparatus, the relationship between water content and matric potential was easily obtained.

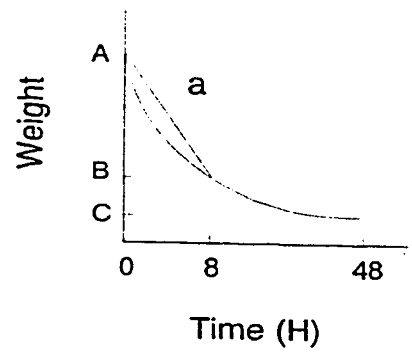
The undisturbed soil samples in the brass rings (66.42 cm^3) on the porous ceramic plate were brought to saturation and then placed in the pressure chamber under a certain pressure. Following equilibrium, the samples were removed from the pressure plates, weighed, and replaced on the plates to continue measurement under a new pressure. Samples and plates were saturated together between every determination to ensure better contact between the soil and the plate. This procedure was repeated for pressures of -0.1, -0.3, -1, -3, -6, and -15 bars (0.01, 0.03, 0.1, 0.3, 0.6, and 1.5 MPa). The weight of saturated samples and dried samples at 105 °C after 24 hours were used to determine soil moisture content (see 4.3.2 Soil moisture content).

4.3.7. Drainage

Drainage, or outflow of water from soil, was calculated by bringing the soils to saturation, letting them drain freely, and recording their change in weight over time.

The undisturbed soil samples were covered on the bottom with a plastic screen, fixed to the ring with a rubber band, to avoid loss of soil. Soil samples were placed into a water filled vacuum desiccator and brought to saturation. Following saturation of samples, excess water was removed from the desiccator and soils were allowed to drain. A small volume of water was left at the bottom of the sealed desiccator to keep a humid atmosphere for the soils and to avoid losses of water by evaporation. Samples were weighed at saturation and over a period of 48 hours (assumed time to reach field capacity). Initial weighings (0 to 2 hours) were recorded in short intervals (half an hour) because drainage is faster right after water addition. Later on, intervals were increased progressively up to 8 hours. The water loss from the samples was plotted against time.

A drainage index was defined to characterize the drainage capacity of the soils:



$$Drainage\ index = (a)\ x\ (b) = (\frac{A-B}{8})\ x\ (\frac{A-B}{A-C}) \qquad [4.7]$$

where:

- (a) represents the amount of water lost in the first 8 hours. In most soils examined more than 70% of free drainage occurred in the first 8 hours. "a" is a measure of the rate of drainage.

- (b) represents the percentage of water lost in 8 hours out of the total lost in 48 hours.

A soil losing more water in 8 hours will have a higher drainage index than another soil even though it lost the same amount of water in 48 hours (ie. it drained faster).

A low index indicates slow drainage, whereas a high index indicates fast drainage.

4.3.8. Potential soil erosion

Potential soil erosion was estimated with the soil erodibility (K) and cropping management (C) factors of the Universal Soil Loss Equation (U.S.L.E.) (Wischmeier and Smith, 1965). The basic U.S.L.E. equation was developed from experimental data collected at a large number of sites, and it is expressed as:

$$A = R \times K \times L \times S \times C \times P \qquad [4.8]$$

where A= soil loss (tones ha^{-1}); R= rainfall erosivity factor (J cm m^{-2} $hour^{-1}$); K= soil erodibility factor (tones m^2 hour ha^{-1} J^{-1} cm^{-1}); L= hillslope-length factor; S= hillslope-gradient factor; C= cropping management factor; and P= erosion-control factor.

K and C were the only factors considered to be affected by site preparation treatments. K was calculated using the nomograph created by Wischmeier et al. (1971), and C was calculated from tables based on the percent of ground covered by decaying compacted duff or litter (Table 4.2).

The potential soil erosion created by treatments was estimated by calculating the product of the factors K and C for mineral soil exposed, organic layer undisturbed, and mixing of organic and mineral material within each 10 x 10 m sampling plots. These factors were weighted by the area of soil disturbance represented in the treatment areas.

Table 4.2. Cropping-management factor (C) of the Universal Soil Loss Equation for pasture, rangeland, and idle land. Ground cover at surface is grass, decaying compacted duff, or litter at least 5 cm deep. (From U.S. Soil Conservation Service, 1975).

Type of canopy	Percent ground cover					
	0	20	40	60	80	95-100
No appreciable canopy	.45	.20	.10	.042	.013	.003

CHAPTER FIVE

RESULTS

5.1 Number of microsites and soil disturbance

The number and type of microsites (mcs) created by the different treatments are shown in Figure 5.1 (page 49). Blading was significantly better in creating microsites than the other treatments with an average of 2017 mcs/ha. Ripper ploughing and disc trenching were similar with 1461 and 1389 microsites/ha. respectively (Appendix 1.2). The data for blading may not be fully representative because the sampling plots, even though randomly located, did not fully or partially include any slash pile, which covered approximately 10% of the area. The adjusted value for blading using only area suitable for planting (excluding slash piles) is 1815 mcs/ha, which is still higher than the other treatments.

Blading was very effective in creating both thin (2167 mcs/ha) and thick microsites (1867 mcs/ha). The large variability shown (big standard error in Figure 5.1) for this treatment was due to the variability in treatment application. In some areas, the operator lifted the blade too much and a thick organic layer left. In these areas the number of thin microsites was very low. On other areas the operator set the blade too low and part of the mineral soil was removed. In these areas the number of thick microsites was very low. Contrary to what is reflected in Figure 5.1, blading can be a uniform treatment if applied by a well trained operator.

Discing and ripper ploughing were very successful in producing number of hinge (2050 and 1950 mcs/ha respectively) and trench (1508 and 1383 mcs/ha) microsites, but not very successful in producing berm microsites (608 and 1050 mcs/ha).

Criteria for evaluation of the effectiveness of the treatments in creating microsites are shown in Figure 5.1, where the percentages are of the total number of microsites created per hectare (2500 mcs/ha), based on an assumed 2 x 2 m spacing of planted seedlings.

Depth of surficial organic and mixed organic-mineral soil layers for microsites by treatments are shown in Figure 5.2. The surficial organic material for berm microsites in ripper ploughing and disc trenching were thicker, averaging 35 and 29 cm, compared to the undisturbed control with an average depth of 23 cm. Surface layers of the hinge microsites for disc trenching and ripper ploughing were similar in depth, averaging 6 and 5 cm respectively, but thinner than the control. Thick microsites in blading were also thinner than the control, with an average depth of 16 cm. The thin (blading) and trench microsites were primarily bare mineral soil with very little organic material present. Average depth of organic surface material for these microsites was 0-2 mm.

Soil disturbance, defined as percent of area occupied by exposed mineral soil or mixed mineral soil with organic matter, was significantly greater in blading than in the other treatments (Appendix 1.4), followed by ripper ploughing and disc trenching (Figure 5.3). In blading, the number of passes the machine makes across the soil is higher than in the other treatments. Soil disturbance from ripper and disc was slightly higher on upper slopes than on lower slopes, probably due to a heavier slash accumulation at the bottom of the slopes, though the differences were not statistically significant (Appendix 1.4). Blading, on the other hand, created higher soil disturbance on lower slopes, which were more wet and therefore more susceptible to soil disturbance. Disturbance was less on upper slopes, with organic layers often left undisturbed. A possible reason for this may be machines had some difficulties working on steeper slopes (loss of traction). In fact, soil disturbance was least on the upper slopes at Judy creek which has the steepest slopes of the three study areas. The large standard error for blading (Figure 5.3) also may be due to variability in treatment application between the three study areas.

In general, higher soil disturbance resulted in a greater number of plantable microsites (Figure 5.4). Regression analysis showed this relation to be weak ($r = 0.54$, $P < 0.01$) probably because of high variability in the data. Differences in treatment application in different areas produced high variability in soil disturbance and number of plantable microsites created.

No relations were found, using ANOVA and contingency tables, between the number of microsites or soil disturbance by the treatments with slope, quantity of slash, or size of slash, even though they were considered factors that could affect treatment application. Reasons for this might be slash was measured after treatment instead of before. Measurements of slash should have been obtained before treatment application to assess their potential effects on treatments. After application, slash was distributed in piles or rows and was not representative of the pre-treatment conditions. To validly determine any relationship between slash and treatment effectiveness we would have needed more sites to obtain range of slash conditions, i.e. a different study.

5.2 Organic matter content

Surficial organic matter content was related to the degree of removal and mixing of organic material and mineral soil. Organic matter content for all the treatments was significantly lower than the control (Appendix 1.5). The control averaged 76% compared to 26 and 27% for the blading and disc trenching, and 20% for ripper ploughing (Figure 5.5). These values suggest soil-organic mixing occurred, but do not give much information because they are averages of the different microsites for each treatment which are very different from each other.

Thin and trench microsites had significantly less organic matter content than the other microsites, averaging 2-3%, because of their mineral nature as a result of the complete removal of the surface organic layer and surface soil horizons. Hinge microsites had the best mixing of organic matter and mineral soil, with organic matter contents of 27 and 18% for disc trenching and ripper ploughing respectively. Maximum organic matter contents occurred on the thick and berm microsites (between 37 and 51%), showing a poor degree of mixing.

No differences in organic matter content were found between upper and lower slopes, except for the thick (blading) and berm (ripper ploughing) microsites on the upper slopes which showed smaller and greater degree of mixing respectively. Reasons for this might be variability of machinery and operators working on different slopes. Ripper ploughing turned the mineral soil over the berm more successfully in the upper slope, so the organic matter content was lower (20%).

5.3 Drainage

Differences in the drainage index are represented in Figure 5.6. Solid bars represent samples at a depth of 0-10 cm in the first mineral horizon encountered, whereas striped bars represent samples from the forest floor (2-7 cm of the ground surface) constituted either by organic matter or by mixture of organic matter and mineral soil. Thin and trench microsites were classified as deep samples because of their mineral nature but, in fact, they are located at the surface since there were no organic layers present.

As expected, the control showed the fastest drainage of all the treatments with a drainage index of 0.78, followed by blading and ripper ploughing (drainage index of 0.66 and 0.62 respectively). Disc trenching showed the slowest drainage with a drainage index of 0.55 (Appendix 1.6).

Surface drainage index for all of the treatments and microsites was less than the control which had a surface drainage index of 1.08. The best drained microsites were berm (ripper and disc), thick, and hinge (ripper) with drainage indexes between 0.78 and 0.84. Poorest drainage occurred on trench (disc and ripper) and hinge (disc) microsites with values between 0.45 and 0.52. In general, drainage was fastest on microsites characterized by low disturbance, thick organic layers, and high organic matter content which maintained large pores and pathways for rapid water flow. Two exceptions to this were the thin microsite, with a drainage index of 0.70 (greater than that of others with the same mineral nature), and the hinge (disc) microsite, with an unusual lower drainage index of 0.52.

Mineral soil horizons of thick, hinge, and berm microsites were the least well drained. They had the lowest drainage index values which ranged between 0.44 and 0.60 (Appendix 1.6).

5.4 Bulk density

All treatments produced higher bulk densities at the surface layers than that of the control (Figure 5.7), which was 0.15 Mg/m^3, because they removed organic surface layers, mixed organic and mineral material, and exposed denser horizons. Variability in the data was high. However, the only significant difference in bulk density was between the control (0.15 Mg/m^3) and the hinge-ripper microsite (0.70 Mg/m^3) because of the higher mineral content in the later.

Bulk densities for the mineral horizons were significantly greater than the surface layers, with values ranging from 1.14 and 1.39 Mg/m^3 (Appendix 1.7). No significant differences were detected in bulk density between the control (1.22 Mg/m^3) and the different microsites. This suggests soils were relatively uniform in bulk density between the different study sites, and that treatment effects of mixing and disturbance were primarily limited to the ground surface and treatments did not compact mineral soil.

There were no significant differences in bulk density between upper and lower slopes (Appendix 1.7).

5.5 Water retention

In general, organic samples (open circles in Figure 5.8) had higher porosity and larger pores than mineral samples (filled circles), which gave them a lower air-entry suction value (Hillel, 1980). Thus, soil-moisture desorption curves for organic surface samples start at a higher volumetric water contents than those for mineral samples, but decrease sharply to lower levels because the large pores empty at high water potentials (i.e. drain fast). After this point, the slope of the curve is very low until suction is increased so the smaller pores are emptied. Organic samples have higher porosity and contain more water at saturation. But under suction, mineral samples retain more water though some of the water is not readily available for plants because it is held by strong capillary forces (Harris, 1992). This can be observed in Figure 5.8 where curves for different microsites for mineral samples were consistently similar in level and shape (slope), as were those for organic samples, but the two groups were always significantly different (Appendix 1.8). An exception was the hinge microsite for ripper ploughing where samples from deep (mineral) and surface (organic mixed with mineral) layers showed similar curves in shape and level because of the high mineral content in the latter layer (see Figure 5.5).

The first inflection point at -0.1 bars (0.01 MPa) (Figure 5.8), was considered to represent the change from fully water saturated to partially saturated conditions. Here, all samples from shallow organic horizons, except the thick microsite with a value of 0.33, had volumetric water contents similar to the control (0.26), with values of 0.27 (berm - disc) to 0.30 (hinge - disc). At the same time, all samples from mineral horizons (deep samples and samples from thin and trench microsites) had volumetric water content similar to the control (0.36), with values of 0.34 (thin - blading) to 0.38 (thick - blading). In general, surficial organic layers had lower volumetric water contents at -0.1 bars than deeper mineral layers, except in the hinge microsite for disc trenching where both layers were similar (Appendix 1.8).

A second inflection point at -6 bars (0.6 MPa) was used as the lower boundary for available water given the small change in water content with decreasing water potential to -15 bars. There were no significant differences in volumetric water content between microsites or treatments and controls at -6 bars. Values ranged from 0.13 (hinge-surface - ripper) to 0.20 (thick-surface - blading) (Appendix 1.8).

Available water-storage capacity (AWC), estimated as the difference in water content between -0.1 and -6 bars, followed a pattern similar to volumetric moisture content at -0.1 bars (Figure 5.9). Samples from surficial organic layers, except hinge-surface - ripper (0.17), had values of 0.09 (berm-surface - disc) to 0.14 (berm-surface - ripper) (Appendix 1.8). Samples from deeper mineral layers, including thin and trench microsites, also had similar AWC with values of 0.18 (trench - ripper) to 0.21 (trench - disc). In general, AWC of surficial organic layers was lower than that of deeper mineral layers, in disagreement to what Page-

Dumroese et al. (1986) found. The reason of this may be the poor degree of mixing of organic matter with mineral soil which creates many macropores that do not hold water under negative pressure. Organic matter has not improved the soil structure yet, it has just increased porosity with macropores.

Site preparation treatments, by mixing mineral soil with organic matter, should bring the curves (the ones for deep-mineral layers and the ones for surface-organic layers) close together to intermediate values. Thus, curves for mineral layers would start at a higher volumetric water content and have higher slope, so soils would drain faster but still keeping high available water-storage capacity. Organic layers would have lower volumetric water content (curves would start at a lower value) and drain slower (curves with higher slopes) than before treatment effects increasing the available water-storage capacity. This effect is shown in the curves for the hinge - ripper microsites in Figure 5.8, which were similar with intermediate values between other curves for mineral and organic layers.

5.6 Potential soil erosion

Potential soil erosion was estimated with the soil erodibility (K) and cropping management (C) factors of the U.S.L.E. Soil parameters needed to calculate K using the nomograph created by Wischmeier et al. (1971) are organic matter content, permeability, structure, and texture (percent of silt plus very fine sand and percent of sand).

Organic matter content for the different microsites sampled at the mineral soil layer is shown in Figure 5.10. In general, upper slopes had slightly less organic matter than lower slopes. Microsites in the ripper and disc treatments had lower organic matter content than the undisturbed control, but the differences between treatments or slope positions were not statistically significant (Appendix 1.9).

Permeability was assessed with the drainage index (see Section 4.3.7) and the following guide:

6 - very slow: drainage index values between 0 and 0.3

5 - slow: drainage index values between 0.3 and 0.6

4 - slow to moderate: drainage index values between 0.6 and 0.9

3 - moderate: drainage index values between 0.9 and 1.2

2 - moderate to rapid: drainage index values between 1.2 and 1.5

1 - rapid: drainage index values > 1.5

Permeability of mineral soils for all treatments and microsites was low. Thin (blading) and hinge and trench (ripper ploughing) microsites, however, were more variable with samples varying from slow to moderate drainage (Figure 5.11).

Soil structure in control and disc trenching was predominantly blocky or massive probably because of less soil disturbance. Soil structure in blading and ripper ploughing was heterogeneous. These treatments caused more disturbance and soil mixing, with samples including fine granular, medium or coarse granular, and blocky or massive structure (Figure 5.12).

There were significant differences in soil texture between locations (Appendix 1.10). Fox and Ante Creek areas had silt loam soils, whereas Judy Creek had loamy soils with a better balance of fine and coarse particles (Table 5.1). However, no textural differences were found between the treatments and the controls. Hinge microsites for disc trenching had significantly higher content of clay and lower silt than the trench microsite. On the other hand, the same hinge microsite for ripper ploughing had a higher percent of coarse particles and lower percent of medium particles than trench and berm microsites. Thin microsite for blading shows lower content of clay than the thick, probably because of a loss of fine material by soil erosion, though the difference was not statistically significant (Appendix 1.10).

Potential soil erosion (K*C factor) created by the treatments followed the same pattern as soil disturbance (Figure 5.13). There was no significant differences between slope positions (Appendix 1.11), however the slope factor (LS) was not included in the potential soil erosion estimates for this study. Besides, slopes were not big enough to make an important difference in K*C, especially in Fox and Ante Creek. Blading produced the greatest potential soil erosion, followed by ripper ploughing and disc trenching. In fact, on areas with a high percentage of mineral soil exposure (blading and ripper), erosion was a serious problem. Gullies were created by water erosion in the blading treatment area, especially in Ante Creek, exposing the roots of the seedlings. In the same location we also found large amounts of sediment transported by runoff from the trenches in ripper ploughing.

5.7 Bulk density and moisture content for selected microsites

The effects of microsite aspect within ripper ploughing and disc trenching, and boot screeffing on the controls on bulk density and water content were evaluated, as well as the blading microsites (Appendices 1.12 and 1.13, Figures 5.14 and 5.15). Results regarding bulk density in this section are discussed independently from results in section 5.4 because microsites sampled are different (only selected microsites were considered in this section) and the sample size is larger here (see Sample set no. 2 in section 4.2).

All treatments created higher bulk densities at surface layers than control, which averaged 0.34 Mg/m^3. Ripper ploughing and disc trenching had the greatest bulk densities (0.96 and 0.95 Mg/m^3 respectively), followed by blading (0.81 Mg/m^3).

Ripper ploughing and disc trenching had similar bulk density for both microsite aspects (exposed and shaded) with values averaging between 0.92 and 0.99 Mg/m^3. On the other hand, microsites for blading showed very different values. Thin microsite had the highest bulk density (1.15 Mg/m^3) because of its high mineral content (see Figure 5.5); whereas thick microsites had lower bulk density (0.47 Mg/m^3) because of their organic nature. Bulk density of thick microsites were 93% greater than the control (0.24 Mg/m^3) which suggested some degree of compaction of surface organic material occurred. Bulk density in the screef microsite was 86% higher than in the control, with values (0.45 Mg/m^3) similar to the thick microsites. No differences in bulk density were found between slope positions (Appendix 1.12).

Soil moisture content was closely related to the degree of soil disturbance and mineral soil exposure. Samples were taken from the surface layer at least two days after precipitation to allow gravitational drainage. Undisturbed control and disc trenching had the highest volumetric water contents at 32 and 33% respectively, followed by more drastic treatments such as ripper ploughing (28%) and blading, which created the driest microsites (24%). Maximum water content occurred in screef (36%) and disc-shaded (35%) microsites. Screef microsites were moister than the control (29%) because part of the loose surface layer was removed or compressed thereby improving water retention properties. This difference was greater on the lower slopes (higher water content) than on the upper slopes. Thin microsites were the driest (20%) since they are mainly composed by mineral soil and, therefore, had higher soil temperature and greater evaporation of soil water. In general, microsites at upper slopes and exposed aspects (in ripper and disc treatments) were drier than microsites at lower slopes and shaded aspects, but the differences were not statistically significant (Appendix 1.13).

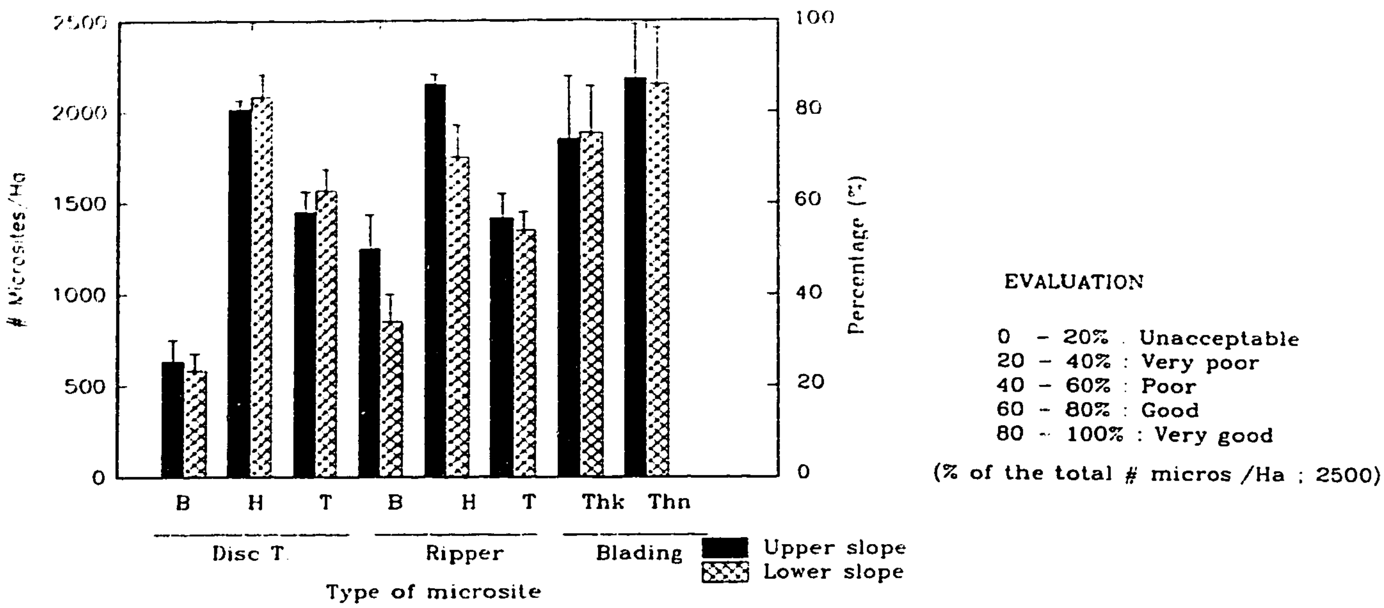


Figure 5.1. Number of microsites per hectare created by the treatments.

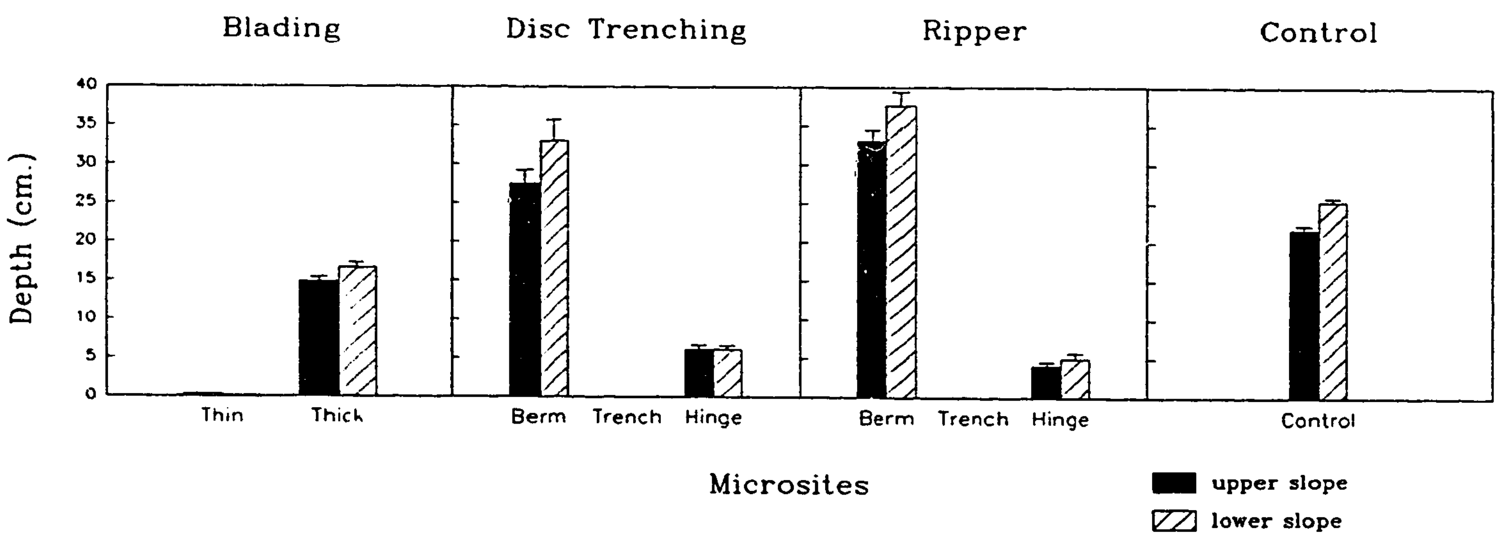


Figure 5.2. Depth of the organic layer above the mineral soil layer.

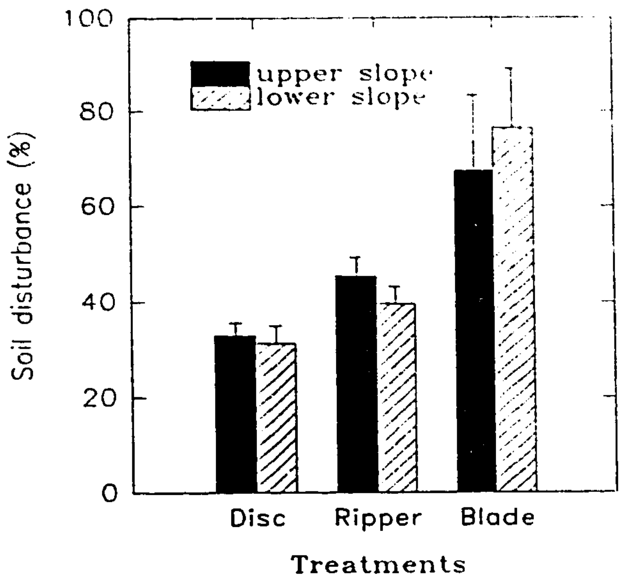


Figure 5.3. Percent soil disturbance on randomly located 10 x 10 m. plots within each treatment.

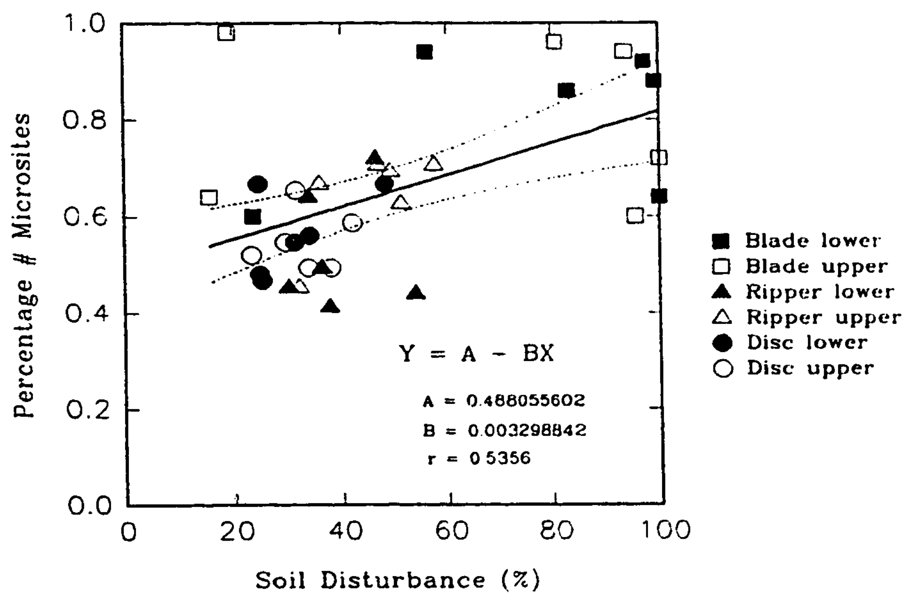


Figure 5.4. Relationship between soil disturbance and the number of plantable microsites created by each treatment. Dotted lines represent confidence limits (95%).

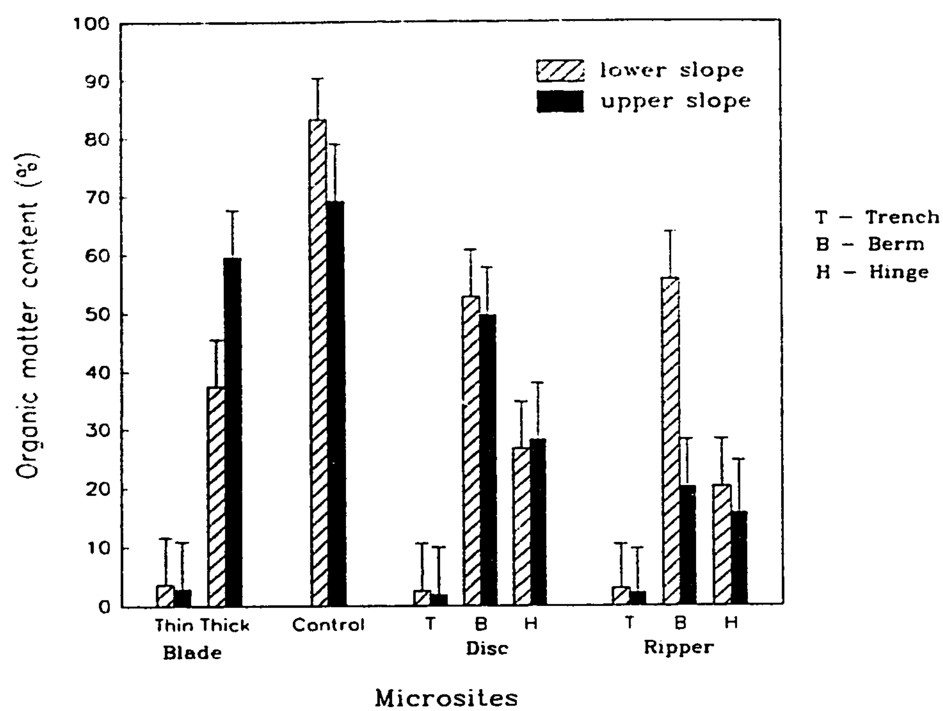


***Figure 5.5.* Organic matter content. Standard errors shown are the result of a balanced design used in the analysis of the data (Appendix 1.5). Standard errors of the actual data for thin and trench microsites are smaller than shown.**

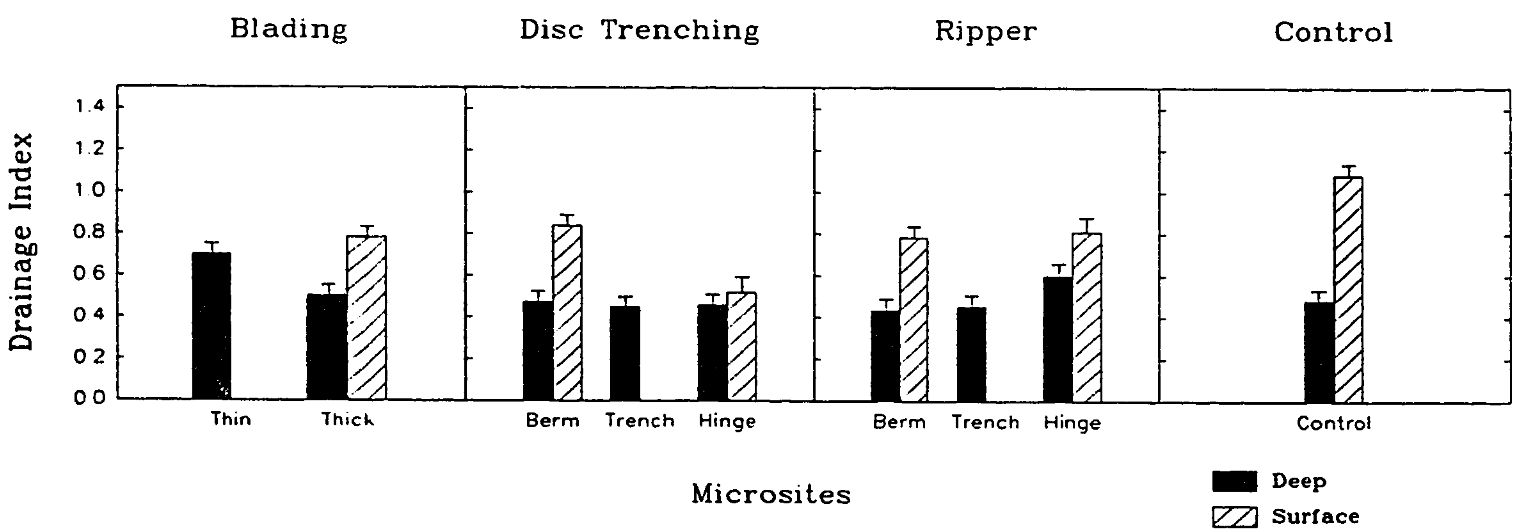


***Figure 5.6.* Drainage index values for deep-mineral and ground surface-organic samples.**

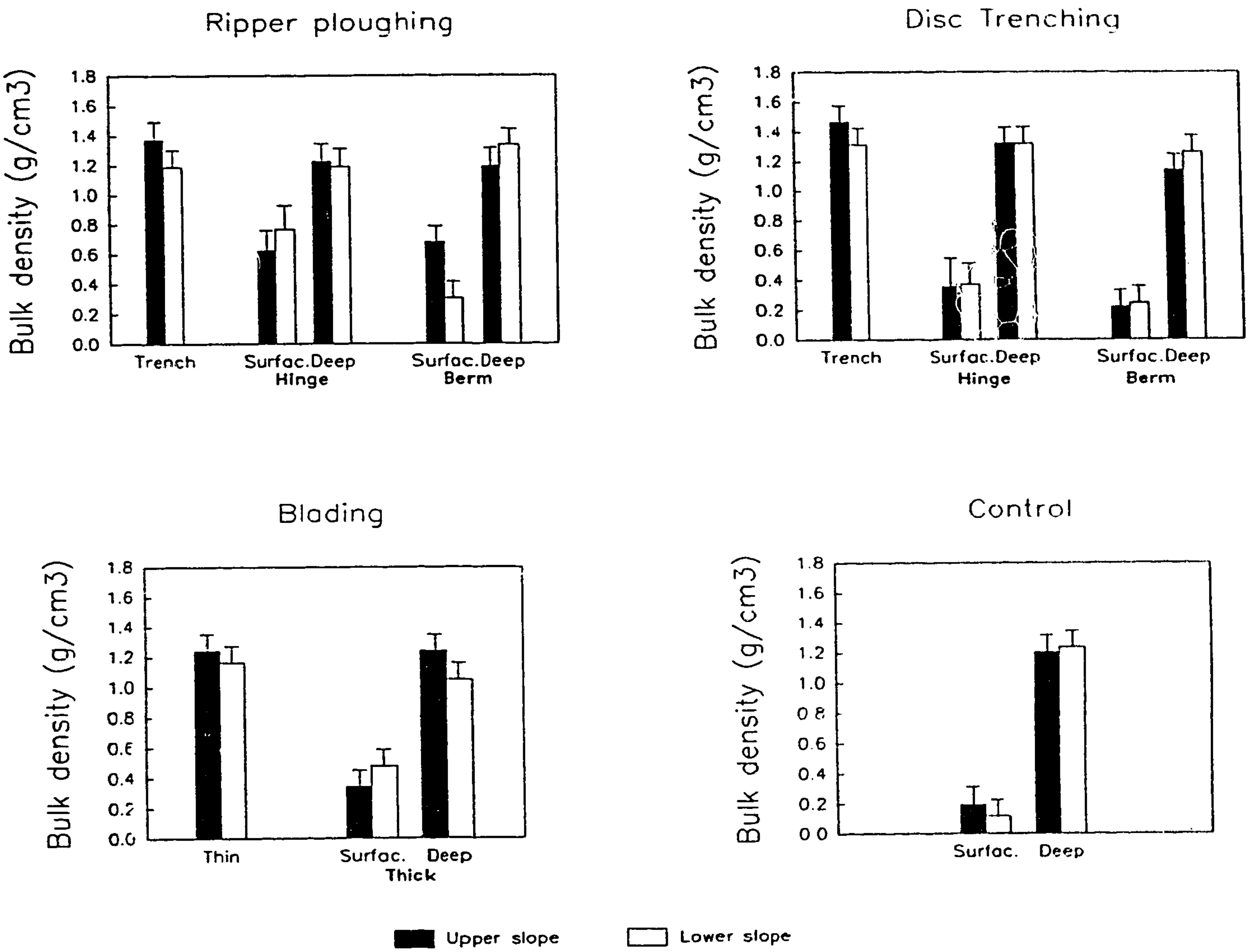


Figure 5.7. Bulk density of the different treatments and microsites.

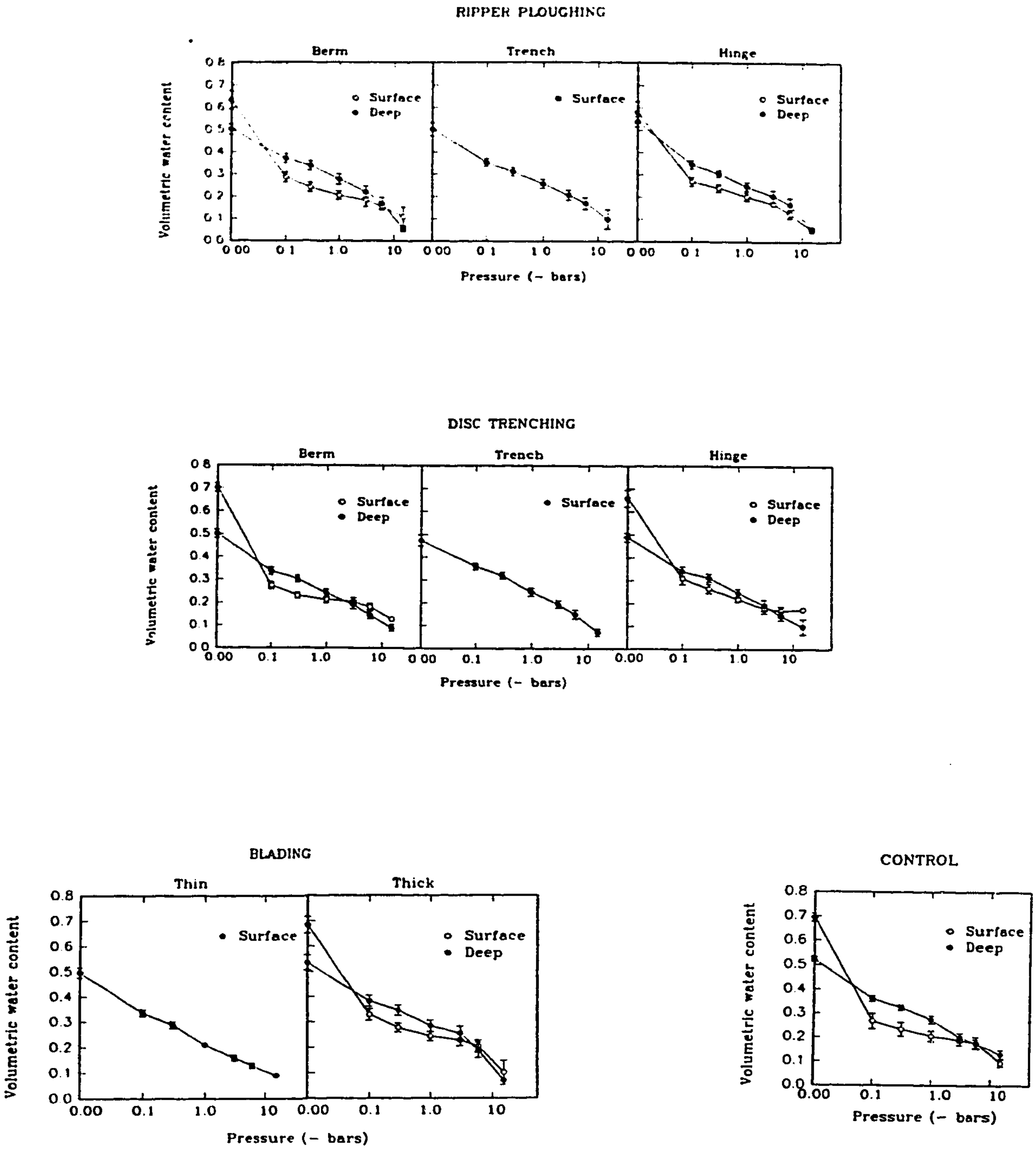


Figure 5.8. *Soil-moisture desorption curves for the different treatments and microsites. Filled circles represent samples from mineral layers and hollow circles represent samples from organic and mixed (organic matter and mineral soil) layers. Standard errors for pressures of -15 bars are sometimes big or do not exist because sample size for this pressure is very low (2 or sometimes 1).*

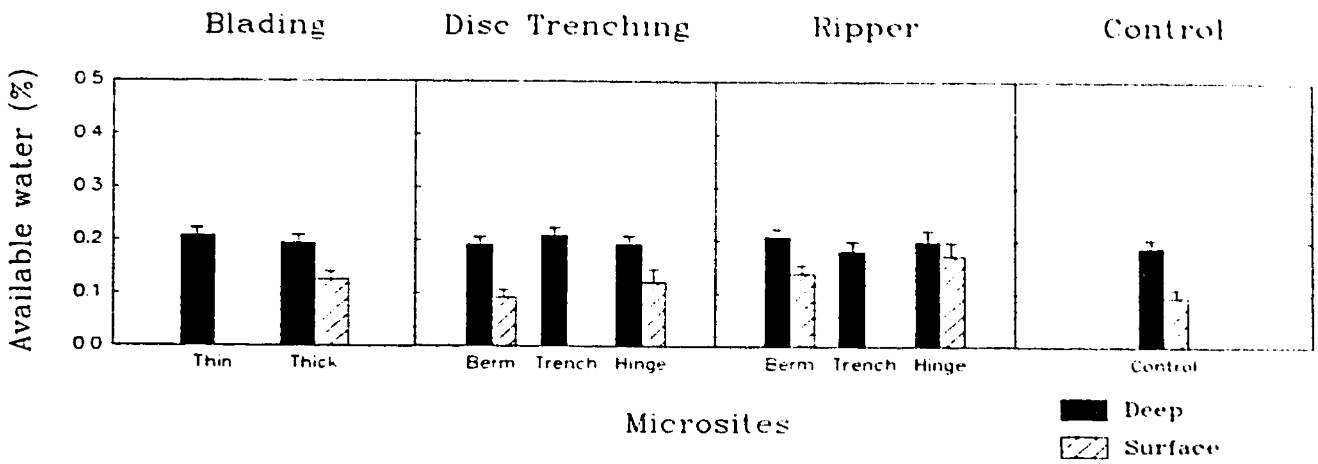


Figure 5.9. Available water-storage capacity of the different microsites.

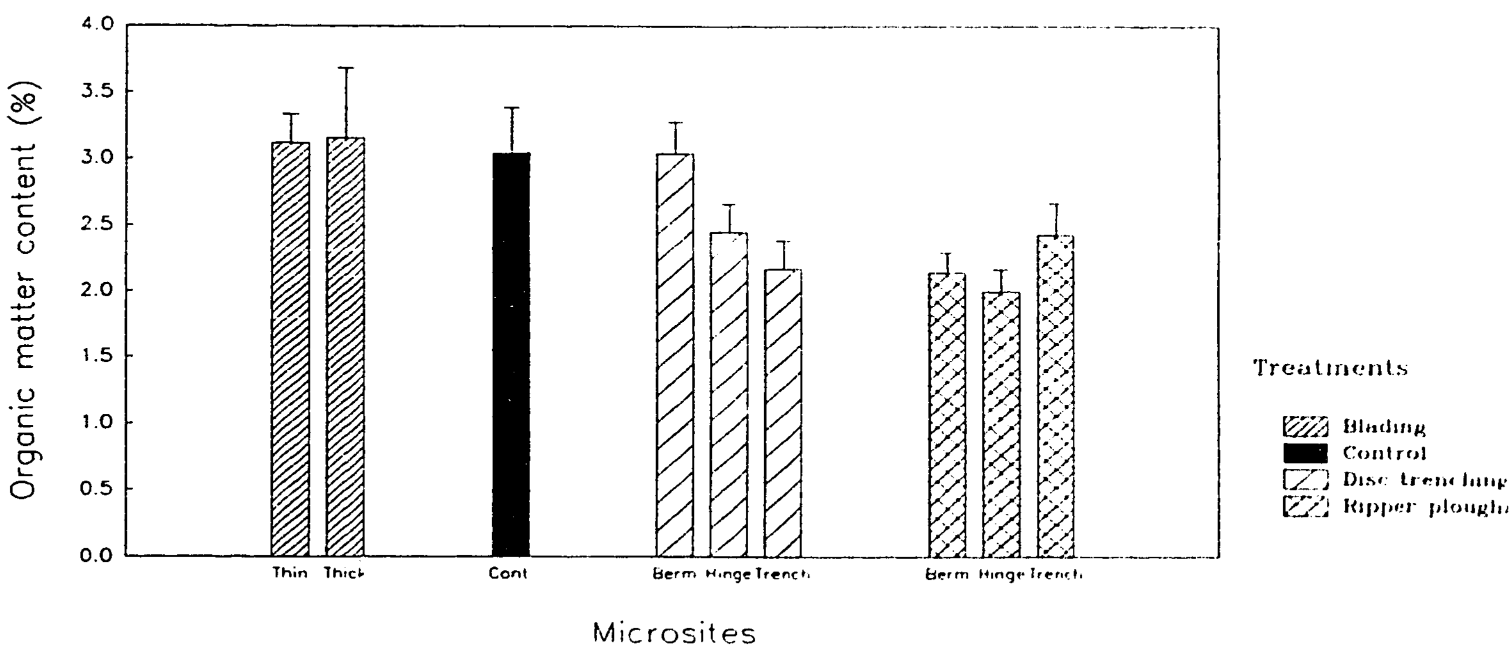


Figure 5.10. Organic matter content in the mineral layer of the microsites sampled.

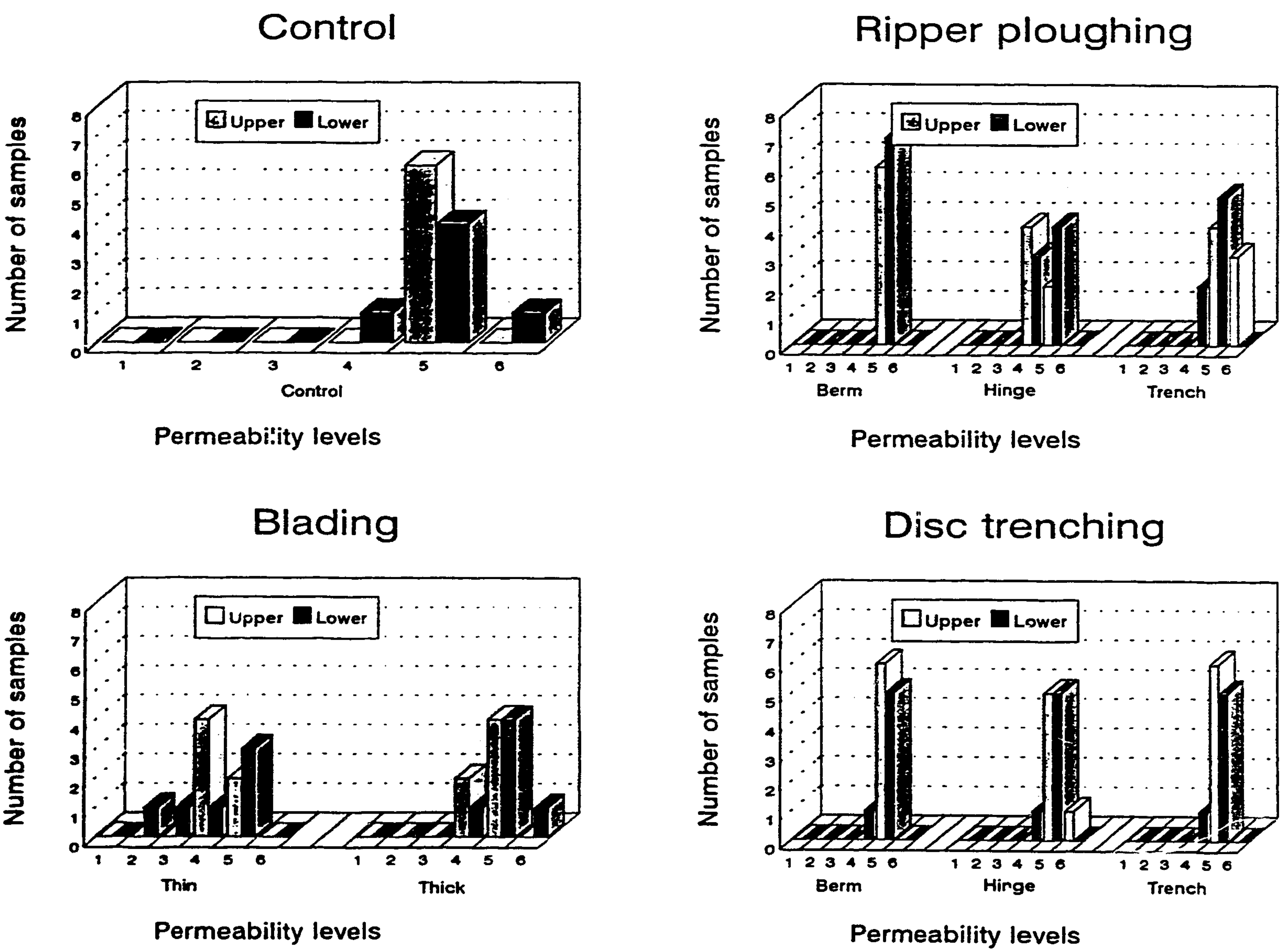


***Figure 5.11.** Frequency distribution of permeability levels (U.S.L.E.) for the different microsites. 1= rapid, 2= moderate to rapid, 3= moderate, 4= slow to moderate, 5= slow, and 6= very slow.*

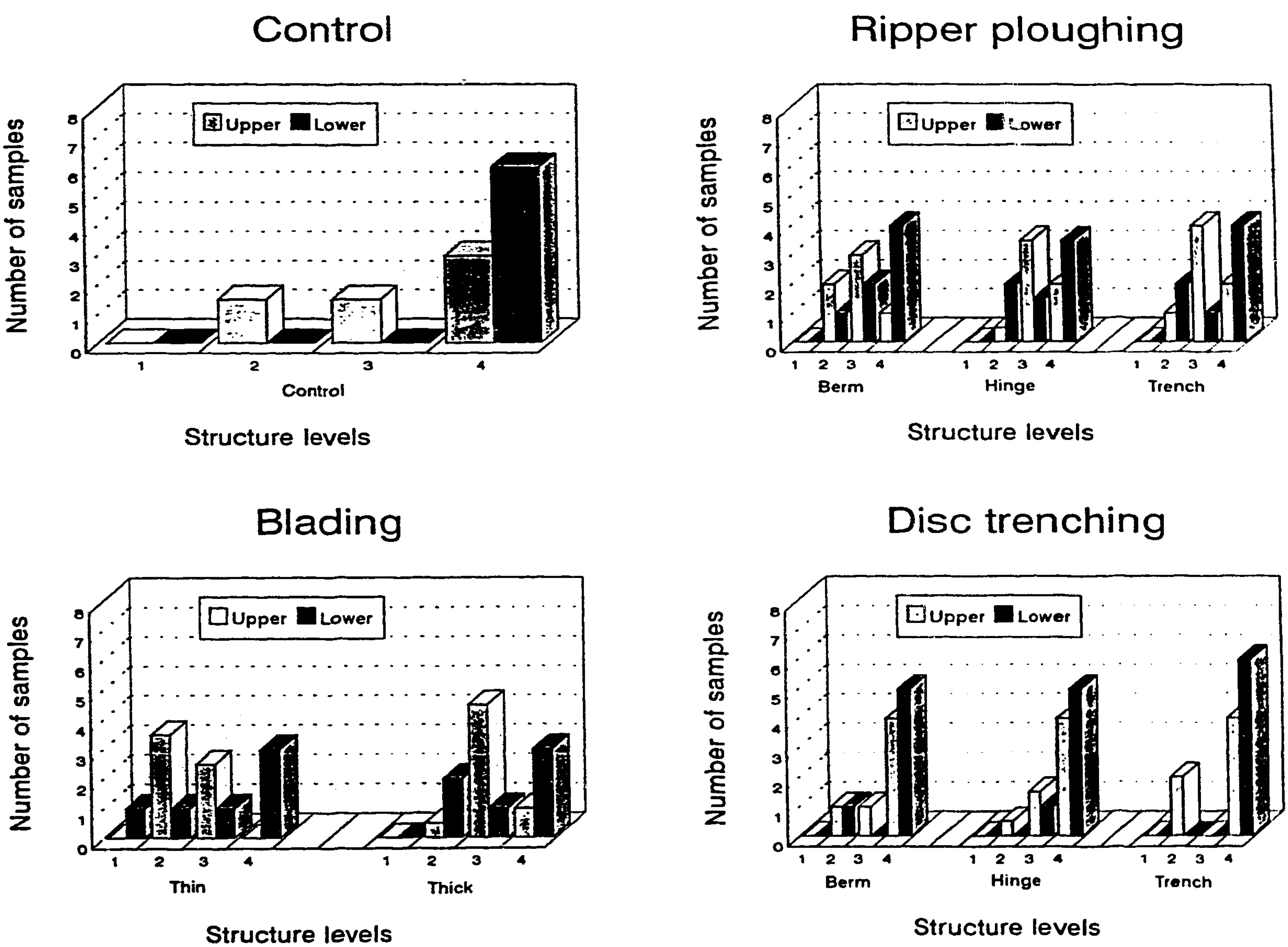


Figure 5.12. Frequency distribution of structure levels (U.S.L.E.) for the different microsites. 1= very fine granular, 2= fine granular, 3= medium or coarse granular, and 4= massive or blocky.

Table 5.1. Soil texture of the different locations.

Location	Silt (%)	Clay (%)	Sand (%)	Textural class
Judy Creek	46.66 (1.56)*	17.16 (0.90)	36.18 (1.48)	loam
Fox Creek	57.73 (1.08)	15.56 (0.64)	26.71 (0.76)	silt loam
Ante Creek	55.06 (1.13)	19.61 (1.00)	25.33 (0.61)	silt loam

* Standard errors are shown in parenthesis.

Table 5.2. Soil texture for the different microsites.

Treatment	Microsite	Silt (%)	Clay (%)	Sand (%)
Ripper plough.	Trench	53.89 (1.85)*	17.70 (1.08)	28.42 (1.49)
	Hinge	50.24 (1.77)	15.63 (1.04)	34.13 (1.43)
	Berm	56.90 (1.79)	16.39 (1.05)	26.71 (1.45)
Disc trenching	Trench	56.31 (1.95)	15.07 (1.14)	28.63 (1.57)
	Hinge	49.56 (1.95)	19.37 (1.14)	31.07 (1.57)
	Berm	52.67 (1.95)	17.83 (1.14)	29.51 (1.57)
Blading	Thick	52.15 (1.95)	20.18 (1.14)	27.67 (1.57)
	Thin	53.43 (1.90)	17.92 (1.12)	28.65 (1.54)
Control	Control	54.28 (1.95)	16.71 (1.14)	29.01 (1.57)

* Standard errors are shown in parenthesis.

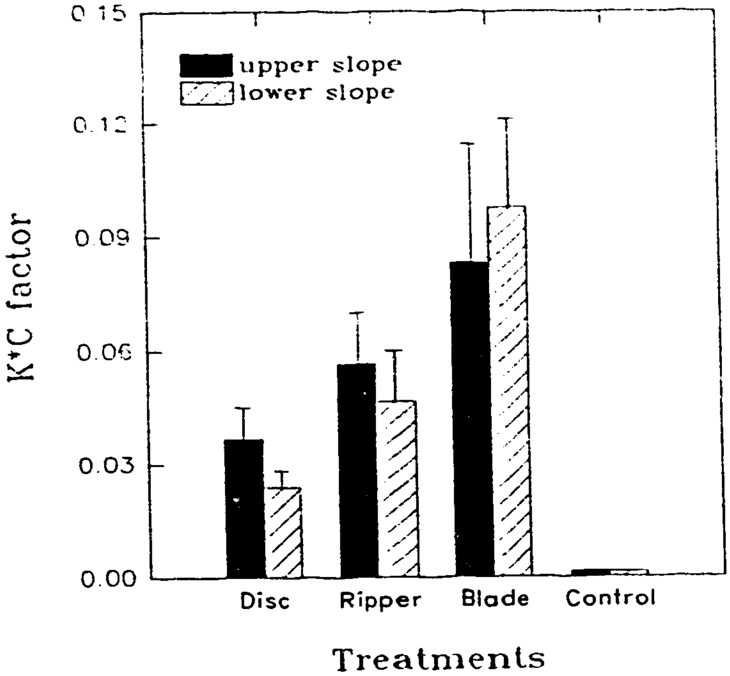


*Figure 5.13. Potential soil erosion (K*C factor of the Universal Soil Loss Equation) created by the different treatments.*

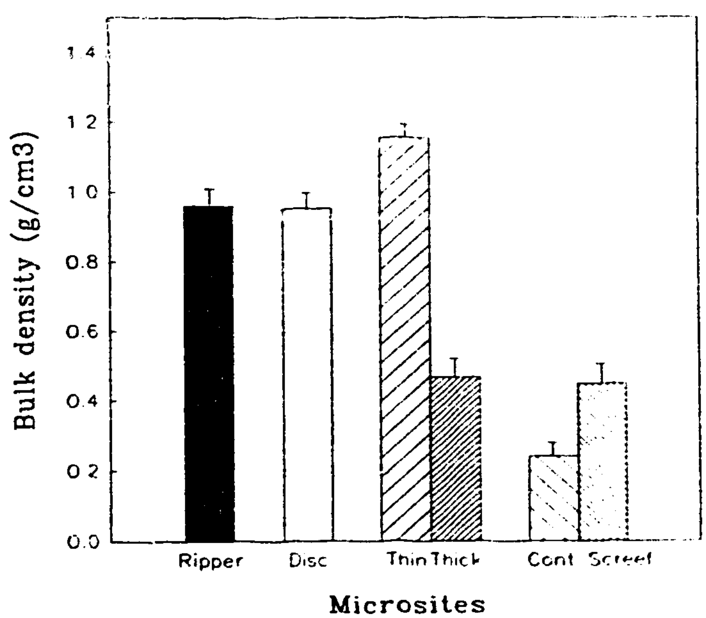


Figure 5.14. Bulk density at surface layers for selected microsites.

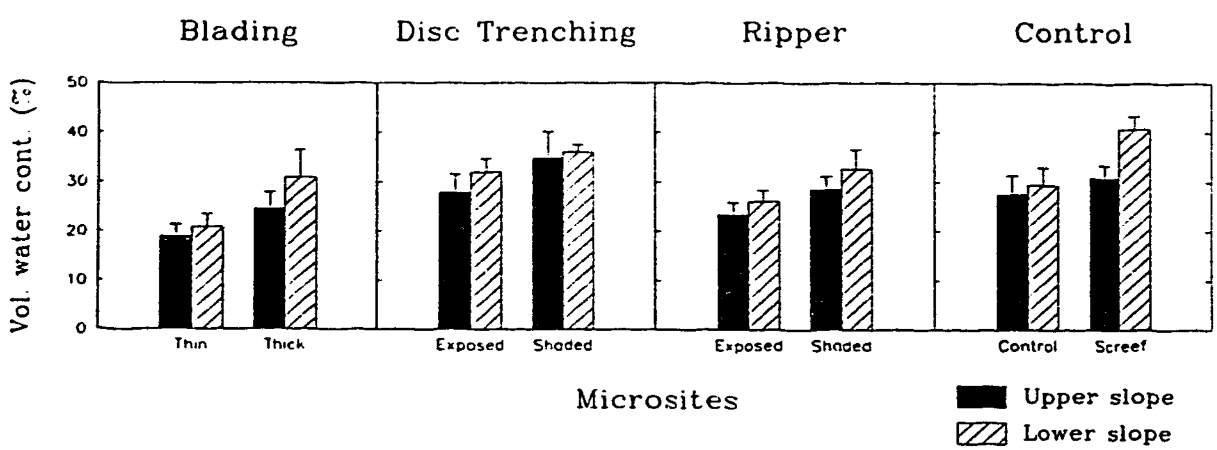


Figure 5.15. Volumetric moisture content at surface layers for selected microsites.

CHAPTER SIX

DISCUSSION

6.1 Optimal range of soil properties

It is very difficult to define optimal values of soil properties for seedling establishment and growth because they are interrelated with many biotic and abiotic factors (see Section 1.2). However, many authors agree in general on certain soil requirements for seedling establishment.

Roots need air and water to survive. Air and water fill the pore volume of the soil. Air usually fills macropores in the soil whereas water is retained in the micropores. An appropriate balance between air-filled and water-filled pores gives optimum plant growth (Kimmins, 1987), and it varies with soil texture. A minimum oxygen content of 10% is required for normal seedling root growth (Örlander et al., 1990; Pritchett and Fisher, 1987). Söderström (1974, 1976, 1977, as cited by Hunt, 1987) reports sandy soils have optimum water contents at field capacity, whereas finer textured soils need more aeration. Water has to be readily available for plants and should not be retained at low water potentials. Squire et al. (1987) found a 24% reduction in root growth in seedlings of *Pinus radiata* at a water potential of -0.4 bar (0.04 MPa), and 60% reduction at -1.8 bar (0.18 MPa). Other studies report reduction in root growth for conifers at matric potentials between -1 and -2 bar (0.1 and 0.2 MPa) (Jarvis and Jarvis, 1963; Kaufmann, 1968; cited by Squire et al., 1987). Approximately 75% of available water has been removed from clay soils at a tension of -5 bars (0.5 MPa) (Singer and Munns, 1987, cited by Harris, 1992).

Loamy soils have the best texture to provide water and air to a wide variety of plants (Stathers et al., 1990; Harris, 1992). They have small pores between fine particles which hold water and large pores between big particles which allow drainage and provide air to the roots. A well-developed structure can help to solve textural deficiencies either in fine-textured (it creates more large pores between aggregates) or in coarse-textured (it increases the percentage of small pores within aggregates) soils (Pritchett and Fisher, 1987). Organic matter helps to create aggregates and therefore well-structured soils (Hillel, 1980; Stathers et al., 1990). Also, organic matter in soils provides nutrients to roots and increases water-holding capacity and therefore available water. Tree growth has been found to be related to organic matter levels and available water (e.g. Gilmore et al., 1968; Fernandez and Struchtemeyer, 1985).

Soil drainage is directly related to texture and pore size distribution. Soils with slow drainage are easily flooded and have oxygen deficiencies. Soils with very fast drainage lose water quickly and are usually dry. Optimal drainage values are within the moderate range (permeability levels of 2, 3, and 4 in section 5.6) where roots have access to water and there is good aeration (Figure 6.1).

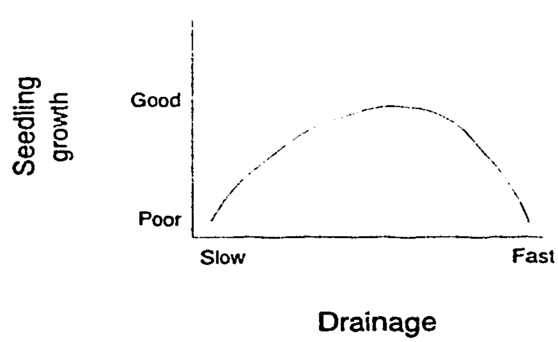


Figure 6.1. *Hypothetical relationship between drainage and seedling growth.*

Bulk density can be used as a measure of soil compaction, which can increase soil strength and decrease aeration thereby affecting root growth (Froehlich and McNabb, 1984). Several authors have found high bulk densities can limit root growth:

- Lull (1959), cited by Gent et al. (1984) found bulk densities exceeding 1.4 Mg/m^3 and 1.6 Mg/m^3 restricted root growth in fine-textured and coarse-textured soils respectively.

- Froehlich and McNabb (1984) found that an increase in bulk density of 26% reduced height growth and stem volume of *Pinus ponderosa* by 17% and 48% respectively.

- Pritchett and Fisher (1987) found bulk densities greater than 1.75 Mg/m^3 for sands and 1.55 Mg/m^3 for clays may prevent the penetration of tree roots.

- Daddow and Warrington (1983), cited by Morris and Lowery (1988) reported bulk densities of 1.48-1.5 Mg/m^3 can limit root growth in loamy/silt loamy soils (these are the textures we actually found in this study).

- Alberty et al. (1984), cited by Harris (1992), found root growth was restricted at bulk densities of 1.4 to 1.6 Mg/m^3.

On the other hand, low bulk densities (< 0.7 Mg/m^3) indicate poor soil packing thereby reducing root-soil contact at planting, resulting in water stress (Örlander et al., 1990; Veen et al., 1992). Optimal bulk density for spruce roots was found at values of 1.2 Mg/m^3 in fine-textured soils (Sokolovskaya et al, 1977, cited by Örlander et al., 1990).

Retention of some part of the organic forest floor following site preparation is necessary as it is the main source of nutrients for roots, protects soils from erosional forces and extremes in temperature and moisture, and provides higher water infiltration rates and water-holding capacity (Pritchett and Fisher, 1987). Complete retention of a thick organic forest floor however can be bad for seedling establishment in terms of low soil temperatures and water stress (roots stay in the zone of low bulk density with a poor root-soil contact and do not reach the mineral soil).

Optimal range of soil properties are summarized in Table 6.1. Based on the literature, an "ideal" planting site should have loamy texture, high organic matter content (>5%) creating an aggregated (well structured) soil, a bulk density of 1.20 Mg/m^3 and a shallow organic layer overlying the mineral soil with live roots in the mineral/organic interphase, moderate drainage, and a soil moisture content close to field capacity.

Table 6.1. Optimal range of mineral soil properties for seedling establishment and growth.

Soil properties	Poor	Fair	Good
Depth of organic forest floor (cm)	deep > 30	10 - 30	*shallow* 0 - 10
Organic matter content/nutrients availability	Roots do not reach nutrients from forest floor. Mineral soil with < 2% O.M.	Intermediate conditions	Roots reach and penetrate organic/mineral interphase of forest floor. Mineral soil with >5% O.M.
Drainage (drainage index)	Very slow (0-0.3) Very fast (>1.5)	Moderate to slow (0.6-0.9) Moderate to rapid (1.2-1.5)	Moderate (1)
Bulk density (Mg/m^3)	>1.5 inhibit rooting < 0.7 low water storage	Between 1.2 and 1.5 <1.2	1.2
Texture	Pure clay (>40% clay) Pure sand (>85% sand)	Intermediate conditions	Loamy (8-28% clay, 28-50% silt, 25-52% sand)
$AWP = \frac{\theta - \theta_w{}^1}{AWC} X$	$\theta = \theta_w$ AWP = 0 (perman. wilting point) $\theta = \theta_{sat}$ AWP >> 100 (saturation)	AWP < 100 (θ < field capacity) AWP > 100 (θ > field capacity)	AWP = 100 (θ = field capacity)
Erosion risk (K*C factor)(Tonnes/ha) [2]	>0.8	Between 0.05 and 0.8	< 0.05

[1] θ = field soil moisture content. θ_w = soil moisture content at permanent wilting point. AWC = available water-storage capacity. AWP = available water percentage.
[2] Assuming a constant rainfall erosivity factor (R) of 10.

6.2 Control conditions

A comparison of the control conditions in the study to the "optimal soil properties" indicated the study areas were less than ideal planting sites. Planting sites were characterized by thick organic surface layers that can inhibit seedling establishment because of their poor water retention and storage characteristics. However, this was not apparent in the results as soil moisture in the control was high and similar to the other microsites. The control appeared to be dry on sampling, which suggests that the water measured was held in the organic matter and would not be readily available to plants. This organic layer was mainly composed of non-decomposed debris. It had a low bulk density and high porosity characterized by large macropores, which created fast drainage and low AWC. The water retention-storage characteristics of the underlying mineral soils were better, but drainage was rated as slow, which favoured high soil water contents through the growing season. The combination of the thick organic layer, low drainage, and high soil water also would contribute to low soil temperatures and reduced seedling development.

Reduction of organic layer thickness, and some level of organic/soil mixing to improve water retention and drainage characteristics were the soil parameters to be changed by mechanical site preparation to create better planting sites.

The boot screef microsite in the controls was judged a relatively good microsite because it had, by definition, a thinner organic forest floor and higher bulk density (approximately twice) than the undisturbed control. It had higher soil moisture content than the control and probably better conditions for seedling growth, although it was not studied in detail.

6.3 Ripper ploughing

From the overall physical conditions of the microsites and performance of the treatment in creating microsites (Figure 5.1), the hinge was considered the best microsite created by ripper ploughing under the conditions of this study. The hinge microsite had a thin organic layer (4.9 cm) so roots had access to the mineral soil where water is stored. This layer was a source of nutrients for seedlings and protects against direct water evaporation from mineral soil. It also offered some protection against soil erosion and frost heaving. Furthermore, this surface layer was usually a mixture of mineral soil and organic matter, which increased bulk density (0.7 Mg/m^3 at surface and 1.2 Mg/m^3 at mineral soil), decreased drainage (it is slow to moderate), and retained more water in micropores (available water-storage capacity of 0.17 at surface layer and 0.20 at mineral layer), which could increase soil temperature and therefore speed mineralization rate. The mineral soil in hinge had less clay and more sand than the other microsites in this treatment, which created more macropores and allowed better aeration. The volumetric moisture content was 27.7 %, which was very close to field capacity (see Figure 5.8).

The berm microsite in comparison to the hinge had a thick unconsolidated organic layer (35.7 cm) which can limit root growth and the success of seedling establishment. This layer provides insulation and protects seedlings against erosion and frost heaving hazards. This microsite was highly variable in composition and character between different slopes and ground conditions. On steeper, upper slopes the organic matter content of berms for the surficial layer was 20%, which indicated a good mixing of organic matter and mineral soil. The bulk density here was 0.68 (Mg/m^3). On the other hand, on flatter, lower slopes organic matter content increased because of poor soil mixing, which decreased bulk density (0.31

Mg/m^3). These low bulk densities together with the soil-moisture characteristic curve, which was very similar to the one for undisturbed organic matter (control), indicated a high porosity constituted mainly by macropores. Available water-storage capacity averaged 0.14, and was statistically similar to the untreated control (0.09). Since the soil was loose, poor root-soil contact could be a problem for seedling establishment, especially on lower slopes where the thick organic layer could prevent roots from reaching mineral soil where water is held. The content of mineral particles mixed with the organic matter decreased the total porosity compared to the control, delayed drainage, and retained some water in the micropores, but it was not enough to solve the poor root-soil contact.

The trench was considered the poorest or least desirable microsite because of its bare mineral surface. Total infiltration of water into the mineral soil probably was greater than on the other microsites because of reduction in water storage in the litter and interception losses. However, at the same time available water was less because of losses in water by direct evaporation from the soil and low matric potentials. Bulk density for the trench (1.28 Mg/m^3) was higher than the other two microsites (hinge and berm), but it is far from levels that reported to reduce root growth. Trench microsites had a high erosion potential and chance of frost heaving.

6.4 Disc trenching

The best microsite created by disc trenching in terms of numbers and soil properties was the hinge. The hinge microsite created by this treatment was very similar to that created by ripper ploughing. The organic layer was 6.14 cm thick, which allowed roots to grow in both, mineral and organic soil, and at the same time offered some protection against soil erosion and frost heaving. This layer was characterized by a good mixture of mineral and organic matter, which contributed to better drainage than pure mineral soil and higher water retention than in a pure organic layer. It also was a good source of nutrients for the roots. Bulk density of the underlying mineral soil was higher than optimal values, but still far from values that can reduce root growth. Volumetric moisture content was close to field capacity.

Disc trenching created a low number of berm microsites, but they were similar on both upper and lower slopes. The berm microsites had a thick (29.7 cm) organic layer which was not well mixed with mineral soil. As a result, bulk density in the root zone (organic zone) was low and drainage was faster than in any other microsite. Soil-moisture curves were very similar to that of undisturbed organic layer in the control, so available water-storage capacity was not improved by site preparation (0.09). Poor root-soil contact would be expected making seedlings suffer from water stress and preventing roots from reaching mineral soil.

The trench was the poorest microsite in this treatment. It was similar in its properties to the trench in ripper ploughing. Bulk density was 1.39 Mg/m^3, which was higher than on any other microsite, and is close to reported values that can reduce root growth. This might be due to compaction from the machinery working on wet soils. Trench microsites were also under erosion and frost heaving risks and had slow drainage.

6.5 Blading

The thick microsite with its organic layer was considered the best for this treatment. The thick microsite had an organic layer 16.26 cm thick (Figure 5.2) which protected seedlings from soil erosion and frost heaving problems, but planted seedling roots were still able to reach the mineral layer. This layer was also a better source of nutrients than the bare mineral soil of the thin microsite (it usually did not had any organic layer), and also prevented evaporation of water from underlying mineral soil. The thick organic layer however indicated that soil mixing was very low. As a result, bulk density at surface was low, but not low enough to be limiting for seedling establishment and growth. This microsite had good drainage that provided aeration, but at the same time it held a little more water at field capacity than the other microsites. Volumetric water content found for this microsite was 27.76% (Figure 5.15), which was still lower than field capacity.

Blading was very effective in creating microsites in quantity, especially thin microsites. The thin microsite had, on average, a very thin organic layer (0.27 cm) which was not enough to prevent soil erosion. Soils in these areas (especially in Judy Creek) contained a balanced mixture of coarse and fine particles and had well developed structure. When exposed, soil structure broke down easily by with raindrop splash which appeared to seal soil pores and enhance surface runoff and erosion. Bulk density values found in this microsite were close to optimal reported values. The organic matter content in mineral horizons was higher than the other microsites (except thick, which has similar values) but may not be an adequate source of nutrients because of erosion processes which remove soil and expose seedling roots. Drainage values were high for the mineral layer, which provided aeration and was good for root development. Available water was less on this microsite because of higher clay content, high drainage, and higher potential for soil water evaporation. Volumetric moisture content was 19.89% (Figure 5.15) which was far lower than field capacity. Therefore, seedlings on these microsites probably will suffer from water stress.

6.6 Microsite summary

A comparison of all microsites together (Table 6.2) was made based on "optimal" soil properties in Table 6.1 and on site observations. Physical conditions of the different microsites were ranked from 1 (very poor) to 5 (very good) as they negatively or positively affect seedling establishment and growth. The highest ranked microsites were the hinge for ripper ploughing and disc trenching, followed by the thick and thin microsites for blading. The lowest ranked microsites were the trench for ripper ploughing and disc trenching. An averaging of microsites by treatment suggested that all three treatments were equally effective in creating acceptable microsites. If several treatments have the capability to produce similar soil conditions for planting, the treatment that creates the least soil disturbance and is least costly is recommended.

The ranking system and Table 6.1 were meant to only evaluate the microsites in this study, and they are not applicable to other conditions. This ranking system only evaluates soil properties in an additive fashion and does not consider them as limiting factors, nor does it accurately reflect interaction between them, nor does it account for site variability. For example, if one factor for a microsite was completely limiting on seedling success, then that microsite would be unsuitable regardless of the condition of other factors. An example might be high soil moisture on lower slopes, that prevents seedling establishment. Furthermore the ranking system does not explicitly consider such things as temperature, topography, etc., although the rank assigned to microsites for each soil property is based on what is best for seedling establishment and growth in that particular environmental conditions.

Table 6.2. Physical conditions of the different microsites. 1 = very poor, 2 = poor, 3 = fair, 4 = good, and 5 = very good.

	Ripper ploughing			Disc trenching			Blading		Control	
	Trench	Hinge	Berm	Trench	Hinge	Berm	Thin	Thick	Control	Screef
# of microsites/ha	2-3	4	2	3-4	4-5	1-2	5	4	-	-
Depth to mineral soil	3	5	2	3	5	2	4-5	4	2	-
Mixture/nutrients availability	1-2	4-5	3-4	1-2	4-5	3-4	2	4-5	1	-
Drainage	2	4	2	2	3	2	4	4	1-2	-
Bulk density	4	4	2	2	3	2	5	4-5	1	3
Texture	4	4-5	-	4	4	-	4	4	-	-
Water retention	3	4	2	3	3	2	2-3	3	2	-
Erosion risk	1	3	5	1	3-4	5	1	4	5	5
Frost heaving risk[1]	1	3-4	5	1	3-4	5	1	4	5	4
Soil moisture	-	4-5	-	-	4-5	-	2	2	4	4-5
Average	2.44	4.10	2.94	2.33	3.85	2.87	3.10	3.80	2.69	-

[1] Not measured here. It was estimated from the depth of the insulating organic layer.

CHAPTER SEVEN

CONCLUSIONS AND RECOMMENDATIONS

These conclusions and recommendations should be carefully assessed and not extrapolated beyond the scope of this study. The results of the study show significant changes in physical soil parameters between the different treatments and microsites. However it is very difficult to translate these results into conclusions and recommendations that will identify treatment and microsite success over a wide range of site conditions. The ranking system used subjectively considers the microsites in terms of a relatively small set of soil properties, and does not directly include other factors such as temperature, nutrients, topography, etc into the rankings.

1. All three treatments resulted in an improvement of physical soil conditions compared to the control. The differences among treatments were not as big as expected. Reasons for this might be treatments were not performed properly (did not create expected potential plantable microsites) or consistently between study sites, or the right soil properties were not chosen for evaluation.

2. The most suitable planting spots for the different treatments were thick in blading and hinge in both ripper ploughing and disc trenching. This ranking was based on a review of "optimal soil conditions" in the literature and on site observations, and should not be applied to other circumstances.

3. Ripper ploughing, based on the physical soil conditions analyzed and particular conditions of this study, was judged the best choice of site preparation treatment, using the hinge microsite as the preferred planting spot. Ripper ploughing can be applied on frozen

ground minimizing soil damage caused by heavy equipment operating on wet soil. The hinge microsite in ripper ploughing also had slightly better conditions in terms of drainage and bulk density than the hinge in disc trenching.

4. The thick microsite in blading was considered in this study an inferior microsite compared to the hinges in ripper ploughing and disc trenching because it was the driest. Furthermore, it was not an easy treatment to perform (different results were obtained in different sites and slope positions), and mineral soil often exposed a high risk of soil erosion.

5. The boot screef microsites tested in the control produced favourable results, but only two physical soil properties, bulk density and soil moisture content, were tested. Further research should be done on this particular microsite to determine if it creates good planting conditions similar to other more expensive site preparation treatments.

6. Small differences were found in treatment performance between upper and lower slope positions, probably due to some difficulties the machinery had working on steeper slopes (loss of traction). The differences were not significant but followed anticipated trends. In general :

- Blading produced less soil disturbance on steeper (upper) slopes, leaving a reduced organic layer intact.
- Ripper ploughing created a better degree of mixing for berm microsites on upper slopes.
- Microsites on lower slopes and shaded aspects were wetter than microsites on upper slopes and exposed aspects.

7. Blading was the most effective treatment in the number of microsites created under the specific conditions of this study, followed by ripper ploughing and disc trenching. The number of microsites created was weakly related to soil disturbance produced by the

treatments.

8. No relationships were found between number of microsites created and slope, quantity of slash, or size of slash. These results were not conclusive since experimental design was not intended for testing slope and slash effects on site preparation. Treatment effects should be tested on a wider range of slopes and amounts and sizes of slash. Slash characteristics should be described before as well as after treatments applications.

9. The potential for soil erosion was increased by all three treatments. The potential for increased soil erosion was related to soil disturbance or mineral soil exposure, and it was high for blading followed by ripper ploughing and disc trenching. Increased erosion potential appeared to be related to a loss of soil structure from raindrop impact on bare mineral surfaces, followed by increased overland flow and soil washing.

10. Soil erosion in ripper ploughing could be reduced if the treatment was applied intermittently, not in long continuous furrows, or by following contours instead of running up and down slopes.

11. This study was an evaluation of the short term effects of mechanical site preparation on physical soil properties. Longer term responses need to be monitored, as well as their interactive effects on other soil properties such as temperature, chemistry, and biology. For example, a study of the subsidence of berm microsites might show them to be better planting spots 2-3 years after treatment.

12. For a complete evaluation of mechanical site preparation all the effects of site preparation need to be related to seedling establishment, survival, and growth. Natural systems and the management schemes applied to them are complex and highly variable in time and space, making them difficult to evaluate.

More research into soil properties and microsite conditions is needed to relate changes in soil properties due to site preparation treatments to water and nutrients, seedling survival, and root growth. In this sense, benefits attributable to changes in soil factors should be separated from benefits resulting from land clearing and competition control (Morris and Lowery, 1988).

LITERATURED CITED

Alberta Forest Service. 1985. Alberta phase 3 Forest inventory: Forest cover type especifications. Alberta Energy and Natural Resources, Resource Evaluation and Planning Division. ENR Report no. Dept. 58. Edmonton.

Alberta Forest Service. Reforestation Statistics 1990/91. Reforestation Branch. Edmonton, Unpublished.

Ballard, T.M. 1988. Soil degradation associated with forest site preparation. *In* Degradation of forested land: "Forest soils at risk". Proc. 10th B.C. Soil Science Workshop. Land management report no. 56. B.C. Min. For., Victoria. pp. 74-81.

Bamsey, C. 1985. Silvicultural equipment used by the Alberta Forest Service. *In* Proc. of the 1984 Mechanized Silviculture Workshop. Can. For. Serv., Nor. For. Res. Cen. Info. Rep. NOR-X-272. pp. 8-16.

Canada Soil Survey Committee, Subcommittee on Soil Classification. 1974. The system of soil classification for Canada. Can. Dep. Agric. Publ. No. 1455.

Coates, D. and S. Haeussler. 1987. A guide to the use of mechanical site preparation equipment in North Central British Columbia. 2nd ed. Revised by A. Mackinnon, L. Bedford, and J. Maxwell. May 1989. B.C. Min. For., Victoria, B.C. FRDA Handb. No. 002.

Corns I.G.W. 1985. Interpretation of site factors for mechanized site preparation. *In* Proc. of the 1984 Mechanized Silviculture Workshop. Can. For. Serv., Nor. For. Res. Cen. Info. Rep. NOR-X-272. pp. 40-42.

Corns I.G.W. and R.M. Annas. 1986. Field guide to forest ecosystems of west central Alberta. Can. For. Serv. North For. Centre. Edmonton, Alberta.

Drew, J.J. 1988. Managing white spruce in Alberta's mixed-wood forest: The Dilemma. *In* Management and utilization of northern mixed-wood forest. *Edited by* J.K. Samoil. Can. For. Serv. Infor. Rep. NOR-X-296. pp. 35-40.

Fernandez, I.J. and R.A. Struchtemeyer. 1985. Chemical characteristics of soils under spruce-fir forests in eastern Maine. Can. J. Soil Sci. **65**: 61-69.

Froehlich, H.A. and D.H. McNabb. 1984. Minimizing Soil Compaction in Pacific Northwest Forests. *In* Forest Soils and Treatment Impacts. Proceedings of the 6th North American Forest Soils Conference, Knoxville, TN 1983. *Edited by* Earl L. Stone. Department of Forestry, Wildlife and Fisheries, University of Tennessee, Knoxville. pp. 159-192.

Gent, Jr., J.A., R. Ballard, A.E. Hassan, and D.K. Cassel. 1984. Impact of harvesting and site preparation on physical properties of Piedmont forest soils. Soil Sci. Soc. Am. J. **48**: 173-177.

Gilmore, A.R.; W.A. Geyer; and W.R. Boggess. 1968. Microsite and heigth growth of yellow-poplar. Forest Science. **14**(4): 420-426.

Harris, R.W. 1992. Arboriculture: integrated management of landscape trees, shrubs, and vines. 2nd ed. Prentice Hall, Englewood Cliffs, N.J.

Hunt, J.A. 1987. Mechanical site preparation. Part II - A literature review of some biological aspects of mechanical site preparation. Swedish University of Agricultural Sciences. Department of Silviculture. MSc. thesis.

Hunt, J.A. and R.G. McMinn. 1988. Mechanical site preparation and forest regeneration in Sweden and Finland: Implications for technology transfer. B.C. FRDA Rep. 031. B.C. Ministry of Forest and Lands, Victoria.

Hillel, D. 1980. Introduction to Soil Physics. Academic Press, New York.

Kalra, Y.P. and D.G. Maynard. 1991. Methods manual for forest soil and plant analysis. For. Can., Northwest Reg., North. For. Cent., Edmonton, Alberta. Information Report NOR-X-319.

Kimmins, J.P. 1987. Forest Ecology. Macmillan, New York.

Knapik, L.J. and J.D. Lindsay. 1983. Soil survey of the Iosegun Lake area. Alberta Res. Counc. Soils Dep., Edmonton, Alberta. Bull. 43.

Lantagne, D.O. and J.A. Burger. 1983. First-year survival and growth of loblolly pine (*Pinus taeda* L.) as affected by site preparation on the South Carolina and Georgia Piedmont. pp. *In* Proc. Second Bienn. South. Silvic. Res. Conf. *Edited by* E. P. Jones. USDA For. Ser. Gen. Tech. Rep. SE-24. pp. 5-10.

Larionov, A.K. 1982. Methods of Studying Soil Structure. Amerind Publishing Co. Pvt. Ltd., New Delhi.

Margolis, H.A., and D.G. Brand. 1990. An ecophysiological basis for understanding plantation establishment. Can. J. For. Res. **20**: 375-390.

McKeague, J.A. 1978. Manual on Soil Sampling and Methods of Analysis. 2nd Edition. Canadian Society of Soil Science, Ottawa, Ontario.

McMinn, R.G. 1985. Use and development of site preparation equipment. *In* Proc. of the 1984 Mechanized Silviculture Workshop. Can. For. Serv., Nor. For. Res. Cen. Info. Rep. NOR-X-272. pp. 2-7.

McMinn, R.G. and I.B. Hedin. 1990. Site preparation: mechanical and manual. *In* Regenerating British Columbia's Forests. *Edited by* D.P. Lavender, R. Parish, C.M. Johnson, G. Montgomery, A. Vyse, R.W. Willms and D. Winston. University of British Columbia Press. pp. 150-163.

Milliken, G.A. and D.E. Johnson. 1984. Analysis of Messy Data. Volume 1: Designed experiments. Van Nostrand Reinhold, New York.

Moon, D.E. 1988. Approaches to predicting soil degradation. *In* Proceedings of the 10th B.C. Soil Science Workshop, February 1986. B.C. Min. For., Victoria, B.C. pp. 138-152.

Morris, L.A., and R.F. Lowery. 1988. Influence of Site Preparation on Soil Conditions Affecting Stand Establishment and Tree Growth. South. J. Appl. For. **12**(3): 170-178.

Nelson, D.W. and L.E. Sommers. 1982. Total carbon, organic carbon, and organic matter. *In* Methods of Soil Analysis, Part 2. Chemical and microbiological properties. Second edition. *Edited by* A.L. Page, R.H. Miller, and D.R. Keeney. American Society of Agronomy, Inc. and Soil Science Society of America, Inc., Madison, Wisconsin. pp. 539-579.

Örlander, G.; P. Gemmel; and J. Hunt. 1990. Site preparation: a Swedish overview. FRDA Rep. No. 105. Economic & Regional Development Agreement. B.C.

Outcalt, K.W. 1983. Mechanical site preparation improves growth of genetically improved and unimproved slash pine on a Florida flatwoods site. *In* , Proc. Second Bienn. South. Silvic. Res. Conf. *Edited by* E. P. Jones. USDA For. Ser. Gen. Tech. Rep. SE-24. pp. 11-13.

Page-Dumroese, D.S.; M.F. Jurgensen; R.T. Graham; and A.E. Harvey. 1986. Soil physical properties of raised planting beds in a northern Idaho forest. USDA For. Ser. Res. Paper INT-360.

Pritchett, W.L. and R.F. Fisher. 1987. Properties and Management of Forest Soils. Sec. ed. John Wiley & Sons, Inc., New York.

SAS Institute Inc. 1988. SAS/STAT User's Guide, Release 6.03 Edition. Cary, NC:SAS Institute Inc.

Sims, H.P. 1975. Temperature and moisture conditions on a ploughed jack pine strip cut in southeastern Manitoba. Can. J. For. Res. **5**: 541-545.

Squire, R.O., P.M. Attiwill, and T.F. Neales. 1987. Effects of changes of available water and nutrients on growth, root development, and water use efficiency in *Pinus radiata* seedlings. Aust. For. Res. **17**: 99-111.

Stathers, R.J., R. Trowbridge, D.L. Spittlehouse, A. Macadam, and J.P. Kimmins. 1987. Ecological principles: basic concepts. *In* Regenerating British Columbia's Forests. *Edited by* D.P. Lavender, R. Parish, C.M. Johnson, G. Montgomery, A. Vyse, R.W. Willms and D. Winston. University of British Columbia Press. pp. 45-54.

Storer, D.A. 1984. A simple high sample volume ashing procedure for determination of soil organic matter. Commun. in Soil Sci. Plant Anal. **15**(7): 759-772. Marcel Dekker, New York.

U.S. Soil Conservation Service. 1975. Procedure for computing sheet and rill erosion on project areas. Technical Release no. 32, Washington, DC, 15 pp.

Veen, B.W.; M. Van Noordwijk; P. De Willigen; F.R. Boone; and M.J. Kooistra. 1992. Root-soil contact of maiz, as measured by a thin-section technique. III. Effects on shoot growth, nitrate and water uptake efficiency. Plant and Soil **139**: 131-138.

Von der Gönna, M.A. 1992. Fundamentals of mechanical site preparation. B.C. Min. of For. and For. Can., Victoria, B.C. FRDA Rep. No. 178.

Wischmeier, W.H. and D.D. Smith. 1965. Predicting rainfall-erosion losses from cropland east of the Rocky Mountains. Agriculture Handbook No. 282. U.S. Dep. of Agric. Washington, D.C.

Wischmeier, W.H., C.B. Johnson, and B.V. Cross. 1971. A soil erodibility nomograph for farmland and construction sites. J. Soil and Water Conserv. **26**: 189-193.

Wynnyk, A., J.D. Lindsay, and Wm. Odynsky. 1969. Soil survey of the Whitecourt and

Barrhead area. Alberta Soil Survey Report No. 27. Alberta Res. Counc. Soils Dep., Edmonton.

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APPENDICES

Appendix 1.1. Statistical Analysis

All variables except soil-moisture characteristic curves are analyzed using the statistical package SAS, particularly the GLM procedure (SAS Institute Inc., 1988). A strip-plot analysis of variance design is used (Milliken and Johnson, 1984), where treatment and slope are the main factors and microsite is nested within treatments. The ANOVA table used is:

Source	d.f.
Location	2 = (3-1)
Block(Location)	**3 = (2-1)3**
Slope	1 = (2-1)
Slope*Location	2 = (2-1)(3-1)
Slope*Block(Location)	**3 = (2-1)(2-1)3**
Treatment	3 = (4-1)
Treatment*Location	6 = (4-1)(3-1)
Treatment*Block(Location)[2]	**9 = (4-1)(2-1)3**
Treatment*Slope	3 = (4-1)(2-1)
Treatment*Slope*Location	6 = (4-1)(2-1)(3-1)
Treat*Slope*Block(Location)	**9 = (4-1)(2-1)(2-1)3**
Microsite(Treatment)	(m-1)
Slope*Microsite(Treatment)	(2-1)(m-1)
Location*Microsite(Treatment)	(3-1)(m-1)
Location*Slope*Micros(Treat)	(3-1)(2-1)(m-1)
Error[1]	**(3-1)(2-1)(m-1)(2-1)3**

The error term used to test for differences between microsites within the same treatment was the general error of the model ([1]), while the error term used to look for the differences in microsites between treatments was treatment*block(location) ([2]).

In the analyses where empty cells are found (Appendix 1.5, 1.6, and 1.7), the factor location is removed if there are no differences among locations since it is not the objective of this study.

Soil-moisture characteristic curves are analyzed pairwise with nonlinear regression comparisons using the statistical package SPSS. A third degree polynomial is assigned to each curve. A function f is created subtracting one curve from the other. The null hypothesis is $f = 0$, i.e. there are no differences between the two curves.

Appendix 1.2. Number of microsites per hectare created by each treatment.

General Linear Models Procedure
Class Level Information

Class	Levels	Values
LOCATION	3	ANTE FOX JUDY
BLOCK	2	I II
SLOPE	2	LOWER UPPER
TREAT	3	BLADING DISC RIPPER
MICROS	5	BERM HINGE THICK THIN TRENCH

Number of observations in data set = 96

General Linear Models Procedure

Dependent Variable: NUMBER

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	65	38016249.99999999	584865.38461538	3.99	0.0001
Error	30	4393333.33333336	146444.44444445		
Corrected Total	95	42409583.33333335			

R-Square	C.V.	Root MSE	NUMBER Mean
0.896407	24.32936	382.68060376	1572.91666667

Source	DF	Type I SS	Mean Square	F Value	Pr > F
LOCATION	2	645208.33333334	322604.16666667	2.20	0.1289
BLOCK(LOCATION)	3	375625.00000000	125208.33333333	0.85	0.4750
SLOPE	1	201666.66666666	201666.66666666	1.38	0.2498
LOCATION*SLOPE	2	1458.33333334	729.16666667	0.00	0.9950
BLOCK*SLOPE(LOCATIO)	3	935625.00000000	311875.00000000	2.13	0.1173
TREAT	2	6395138.88888889	3197569.44444445	21.83	0.0001
LOCATION*TREAT	4	475069.44444445	118767.36111111	0.81	0.5281
BLOCK*TREAT(LOCATIO)	6	3010208.33333334	501701.38888889	3.43	0.0107
SLOPE*TREAT	2	567222.22222222	283611.11111111	1.94	0.1610
LOCATION*SLOPE*TREAT	4	393819.44444445	98454.86111111	0.67	0.6164
BLOC*SLOP*TREA(LOCA)	6	755208.33333334	125868.05555556	0.86	0.5355
MICROS(TREAT)	5	18236111.11111100	3647222.22222222	24.91	0.0001
SLOPE*MICROS(TREAT)	5	272777.77777779	54555.55555556	0.37	0.8634
LOCATI*MICROS(TREAT)	10	5253055.55555555	525305.55555555	3.59	0.0032
LOCA*SLOP*MICR(TREA)	10	498055.55555556	49805.55555556	0.34	0.9621

Source	DF	Type III SS	Mean Square	F Value	Pr > F
LOCATION	2	554315.76144835	277157.88072418	1.89	0.1682
BLOCK(LOCATION)	3	758690.47619048	252896.82539683	1.73	0.1826
SLOPE	1	167631.92950098	167631.92950098	1.14	0.2932
LOCATION*SLOPE	2	13437.16719915	6718.58359957	0.05	0.9552
BLOCK*SLOPE(LOCATIO)	3	763214.28571428	254404.76190476	1.74	0.1805
TREAT	2	6395138.88888917	3197569.44444459	21.83	0.0001
LOCATION*TREAT	4	475069.44444445	118767.36111111	0.81	0.5281
BLOCK*TREAT(LOCATIO)	6	3010208.33333332	501701.38888889	3.43	0.0107
SLOPE*TREAT	2	567222.22222221	283611.11111110	1.94	0.1616
LOCATION*SLOPE*TREAT	4	393819.44444444	98454.86111111	0.67	0.6164
BLOC*SLOP*TREA(LOCA)	6	755208.33333332	125868.05555555	0.86	0.5355
MICROS(TREAT)	5	18236111.11111100	3647222.22222222	24.91	0.0001
SLOPE*MICROS(TREAT)	5	272777.77777778	54555.55555556	0.37	0.8634
LOCATI*MICROS(TREAT)	10	5253055.55555554	525305.55555555	3.59	0.0032
LOCA*SLOP*MICR(TREA)	10	498055.55555556	49805.55555556	0.34	0.9621

General Linear Models Procedure

Dependent Variable: NUMBER

Tests of Hypotheses using the Type III MS for BLOCK(LOCATION) as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
LOCATION	2	554315.76144835	277157.88072418	1.10	0.4392

Tests of Hypotheses using the Type III MS for BLOCK*SLOPE(LOCATIO) as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SLOPE	1	167631.92950098	167631.92950098	0.66	0.4764
LOCATION*SLOPE	2	13437.16719915	6718.58359957	0.03	0.9742

Tests of Hypotheses using the Type III MS for BLOCK*TREAT(LOCATIO) as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	6395138.88888917	3197569.44444459	6.37	0.0328
LOCATION*TREAT	4	475069.44444445	118767.36111111	0.24	0.9077

Tests of Hypotheses using the Type III MS for BLOC*SLOP*TREA(LOCA) as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SLOPE*TREAT	2	567222.22222222	283611.11111110	2.25	0.1862
LOCATION*SLOPE*TREAT	4	393819.44444444	98454.86111111	0.78	0.5755

General Linear Models Procedure
Least Squares Means

Standard Errors and Probabilities calculated using the Type III MS for BLOCK*TREAT(LOCATIO) as an Error term

TREAT	NUMBER LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0
BLADING	2016.66667	144.58293	0.0001
DISC	1388.88889	118.05147	0.0001
RIPPER	1461.11111	118.05147	0.0001

General Linear Models Procedure
Least Squares Means

MICROS	TREAT	NUMBER LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0	Pr > |T| H0: LSMEAN(i)=LSMEAN(j) i/j	1	2	3	4	5	6	7	8
THICK	BLADING	1866.66667	110.47037	0.0001	1	.	0.0644	0.0001	0.2498	0.0290	0.0001	0.5977	0.0043
THIN	BLADING	2166.66667	110.47037	0.0001	2	0.0644	.	0.0001	0.4610	0.0002	0.0001	0.1757	0.0001
BERM	DISC	608.33333	110.47037	0.0001	3	0.0001	0.0001	.	0.0001	0.0001	0.0083	0.0001	0.0001
HINGE	DISC	2050.00000	110.47037	0.0001	4	0.2498	0.4610	0.0001	.	0.0016	0.0001	0.5270	0.0002
TRENCH	DISC	1508.33333	110.47037	0.0001	5	0.0290	0.0002	0.0001	0.0016	.	0.0064	0.0083	0.4299
BERM	RIPPER	1050.00000	110.47037	0.0001	6	0.0001	0.0001	0.0083	0.0001	0.0064	.	0.0001	0.0412
HINGE	RIPPER	1950.00000	110.47037	0.0001	7	0.5977	0.1757	0.0001	0.5270	0.0083	0.0001	.	0.0011
TRENCH	RIPPER	1383.33333	110.47037	0.0001	8	0.0043	0.0001	0.0001	0.0002	0.4299	0.0412	0.0011	.

NOTE: To ensure overall protection level, only probabilities associated with pre-planned comparisons should be used.

General Linear Models Procedure
Least Squares Means

Standard Errors and Probabilities calculated using the Type III MS for BLOCK*TREAT(LOCATIO) as an Error term

MICROS	TREAT	NUMBER LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0	Pr > |T| H0: LSMEAN(i)=LSMEAN(j) i/j	1	2	3	4	5	6	7	8
THICK	BLADING	1866.66667	204.47114	0.0001	1	.	0.3395	0.0048	0.5495	0.2615	0.0302	0.7829	0.1457
THIN	BLADING	2166.66667	204.47114	0.0001	2	0.3395	.	0.0017	0.7006	0.0631	0.0083	0.4820	0.0352
BERM	DISC	608.33333	204.47114	0.0248	3	0.0048	0.0017	.	0.0025	0.0208	0.1775	0.0035	0.0365
HINGE	DISC	2050.00000	204.47114	0.0001	4	0.5495	0.7006	0.0025	.	0.1102	0.0135	0.7413	0.0606
TRENCH	DISC	1508.33333	204.47114	0.0003	5	0.2615	0.0631	0.0208	0.1102	.	0.1641	0.1775	0.6806
BERM	RIPPER	1050.00000	204.47114	0.0021	6	0.0302	0.0083	0.1775	0.0135	0.1641	.	0.0208	0.2929
HINGE	RIPPER	1950.00000	204.47114	0.0001	7	0.7829	0.4820	0.0035	0.7413	0.1775	0.0208	.	0.0977
TRENCH	RIPPER	1383.33333	204.47114	0.0005	8	0.1457	0.0352	0.0365	0.0606	0.6806	0.2929	0.0977	.

NOTE: To ensure overall protection level, only probabilities associated with pre-planned comparisons should be used.

Means with the same letter are not significantly different.

MICROSITE	TREATMENT	MEAN	GROUPING		
Thin	Blading	2166.67	A		
Hinge	Disc	2050	A	B	
Hinge	Ripper	1950	A	B	
Thick	Blading	1866.67	A	B	
Trench	Disc	1508.33	A	B	C
Trench	Ripper	1383.33		B	C
Berm	Ripper	1050	D		C
Berm	Disc	608.33	D		

Appendix 1.3. Depth of the organic layer above the mineral soil.

General Linear Models Procedure
Class Level Information

Class	Levels	Values
LOCATION	3	ANTE FOX JUDY
BLOCK	2	I II
SLOPE	2	LOWER UPPER
TREAT	4	BLADE CONTROL DISC RIPPER
MICROS	6	BERM CONTROL HINGE THICK THIN TRENCH

Number of observations in data set = 108

General Linear Models Procedure

Dependent Variable: AVEDEPTH

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	77	20624.77260284	267.85418965	13.83	0.0001
Error	30	580.99760814	19.36325360		
Corrected Total	107	21205.67021098			

R-Square	C.V.	Root MSE	AVEDEPTH Mean
0.972606	33.99114	4.40036971	12.94[illegible]

Source	DF	Type I SS	Mean Square	F Value	Pr > F
LOCATION	2	495.10906562	247.55453281	12.78	0.0001
BLOCK(LOCATION)	3	84.99797912	28.33265971	1.46	0.2444
SLOPE	1	47.79838041	47.79838041	2.47	0.1266
LOCATION*SLOPE	2	128.33947977	64.16973988	3.31	0.0501
BLOCK*SLOPE(LOCATIO)	3	61.47287872	20.49095957	1.06	0.3814
TREAT	3	1902.63500866	634.21166955	32.75	0.0001
LOCATION*TREAT	6	59.48644445	9.91440741	0.51	0.7944
BLOCK*TREAT(LOCATIO)	9	114.17338043	12.68593116	0.66	0.7415
SLOPE*TREAT	3	29.13117664	9.71039221	0.50	0.6841
LOCATION*SLOPE*TREAT	6	21.96196431	3.66032739	0.19	0.9776
BLOC*SLOP*TREA(LOCA)	9	56.41963129	6.26884792	0.32	0.9605
MICROS(TREAT)	5	16421.96927614	3284.39385523	169.62	0.0001
SLOPE*MICROS(TREAT)	5	40.73241754	8.14648351	0.42	0.8306
LOCATI*MICROS(TREAT)	10	1000.87002369	100.08700237	5.17	0.0002
LOCA*SLOP*MICR(TREA)	10	159.67549604	15.96754960	0.82	0.6085

Source	DF	Type III SS	Mean Square	F Value	Pr > F
LOCATION	2	442.57276790	221.28638395	11.43	0.0002
BLOCK(LOCATION)	3	80.27485538	26.75828513	1.38	0.2673
SLOPE	1	53.85540910	53.85540910	2.78	0.1056
LOCATION*SLOPE	2	90.86837644	45.43418822	2.35	0.1130
BLOCK*SLOPE(LOCATIO)	3	33.37865384	11.12621795	0.57	0.6361
TREAT	3	1902.63500866	634.21166955	32.75	0.0001
LOCATION*TREAT	6	59.48644445	9.91440741	0.51	0.7944
BLOCK*TREAT(LOCATIO)	9	114.17338043	12.68593116	0.66	0.7415
SLOPE*TREAT	3	29.13117664	9.71039221	0.50	0.6841
LOCATION*SLOPE*TREAT	6	21.96196431	3.66032739	0.19	0.9776
BLOC*SLOP*TREA(LOCA)	9	56.41963129	6.26884792	0.32	0.9605
MICROS(TREAT)	5	16421.96927614	3284.39385523	169.62	0.0001
SLOPE*MICROS(TREAT)	5	40.73241754	8.14648351	0.42	0.8306
LOCATI*MICROS(TREAT)	10	1000.87002369	100.08700237	5.17	0.0002
LOCA*SLOP*MICR(TREA)	10	159.67549604	15.96754960	0.82	0.6085

General Linear Models Procedure

Dependent Variable: AVEDEPTH

Tests of Hypotheses using the Type III MS for BLOCK(LOCATION) as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
LOCATION	2	442.57276790	221.28638395	8.27	0.0602

Tests of Hypotheses using the Type III MS for BLOCK*SLOPE(LOCATIO) as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SLOPE	1	53.85540910	53.85540910	4.84	0.1152
LOCATION*SLOPE	2	90.86837644	45.43418822	4.08	0.1392

Tests of Hypotheses using the Type III MS for BLOCK*TREAT(LOCATIO) as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	3	1902.63500866	634.21166955	49.99	0.0001
LOCATION*TREAT	6	59.48644445	9.91440741	0.78	0.6050

Tests of Hypotheses using the Type III MS for BLOC*SLOP*TREA(LOCA) as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SLOPE*TREAT	3	29.13117664	9.71039221	1.55	0.2682
LOCATION*SLOPE*TREAT	6	21.96196631	3.66032739	0.58	0.7362

General Linear Models Procedure
Least Squares Means

Standard Errors and Probabilities calculated using the Type III MS for BLOCK*TREAT(LOCATIO) as an Error term

TREAT	AVEDEPTH LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0
BLADE	8.2649316	0.7270354	0.0001
CONTROL	23.4700000	1.0281833	0.0001
DISC	11.9615307	0.5936219	0.0001
RIPPER	13.5420984	0.5936219	0.0001

General Linear Models Procedure
Least Squares Means

MICROS	TREAT	AVEDEPTH LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0	LSMEAN Number
THICK	BLADE	16.2550297	1.2702773	0.0001	1
THIN	BLADE	0.2748335	1.2702773	0.8302	2
CONTROL	CONTROL	23.4700000	1.2702773	0.0001	3
BERM	DISC	29.7365771	1.2702773	0.0001	4
HINGE	DISC	6.1424595	1.2702773	0.0001	5
TRENCH	DISC	0.0055556	1.2702773	0.9965	6
BERM	RIPPER	35.6954606	1.2702773	0.0001	7
HINGE	RIPPER	4.9044459	1.2702773	0.0006	8
TRENCH	RIPPER	0.0263889	1.2702773	0.9836	9

Pr > |T| H0: LSMEAN(i)=LSMEAN(j)

i/j	1	2	3	4	5	6	7	8	9
1	.	0.0001	0.0004	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
2	0.0001	.	0.0001	0.0001	0.0027	0.8819	0.0001	0.0151	0.8909
3	0.0004	0.0001	.	0.0015	0.0001	0.0001	0.0001	0.0001	0.0001
4	0.0001	0.0001	0.0015	.	0.0001	0.0001	0.0024	0.0001	0.0001
5	0.0001	0.0027	0.0001	0.0001	.	0.0018	0.0001	0.4960	0.0019
6	0.0001	0.8819	0.0001	0.0001	0.0018	.	0.0001	0.0106	0.9908
7	0.0001	0.0001	0.0001	0.0024	0.0001	0.0001	.	0.0001	0.0001
8	0.0001	0.0151	0.0001	0.0001	0.4960	0.0106	0.0001	.	0.0109
9	0.0001	0.8909	0.0001	0.0001	0.0019	0.9908	0.0001	0.0109	.

NOTE: To ensure overall protection level, only probabilities associated with pre-planned comparisons should be used.

General Linear Models Procedure
Least Squares Means

Standard Errors and Probabilities calculated using the Type III MS for BLOCK*TREAT(LOCATIO) as an Error term

MICROS	TREAT	AVEDEPTH LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0	LSMEAN Number
THICK	BLADE	16.2550297	1.0281833	0.0001	1
THIN	BLADE	0.2748335	1.0281833	0.7953	2
CONTROL	CONTROL	23.4700000	1.0281833	0.0001	3
BERM	DISC	29.7365771	1.0281833	0.0001	4
HINGE	DISC	6.1424595	1.0201833	0.0002	5
TRENCH	DISC	0.0055556	1.0291833	0.9958	6
BERM	RIPPER	35.6954606	1.0281833	0.0001	7
HINGE	RIPPER	4.9044459	1.0281833	0.0010	8
TRENCH	RIPPER	0.0263689	1.0281833	0.9801	9

Pr > |T| H0: LSMEAN(i)=LSMEAN(j)

i/j	1	2	3	4	5	6	7	8	9
1	.	0.0001	0.0008	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
2	0.0001	.	0.0001	0.0001	0.0029	0.8572	0.0001	0.0111	0.8681
3	0.0008	0.0001	.	0.0020	0.0001	0.0001	0.0001	0.0001	0.0001
4	0.0001	0.0001	0.0020	.	0.0001	0.0001	0.0027	0.0001	0.0001
5	0.0001	0.0029	0.0001	0.0001	.	0.0022	0.0001	0.4166	0.0023
6	0.0001	0.8572	0.0001	0.0001	0.0022	.	0.0001	0.0083	0.9889
7	0.0001	0.0001	0.0001	0.0027	0.0001	0.0001	.	0.0001	0.0001
8	0.0001	0.0111	0.0001	0.0001	0.4166	0.0083	0.0001	.	0.0085
9	0.0001	0.8681	0.0001	0.0001	0.0023	0.9889	0.0001	0.0085	.

NOTE: To ensure overall protection level, only probabilities associated with pre-planned comparisons should be used.

Means with the same letter are not significantly different.

MICROSITE	TREATMENT	MEAN	GROUPING	
Berm	Ripper	35.70		
Berm	Disc	29.74		
Control	Control	23.47		
Thick	Blading	16.26		
Hinge	Disc	6.14	A	
Hinge	Ripper	4.90	A	
Thin	Blading	0.27		B
Trench	Ripper	0.03		B
Trench	Disc	0.01		B

Appendix 1.4. Soil disturbance.

General Linear Models Procedure
Class Level Information

Class	Levels	Values
LOCATION	3	Ante Fox Judy
BLOCK	2	I II
SLOPE	2	lower upper
TREAT	3	Blade Disc Ripper

Number of observations in data set = 36

General Linear Models Procedure

Dependent Variable: DISTURB

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	29	24388.86166667	840.99522980	28.17	0.0002
Error	6	179.11833333	29.85305556		
Corrected Total	35	24567.98000000			

R-Square	C.V.	Root MSE	DISTURB Mean
0.992709	11.18103	5.46379498	48.86666667

Source	DF	Type I SS	Mean Square	F Value	Pr > F
LOCATION	2	3174.68666667	1587.34333333	53.17	0.0002
BLOCK(LOCATION)	3	282.36666667	94.12222222	3.15	0.1075
SLOPE	1	2.89000000	2.89000000	0.10	0.7662
LOCATION*SLOPE	2	361.48666667	180.74333333	6.05	0.0364
BLOCK*SLOPE(LOCATIO)	3	1049.29666667	349.76555556	11.72	0.0064
TREAT	2	10251.86166667	5125.93083333	171.71	0.0001
LOCATION*TREAT	4	[illegible]	2127.42666667	[illegible]	0.0001
BLOCK*TREAT(LOCATIO)	6	[illegible]	43.27805556	1.45	0.3317
SLOPE*TREAT	2	[illegible]	175.79250000	5.89	0.0384
LOCATION*SLOPE*TREAT	4	[illegible]	36.32833333	1.22	0.3944

Source	DF	Type III SS	Mean Square	F Value	Pr > F
LOCATION	2	3174.68666667	1587.34333333	53.17	0.0002
BLOCK(LOCATION)	3	282.36666667	94.12222222	3.15	0.1075
SLOPE	1	2.89000000	2.89000000	0.10	0.7662
LOCATION*SLOPE	2	361.48666667	180.74333333	6.05	0.0364
BLOCK*SLOPE(LOCATIO)	3	1049.29666667	349.76555556	11.72	0.0064
TREAT	2	10251.86166667	5125.93083333	171.71	0.0001
LOCATION*TREAT	4	8509.70666667	2127.42666667	71.26	0.0001
BLOCK*TREAT(LOCATIO)	6	259.66833333	43.27805556	1.45	0.3317
SLOPE*TREAT	2	351.58500000	175.79250000	5.89	0.0384
LOCATION*SLOPE*TREAT	4	145.31333333	36.32833333	1.22	0.3944

Tests of Hypotheses using the Type III MS for BLOCK(LOCATION) as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
LOCATION	2	3174.68666667	1587.34333333	16.86	0.0233

Tests of Hypotheses using the Type III MS for BLOCK*SLOPE(LOCATIO) as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SLOPE	1	2.89000000	2.89000000	0.01	0.9333
LOCATION*SLOPE	2	361.48666667	180.74333333	0.52	0.6414

General Linear Models Procedure

Dependent Variable: DISTURB

Tests of Hypotheses using the Type III MS for BLOCK*TREAT(LOCATIO) as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	2	10251.86166667	5125.93083333	118.44	0.0001
LOCATION*TREAT	4	8509.70666667	2127.42666667	49.16	0.0001

General Linear Models Procedure
Least Squares Means

Standard Errors and Probabilities calculated using the Type III MS for BLOCK*SLOPE(LOCATIO) as an Error term

SLOPE	DISTURB LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0
lower	49.15000000	4.4081084	0.0015
upper	48.58333333	4.4081084	0.0016

General Linear Models Procedure
Least Squares Means

Standard Errors and Probabilities calculated using the Type III MS for BLOCK*TREAT(LOCATION) as an Error term

TREAT	DISTURB LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0
Blade	71.9666667	1.8990799	0.0001
Disc	32.1250000	1.8990799	0.0001
Ripper	42.5083333	1.8990799	0.0001

General Linear Models Procedure
Least Squares Means

Standard Errors and Probabilities calculated using the Type III MS for BLOCK(LOCATION) as an Error term

LOCATION	DISTURB LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0	Pr > |T| H0: LSMEAN(i)=LSMEAN(j) i/j	1	2	3
Ante	58.1000000	2.8006282	0.0002	1	.	0.2534	0.0113
Fox	52.5166667	2.8006282	0.0003	2	0.2534	.	0.0250
Judy	35.9833333	2.8006282	0.0010	3	0.0113	0.0250	.

NOTE: To ensure overall protection level, only probabilities associated with pre-planned comparisons should be used.

Means with the same letter are not significantly different.

LOCATION	Mean	GROUPING	
Ante	58.100	A	
Fox	52.517	A	
Judy	35.983		B

Appendix 1.5. Organic matter content.

General Linear Models Procedure
Class Level Information

Class	Levels	Values
BLOCK	2	1 2
SLOPE	2	lower upper
TREAT	4	Blade Control Disc Ripper
MICROS	6	berm control hinge thick thin trench

Number of observations in data set = 107

General Linear Models Procedure

Dependent Variable: OM

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	25	77385.96262475	3095.43850499	7.9[illegible]	[illegible]
Error	61	31600.08740465	390.12453586		
Corrected Total	106	108986.05002940			
	R-Square	C.V.	Root MSE		OM Mean
	0.710054	66.70809	19.75157047		29.6[illegible]

Source	DF	Type I SS	Mean Square	F Value	Pr > F
SLOPE	1	1450.61351549	1450.61351549	3.72	[illegible]
TREAT	3	33433.32952171	11144.44317390	28.5[illegible]	0.0001
BLOCK	1	232.73568035	232.73568035	0.60	0.4421
SLOPE*TREAT	3	2411.05896343	803.68632114	2.06	0.11[illegible]
BLOCK*SLOPE	1	23.46074596	23.46074596	0.06	[illegible]
BLOCK*TREAT	3	899.42596606	299.80865536	0.77	0.5150
BLOCK*SLOPE*TREAT	3	1063.01907281	354.33969094	0.91	0.44[illegible]
MICROS(TREAT)	5	34813.58162237	6962.71632447	17.85	0.0001
SLOPE*MICROS(TREAT)	5	3058.7175365	611.74350731	1.57	0.1798

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SLOPE	1	389.95118342	389.95118342	1.00	0.3204
TREAT	3	26857.39013767	8952.46337922	22.95	0.0001
BLOCK	1	249.14800600	249.14800600	0.64	0.4265
SLOPE*TREAT	3	2488.01187373	829.33729124	2.13	0.10[illegible]
BLOCK*SLOPE	1	0.47181876	0.47181878	0.00	0.97[illegible]
BLOCK*TREAT	3	798.93549528	266.31183176	0.68	0.56[illegible]
BLOCK*SLOPE*TREAT	3	974.33180488	324.77726829	0.83	0.47[illegible]
MICROS(TREAT)	5	34797.69484304	6959.53896861	17.84	0.0001
SLOPE*MICROS(TREAT)	5	3058.71753653	611.74350731	1.57	0.1798

Tests of Hypotheses using the Type III MS for BLOCK*SLOPE as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SLOPE	1	389.95118342	389.95118342	826.49	0.0221

Tests of Hypotheses using the Type III MS for BLOCK*TREAT as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	3	26857.39013767	8952.46337922	33.62	0.008[illegible]

Tests of Hypotheses using the Type III MS for BLOCK*SLOPE*TREAT as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SLOPE*TREAT	3	2488.01187373	829.33729124	2.55	0.2308

General Linear Models Procedure
Least Squares Means

Standard Errors and Probabilities calculated using the Type III MS for BLOCK*TREAT as an Error term

TREAT	OM LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0
Blade	25.8084244	3.3311149	0.0045
Control	76.1063333	5.0518858	0.0006
Disc	26.9191072	[illegible].8309033	0.0025
Ripper	19.4366319	2.7109272	0.0056

General Linear Models Procedure
Least Squares Means

MICROS	TREAT	OM LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0	LSMEAN Number
thick	Blade	48.4600000	5.7017873	0.0001	1
thin	Blade	3.1568508	5.7017873	0.5813	2
control	Control	76.1063333	6.1144856	0.0001	3
berm	Disc	51.1975000	5.7017873	0.0001	4
hinge	Disc	27.3904167	6.3747920	0.0001	5
trench	Disc	2.1694050	5.7017873	0.7046	6
berm	Ripper	37.9000000	5.7017873	0.0001	7
hinge	Ripper	17.8707689	5.9985298	0.0038	8
trench	Ripper	2.5391269	5.2994639	0.6331	9

Pr > |T| H0: LSMEAN(i)=LSMEAN(j)

i/j	1	2	3	4	5	6	7	8	9
1	.	0.0001	0.0014	0.7351	0.0159	0.0001	0.1940	0.0004	0.0001
2	0.0001	.	0.0001	0.0001	0.0058	0.9028	0.0001	0.0792	0.9369
3	0.0014	0.0001	.	0.0038	0.0001	0.0001	0.0001	0.0001	0.0001
4	0.7351	0.0001	0.0038	.	0.0067	0.0001	0.1030	0.0001	0.0001
5	0.0159	0.0058	0.0001	0.0067	.	0.0042	0.2227	0.2800	0.0036
6	0.0001	0.9028	0.0001	0.0001	0.0042	.	0.0001	0.0614	0.9622
7	0.1940	0.0001	0.0001	0.1030	0.2227	0.0001	.	0.0178	0.000.
8	0.0004	0.0792	0.0001	0.0001	0.2800	0.0614	0.0178	.	0.0584
9	0.0001	0.9369	0.0001	0.0001	0.0036	0.9622	0.0001	0.0584	.

NOTE: To ensure overall protection level, only probabilities associated with pre-planned comparisons should be used.

General Linear Models Procedure
Least Squares Means

Standard Errors and Probabilities calculated using the Type III MS for BLOCK*TREAT as an Error term

MICROS	TREAT	OM LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0	LSMEAN Number
thick	Blade	48.4600000	4.7109078	0.0020	1
thin	Blade	3.1568508	4.7109076	0.5508	2
control	Control	76.1063333	5.0518858	0.0006	3
berm	Disc	51.1975000	4.7109078	0.0017	4
hinge	Disc	27.3904167	5.2669551	0.0138	5
trench	Disc	2.1694050	4.7109078	0.6765	6
berm	Ripper	37.9000000	4.7109078	0.0040	7
hinge	Ripper	17.8707689	4.9560813	0.0366	8
trench	Ripper	2.5391269	4.3785019	0.6027	9

Pr > |T| H0: LSMEAN(i)=LSMEAN(j)

i/j	1	2	3	4	5	6	7	8	9
1	.	0.0065	0.0280	0.7087	0.0585	0.0061	0.2111	0.0208	0.0057
2	0.0065	.	0.0018	0.0055	0.0416	0.8916	0.0137	0.1205	0.9295
3	0.0280	0.0018	.	0.0366	0.0069	0.0017	0.0116	0.0038	0.0016
4	0.7087	0.0055	0.0366	.	0.0434	0.0052	0.1399	0.0165	0.0048
5	0.0585	0.0416	0.0069	0.0434	.	0.0376	0.2337	0.2796	0.0360
6	0.0061	0.8916	0.0017	0.0052	0.0376	.	0.0127	0.1053	0.9578
7	0.2111	0.0137	0.0116	0.1399	0.2337	0.0127	.	0.0610	0.0118
8	0.0208	0.1205	0.0038	0.0165	0.2796	0.1053	0.0610	.	0.1027
9	0.0057	0.9295	0.0016	0.0048	0.0360	0.9578	0.0118	0.1027	.

NOTE: To ensure overall protection level, only probabilities associated with pre-planned comparisons should be used.

General Linear Models Procedure
Least Squares Means

SLOPE	MICROS	TREAT	OM LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0
lower	thick	Blade	37.4383333	8.0635449	0.0001
lower	thin	Blade	3.5286883	8.0635449	0.6628
upper	thick	Blade	59.4816667	8.0635449	0.0001
upper	thin	Blade	2.7850133	8.0635449	0.7307
lower	control	Control	83.1676667	7.2122538	0.0001
upper	control	Control	69.0450000	9.8757852	0.0001
lower	berm	Disc	52.7266667	8.0635449	0.0001
lower	hinge	Disc	26.6633333	8.0635449	0.0014
lower	trench	Disc	2.4872850	8.0635449	0.7585
upper	berm	Disc	49.6683333	8.0635449	0.0001
upper	hinge	Disc	28.1175000	9.8757852	0.0056
upper	trench	Disc	1.8515250	8.0635449	0.8190
lower	berm	Ripper	55.7366667	8.0635449	0.0001
lower	hinge	Ripper	20.1416667	8.0635449	0.0145
lower	trench	Ripper	2.9192702	7.4936166	0.6979
upper	berm	Ripper	20.0633333	8.0635449	0.0149
upper	hinge	Ripper	15.5998712	8.8830560	0.0828
upper	trench	Ripper	2.1589837	7.4955309	0.7741

Means with the same letter are not significantly different.

MICROSITE	TREATMENT	MEAN	GROUPING	
Control	Control	76.11		
Berm	Disc	51.20	A	
Thick	Blading	48.46	A	B

Berm	Ripper	37.90	A	B	
Hinge	Disc	27.39		B	C
Hinge	Ripper	17.87	D		C
Thin	Blading	3.16	D		
Trench	Ripper	2.54	D		
Trench	Disc	2.17	D		

Appendix 1.6. Drainage.

General Linear Models Procedure
Class Level Information

Class	Levels	Values
LOCATION	3	Ante Fox Ju(
BLOCK	2	1 2
SLOPE	2	lower upper
TREAT	4	Blade Control Disc Ripper
MICROS	10	Berm-dee Berm-sur Deep Hinge-de Hinge-su Surface Thick-de Thick-su Thin-dee Trench-d

Number of observations in data set = 161

General Linear Models Procedure

Dependent Variable: AVEDRAIN

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	37	6.35745345	0.17182307	2.86	0.0001
Error	123	7.39280345	0.06010409		
Corrected Total	160	13.75025690			

R-Square	C.V.	Root MSE	AVEDRAIN Mean
0.462352	39.23267	0.24516136	0.62489066

Source	DF	Type I SS	Mean Square	F Value	Pr > F
BLOCK	1	0.07519414	0.07519414	1.25	0.2655
SLOPE	1	0.01988081	0.01988081	0.33	0.5663
BLOCK*SLOPE	1	0.00824362	0.00824362	0.14	0.7116
TREAT	3	0.76577342	0.25525781	4.25	0.0068
BLOCK*TREAT	3	0.12441257	0.04147086	0.69	0.5598
SLOPE*TREAT	3	0.06632856	0.02210952	0.37	0.7763
BLOCK*SLOPE*TREAT	3	0.00214102	0.00071394	0.01	0.9982
MICROS(TREAT)	11	5.02919180	0.45719925	7.61	0.0001
SLOPE*MICROS(TREAT)	11	0.26628670	0.02420788	0.40	0.9526

Source	DF	Type III SS	Mean Square	F Value	Pr > F
BLOCK	1	0.11225754	0.11225754	1.87	0.1742
SLOPE	1	0.01492074	0.01492074	0.25	0.6192
BLOCK*SLOPE	1	0.02294412	0.02294412	0.38	0.5378
TREAT	3	0.90658829	0.30219610	5.03	0.0025
BLOCK*TREAT	3	0.09335082	0.03111694	0.52	0.6709
SLOPE*TREAT	3	0.12913413	0.04304471	0.72	0.5441
BLOCK*SLOPE*TREAT	3	0.01501312	0.00500437	0.08	0.9690
MICROS(TREAT)	11	5.05364724	0.45942248	7.64	0.0001
SLOPE*MICROS(TREAT)	11	0.26628670	0.02420788	0.40	0.9526

Tests of Hypotheses using the Type III MS for BLOCK*SLOPE as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SLOPE	1	0.01492074	0.01492074	0.65	0.5680

Tests of Hypotheses using the Type III MS for BLOCK*TREAT as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	3	0.90658829	0.30219610	9.71	0.0470

Tests of Hypotheses using the Type III MS for BLOCK*SLOPE*TREAT as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SLOPE*TREAT	3	0.12913413	0.04304471	8.60	0.0552

General Linear Models Procedure
Least Squares Means

Standard Errors and Probabilities calculated using the Type III MS for BLOCK*TREAT as an Error term

TREAT	AVEDRAIN LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0
Blade	0.66324444	0.02939999	0.0002
Control	0.78331922	0.03699418	0.0002

Disc	0.54761399	0.02551766	0.0002
Ripper	0.61651174	0.02641602	0.0002

General Linear Models Procedure
Least Squares Means

MICROS	TREAT	AVEDRAIN LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0	LSMEAN Number
Thick-de	Blade	0.50450083	0.07077199	0.0001	1
Thick-su	Blade	0.78367183	0.07077199	0.0001	2
Thin-dee	Blade	0.70156067	0.07077199	0.0001	3
Deep	Control	0.48216850	0.07077199	0.0001	4
Surface	Control	1.08446994	0.07460023	0.0001	5
Berm-dee	Disc	0.47363483	0.07077199	0.0001	6
Berm-sur	Disc	0.84024967	0.07077199	0.0001	7
Hinge-de	Disc	0.45828417	0.07077199	0.0001	8
Hinge-su	Disc	0.51782861	0.10681127	0.0001	9
Trench-d	Disc	0.44807267	0.07077199	0.0001	10
Berm-dee	Ripper	0.43587311	0.07439911	0.0001	11
Berm-sur	Ripper	0.78388328	0.07440789	0.0001	12
Hinge-de	Ripper	0.59972579	0.08238565	0.0001	13
Hinge-su	Ripper	0.81152244	0.09487199	0.0001	14
Trench-d	Ripper	0.45155408	0.07786583	0.0001	15

Pr > |T| H0: LSMEAN(i)=LSMEAN(j)

i/j	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	.	0.0061	0.0512	0.8238	0.0001	0.7583	0.0011	0.6451	0.9173	0.5739	0.5052	0.0075	0.3823	0.0106	0.6157
2	0.0061	.	0.4136	0.0031	0.0041	0.0024	0.5729	0.0015	0.0401	0.0011	0.0009	0.9984	0.0929	0.8144	0.0020
3	0.0512	0.4136	.	0.0303	0.0003	0.0245	0.1683	0.0165	0.1541	0.0126	0.0108	0.4243	0.3503	0.3547	0.0190
4	0.8238	0.0031	0.0303	.	0.0001	0.9322	0.0005	0.8118	0.7812	0.7339	0.6529	0.0039	0.2812	0.0062	0.7716
5	0.0001	0.0041	0.0003	0.0001	.	0.0001	0.0191	0.0001	0.0001	0.0001	0.0001	0.0051	0.0001	0.0255	0.0001
6	0.7583	0.0024	0.0245	0.9322	0.0001	.	0.0004	0.8784	0.7307	0.7988	0.7137	0.0031	0.2479	0.0051	0.8341
7	0.0011	0.5729	0.1683	0.0005	0.0191	0.0004	.	0.0002	0.0131	0.0001	0.0001	0.5841	0.0286	0.8086	0.0003
8	0.6451	0.0015	0.0165	0.8118	0.0001	0.8784	0.0002	.	0.6430	0.9189	0.8276	0.0019	0.1952	0.0034	0.9491
9	0.9173	0.0401	0.1541	0.7812	0.0001	0.7307	0.0131	0.6430	.	0.5871	0.5301	0.0431	0.5449	0.0419	0.6170
10	0.5739	0.0011	0.0126	0.7339	0.0001	0.7988	0.0001	0.9189	0.5871	.	0.9056	0.0014	0.1651	0.0026	0.9737
11	0.5052	0.0009	0.0108	0.6529	0.0001	0.7137	0.0001	0.6276	0.5301	0.9056	.	0.0012	0.1417	0.0022	0.8842
12	0.0075	0.9984	0.4243	0.0039	0.0051	0.0031	0.5841	0.0019	0.0431	0.0014	0.0012	.	0.0997	0.8185	0.0025
13	0.3823	0.0929	0.3503	0.2812	0.0001	0.2479	0.0286	0.1952	0.5449	0.1651	0.1417	0.0997	.	0.0931	0.1927
14	0.0106	0.8144	0.3547	0.0062	0.0255	0.0051	0.8086	0.0034	0.0419	0.0026	0.0022	0.8185	0.0931	.	0.0036
15	0.6157	0.0020	0.0190	0.7716	0.0001	0.8341	0.0003	0.9491	0.6170	0.9737	0.8842	0.0025	0.1927	0.0036	.

NOTE: To ensure overall protection level, only probabilities associated with pre-planned comparisons should be used.

General Linear Models Procedure
Least Squares Means

Standard Errors and Probabilities calculated using the Type III MS for BLOCK*TREAT as an Error term

MICROS	TREAT	AVEDRAIN LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0	LSMEAN Number
Thick-de	Blade	0.50450083	0.05092228	0.0022	1
Thick-su	Blade	0.78367183	0.05092228	0.0006	2
Thin-dee	Blade	0.70156067	0.05092228	0.0008	3
Deep	Control	0.48216850	0.05092228	0.0025	4
Surface	Control	1.08446994	0.05367679	0.0003	5
Berm-dee	Disc	0.47363483	0.05092228	0.0026	6
Berm-sur	Disc	0.84024967	0.05092228	0.0005	7
Hinge-de	Disc	0.45828417	0.05092228	0.0029	8
Hinge-su	Disc	0.51782861	0.07685347	0.0067	9
Trench-d	Disc	0.44807267	0.05092228	0.0031	10
Berm-dee	Ripper	0.43587311	0.05353208	0.0039	11
Berm-sur	Ripper	0.78388328	0.05353841	0.0007	12
Hinge-de	Ripper	0.59972579	0.05927861	0.0021	13
Hinge-su	Ripper	0.81152244	0.06826285	0.0013	14
Trench-d	Ripper	0.45155408	0.05602648	0.0040	15

Pr > |T| H0: LSMEAN(i)=LSMEAN(j)

i/j	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	.	0.0304	0.0716	0.7768	0.0043	0.6971	0.0186	0.5667	0.8942	0.4905	0.4215	0.0324	0.3101	0.0366	0.5347
2	0.0304	.	0.3370	0.0248	0.0268	0.0231	0.4894	0.0203	0.0633	0.0186	0.0181	0.9979	0.1000	0.7651	0.0219
3	0.0716	0.3370	.	0.0556	0.0140	0.0507	0.1498	0.0432	0.1403	0.0389	0.0369	0.3464	0.2835	0.2871	0.0457
4	0.7768	0.0248	0.0556	.	0.0039	0.9132	0.0156	0.7620	0.7247	0.6682	0.5754	0.0265	0.2296	0.0306	0.7130
5	0.0043	0.0268	0.0140	0.0039	.	0.0037	0.0457	0.0035	0.0091	0.0033	0.0034	0.0287	0.0090	0.0515	0.0039
6	0.6971	0.0231	0.0507	0.9132	0.0037	.	0.0147	0.8449	0.6645	0.7461	0.6445	0.0246	0.2050	0.0286	0.7896
7	0.0186	0.4894	0.1498	0.0156	0.0457	0.0147	.	0.0131	0.0396	0.0122	0.0120	0.5010	0.0542	0.7581	0.0143
8	0.5667	0.0203	0.0432	0.7620	0.0035	0.8449	0.0131	.	0.5644	0.8962	0.7815	0.0217	0.1680	0.0255	0.9348
9	0.8942	0.0633	0.1403	0.7247	0.0091	0.6645	0.0396	0.5644	.	0.5043	0.4460	0.0656	0.4608	0.0647	0.5360
10	0.4905	0.0186	0.0389	0.6682	0.0033	0.7461	0.0122	0.8962	0.5043	.	0.8793	0.0200	0.1476	0.0236	0.9662
11	0.4215	0.0181	0.0369	0.5754	0.0034	0.6445	0.0120	0.7815	0.4460	0.8793	.	0.0194	0.1320	0.0224	0.8523
12	0.0324	0.9979	0.3464	0.0265	0.0287	0.0246	0.5010	0.0217	0.0656	0.0200	0.0194	.	0.1045	0.7702	0.0232
13	0.3101	0.1000	0.2835	0.2296	0.0090	0.2050	0.0542	0.1680	0.4608	0.1476	0.1320	0.1045	.	0.1001	0.1663
14	0.0366	0.7651	0.2871	0.0306	0.0515	0.0286	0.7581	0.0255	0.0647	0.0236	0.0224	0.7702	0.1001	.	0.0261
15	0.5347	0.0219	0.0457	0.7130	0.0039	0.7896	0.0143	0.9348	0.5360	0.9662	0.8523	0.0232	0.1663	0.0261	.

NOTE: To ensure overall protection level, only probabilities associated with pre-planned comparisons should be used.

General Linear Models Procedure
Least Squares Means

SLOPE	MICROS	TREAT	AVEDRAIN LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0
lower	Thick-de	Blade	0.46286083	0.10008671	0.0001
lower	Thick-su	Blade	0.82533517	0.10008671	0.0001
lower	Thin-dee	Blade	0.76316100	0.10008671	0.0001
upper	Thick-de	Blade	0.54614083	0.10008671	0.0001
upper	Thick-su	Blade	0.74200850	0.10008671	0.0001
upper	Thin-dee	Blade	0.63994033	0.10008671	0.0001
lower	Deep	Control	0.46240117	0.10008671	0.0001
lower	Surface	Control	0.99436667	0.10008671	0.0001
upper	Deep	Control	0.48193583	0.10008671	0.0001
upper	Surface	Control	1.17457920	0.11065002	0.0001
lower	Berm-dee	Disc	0.48155833	0.10008671	0.0001
lower	Berm-sur	Disc	0.89281933	0.10008671	0.0001
lower	Hinge-de	Disc	0.46441267	0.10008671	0.0001
lower	Hinge-su	Disc	0.68129122	0.12483006	0.0001
lower	Trench-d	Disc	0.44810833	0.10008671	0.0001
upper	Berm-dee	Disc	0.46572133	0.10008671	0.0001
upper	Berm-sur	Disc	0.78768000	0.10008671	0.0001
upper	Hinge-de	Disc	0.45215567	0.10008671	0.0001
upper	Hinge-su	Disc	0.35436600	0.17335526	0.0431
upper	Trench-d	Disc	0.44603700	0.10008671	0.0001
lower	Berm-dee	Ripper	0.44545167	0.10008671	0.0001
lower	Berm-sur	Ripper	0.78610340	0.11013079	0.0001
lower	Hinge-de	Ripper	0.58179662	0.12258066	0.0001
lower	Hinge-su	Ripper	0.82403150	0.14259950	0.0001
lower	Trench-d	Ripper	0.50295640	0.11013079	0.0001
upper	Berm-dee	Ripper	0.42629455	0.11010704	0.0001
upper	Berm-sur	Ripper	0.78166317	0.10008671	0.0001
upper	Hinge-de	Ripper	0.61765495	0.11010704	0.0001
upper	Hinge-su	Ripper	0.79901338	0.12517253	0.0001
upper	Trench-d	Ripper	0.40015175	0.11010704	0.0004

Means with the same letter are not significantly different.

MICROSITE	TREATMENT	MEAN	GROUPING			
Surface	Control	1.08				
Berm-sur	Disc	0.84	A			
Hinge-su	Ripper	0.81	A	B		
Berm-sur	Ripper	0.78	A	B		
Thick-su	Blading	0.78	A	B		
Thin-dee	Blading	0.70	A	B	C	
Hinge-de	Ripper	0.60	A	B	C	D
Hinge-su	Disc	0.52		B	C	D
Thick-de	Blading	0.50			C	D
Deep	Control	0.48			C	D
Berm-dee	Disc	0.47			C	D
Hinge-de	Disc	0.46				D
Trench-d	Ripper	0.45				D
Trench-d	Disc	0.45				D
Berm-dee	Ripper	0.44				D

Appendix 1.7. Bulk density.

General Linear Models Procedure
Class Level Information

Class	Levels	Values
BLOCK	2	1 2
SLOPE	2	lower upper
TREAT	4	Blade Control Disc Ripper
MICROS	10	Berm-dee Berm-sur Cont-dee Cont-sur Hinge-de Hinge-su Thick-de Thick-su Thin Trench

Number of observations in data set = 165

General Linear Models Procedure

Dependent Variable: DENSITY

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	37	33.10113633	0.89462531	12.15	0.0001
Error	127	9.34836795	0.07360920		
Corrected Total	164	42.44950427			

R-Square	C.V.	Root MSE	DENSITY Mean
0.779777	29.13525	0.27131015	0.93120928

Source	DF	Type I SS	Mean Square	F Value	Pr > F
SLOPE	1	0.10017922	0.10017922	1.36	0.2456
TREAT	3	1.51981689	0.50660563	6.88	0.0002
BLOCK	1	0.28418112	0.28418112	3.86	0.0516
SLOPE*TREAT	3	0.00193447	0.00064482	0.01	0.9989
BLOCK*SLOPE	1	0.00052041	0.00052041	0.01	0.9331
BLOCK*TREAT	3	0.30605532	0.10201844	1.39	0.2501
BLOCK*SLOPE*TREAT	3	0.08788127	0.02929376	0.40	0.7547
MICROS(TREAT)	11	29.97743296	2.72522118	37.02	0.0001
SLOPE*MICROS(TREAT)	11	0.82313465	0.07483042	1.02	0.4357

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SLOPE	1	0.03324967	0.03324967	0.45	0.5027
TREAT	3	1.42629795	0.47543265	6.46	0.0004
BLOCK	1	0.23224734	0.23224734	3.16	0.0781
SLOPE*TREAT	3	0.02481785	0.00827262	0.11	0.9527
BLOCK*SLOPE	1	0.00167163	0.00167163	0.02	0.8805
BLOCK*TREAT	3	0.33094958	0.11031653	1.50	0.2181
BLOCK*SLOPE*TREAT	3	0.01610773	0.00536924	0.07	0.9744
MICROS(TREAT)	11	29.56103268	2.68736661	36.51	0.0001
SLOPE*MICROS(TREAT)	11	0.82313465	0.07483042	1.02	0.4357

Tests of Hypotheses using the Type III MS for BLOCK*SLOPE as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SLOPE	1	0.03324967	0.03324967	19.89	0.1404

Tests of Hypotheses using the Type III MS for BLOCK*TREAT as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	3	1.42629795	0.47543265	4.31	0.1306

Tests of Hypotheses using the Type III MS for BLOCK*SLOPE*TREAT as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SLOPE*TREAT	3	0.02481785	0.00827262	1.54	0.3655

General Linear Models Procedure
Least Squares Means

Standard Errors and Probabilities calculated using the Type III MS for BLOCK*TREAT as an Error term

TREAT	DENSITY LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0
Blade	0.91824853	0.05535655	0.0005
Control	0.68641574	0.06965547	0.0022
Disc	0.90117452	0.04804660	0.0003
Ripper	0.98852197	0.04787766	0.0002

General Linear Models Procedure
Least Squares Means

MICROS	TREAT	DENSITY LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0	LSMEAN Number
Thick-de	Blade	1.14284200	0.07832049	0.0001	1
Thick-su	Blade	0.41108142	0.07832049	0.0001	2
Thin	Blade	1.20082217	0.07832049	0.0001	3
Cont-dee	Control	1.21964167	0.07832049	0.0001	4
Cont-sur	Control	0.15316981	0.08255705	0.0656	5
Berm-dee	Disc	1.20020525	0.07832049	0.0001	6
Berm-sur	Disc	0.23377758	0.07832049	0.0034	7
Hinge-de	Disc	1.31900133	0.07832049	0.0001	8
Hinge-su	Disc	0.36319683	0.11820371	0.0026	9
Trench	Disc	1.38969158	0.07832049	0.0001	10
Berm-dee	Ripper	1.26603401	0.07971878	0.0001	11
Berm-sur	Ripper	0.49351142	0.07832049	0.0001	12
Hinge-de	Ripper	1.20698102	0.08614139	0.0001	13
Hinge-su	Ripper	0.69646001	0.10492357	0.0001	14
Trench	Ripper	1.27962339	0.08233448	0.0001	15

Pr > |T| H0: LSMEAN(i)=LSMEAN(j)

i/j	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	.	0.0001	0.6016	0.4893	0.0001	0.6054	0.0001	0.1142	0.0001	0.0276	0.2724	0.0001	0.5827	0.0009	0.2310
2	0.0001	.	0.0001	0.0001	0.0251	0.0001	0.1119	0.0001	0.7361	0.0001	0.0001	0.4581	0.0001	0.0311	0.0001
3	0.6016	0.0001	.	0.8654	0.0001	0.9956	0.0001	0.2880	0.0001	0.0906	0.5606	0.0001	0.9579	0.0002	0.4893
4	0.4893	0.0001	0.8654	.	0.0001	0.8610	0.0001	0.3714	0.0001	0.1272	0.6788	0.0001	0.9136	0.0001	0.5985
5	0.0001	0.0251	0.0001	0.0001	.	0.0001	0.4801	0.0001	0.1477	0.0001	0.0001	0.0033	0.0001	0.0001	0.0001
6	0.6054	0.0001	0.9956	0.8610	0.0001	.	0.0001	0.2855	0.0001	0.0896	0.5569	0.0001	0.9537	0.0002	0.4859
7	0.0001	0.1119	0.0001	0.0001	0.4801	0.0001	.	0.0001	0.3631	0.0001	0.0001	0.0206	0.0001	0.0006	0.0001
8	0.1142	0.0001	0.2880	0.3714	0.0001	0.2855	0.0001	.	0.0001	0.5245	0.6363	0.0001	0.3378	0.0001	0.7295
9	0.0001	0.7361	0.0001	0.0001	0.1477	0.0001	0.3631	0.0001	.	0.0001	0.0001	0.3598	0.0001	0.0369	0.0001
10	0.0276	0.0001	0.0906	0.1272	0.0001	0.0896	0.0001	0.5245	0.0001	.	0.2706	0.0001	0.1191	0.0001	0.3346
11	0.2724	0.0001	0.5606	0.6788	0.0001	0.5569	0.0001	0.6363	0.0001	0.2706	.	0.0001	0.6144	0.0001	0.9056
12	0.0001	0.4581	0.0001	0.0001	0.0033	0.0001	0.0206	0.0001	0.3598	0.0001	0.0001	.	0.0001	0.1236	0.0001
13	0.5827	0.0001	0.9579	0.9136	0.0001	0.9537	0.0001	0.3378	0.0001	0.1191	0.6144	0.0001	.	0.0003	0.5423
14	0.0009	0.0311	0.0002	0.0001	0.0001	0.0002	0.0006	0.0001	0.0369	0.0001	0.0001	0.1236	0.0003	.	0.0001
15	0.2310	0.0001	0.4893	0.5985	0.0001	0.4859	0.0001	0.7295	0.0001	0.3346	0.9056	0.0001	0.5423	0.0001	.

NOTE: To ensure overall protection level, only probabilities associated with pre-planned comparisons should be used.

General Linear Models Procedure
Least Squares Means

Standard Errors and Probabilities calculated using the Type III MS for BLOCK*TREAT as an Error term

MICROS	TREAT	DENSITY LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0	LSMEAN Number
Thick-de	Blade	1.14284200	0.09588036	0.0013	1
Thick-su	Blade	0.41108142	0.09588036	0.0233	2
Thin	Blade	1.20082217	0.09588036	0.0011	3
Cont-dee	Control	1.21964167	0.09588036	0.0010	4
Cont-sur	Control	0.15316981	0.10106678	0.2268	5
Berm-dee	Disc	1.20020525	0.09588036	0.0011	6
Berm-sur	Disc	0.23377758	0.09588036	0.0926	7
Hinge-de	Disc	1.31900133	0.09588036	0.0008	8
Hinge-su	Disc	0.36319683	0.14470560	0.0869	9
Trench	Disc	1.38969158	0.09588036	0.0007	10
Berm-dee	Ripper	1.26603401	0.09759215	0.0010	11
Berm-sur	Ripper	0.49351142	0.09588036	0.0142	12
Hinge-de	Ripper	1.20698102	0.10545475	0.0014	13
Hinge-su	Ripper	0.69646001	0.12844799	0.0123	14
Trench	Ripper	1.27962339	0.10079431	0.0011	15

Pr > |T| H0: LSMEAN(i)=LSMEAN(j)

i/j	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	.	0.0125	0.6978	0.6107	0.0057	0.7008	0.0068	0.2847	0.0206	0.1662	0.4342	0.0173	0.6832	0.0687	0.3980
2	0.0125	.	0.0101	0.0094	0.1612	0.0101	0.2822	0.0068	0.8006	0.0055	0.0083	0.5862	0.0113	0.1730	0.0083
3	0.6978	0.0101	.	0.8984	0.0049	0.9967	0.0057	0.4476	0.0170	0.2579	0.6662	0.0137	0.9682	0.0514	0.6107
4	0.6107	0.0094	0.8984	.	0.0046	0.8951	0.0054	0.5168	0.0160	0.2986	0.7569	0.0127	0.9348	0.0470	0.6954
5	0.0057	0.1612	0.0049	0.0046	.	0.0049	0.6035	0.0036	0.3197	0.0030	0.0042	0.0923	0.0055	0.0449	0.0042
6	0.7008	0.0101	0.9967	0.8951	0.0049	.	0.0057	0.4455	0.0170	0.2567	0.6633	0.0137	0.9651	0.0516	0.6080
7	0.0068	0.2822	0.0057	0.0054	0.6035	0.0057	.	0.0041	0.5100	0.0034	0.0048	0.1513	0.0064	0.0632	0.0049
8	0.2847	0.0068	0.4476	0.5168	0.0036	0.4455	0.0041	.	0.0118	0.6382	0.7245	0.0089	0.4893	0.0302	0.7955
9	0.0206	0.8006	0.0170	0.0160	0.3197	0.0170	0.5100	0.0118	.	0.0097	0.0140	0.5073	0.0181	0.1835	0.0138
10	0.1662	0.0055	0.2579	0.2986	0.0030	0.2567	0.0034	0.6382	0.0097	.	0.4327	0.0071	0.2900	0.0228	0.4866
11	0.4342	0.0083	0.6662	0.7569	0.0042	0.6633	0.0048	0.7245	0.0140	0.4327	.	0.0110	0.7077	0.0384	0.9288
12	0.0173	0.5862	0.0137	0.0127	0.0923	0.0137	0.1513	0.0089	0.5073	0.0071	0.0110	.	0.0153	0.2948	0.0110
13	0.6832	0.0113	0.9682	0.9348	0.0055	0.9651	0.0064	0.4893	0.0181	0.2900	0.7077	0.0153	.	0.0543	0.6520
14	0.0687	0.1730	0.0514	0.0470	0.0449	0.0516	0.0632	0.0302	0.1835	0.0228	0.0384	0.2948	0.0543	.	0.0371
15	0.3980	0.0083	0.6107	0.6954	0.0042	0.6080	0.0049	0.7955	0.0138	0.4866	0.9288	0.0110	0.6520	0.0371	.

NOTE: To ensure overall protection level, only probabilities associated with pre-planned comparisons should be used.

General Linear Models Procedure
Least Squares Means

SLOPE	MICROS	TREAT	DENSITY LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0
lower	Thick-de	Blade	1.04881167	0.11076190	0.0001
lower	Thick-su	Blade	0.48075717	0.11076190	0.0001
lower	Thin	Blade	1.16238950	0.11076190	0.0001
upper	Thick-de	Blade	1.23687233	0.11076190	0.0001
upper	Thick-su	Blade	0.34140567	0.11076190	0.0025
upper	Thin	Blade	1.23925483	0.11076190	0.0001
lower	Cont-dee	Control	1.23465000	0.11076190	0.0001
lower	Cont-sur	Control	0.11691667	0.11076190	0.2932
upper	Cont-dee	Control	1.20463333	0.11076190	0.0001
upper	Cont-sur	Control	0.18946296	0.12245189	0.1243
lower	Berm-dee	Disc	1.26253933	0.11076190	0.0001
lower	Berm-sur	Disc	0.24597333	0.11076190	0.0281
lower	Hinge-de	Disc	1.31970400	0.11076190	0.0001
lower	Hinge-su	Disc	0.37090917	0.13814437	0.0082
lower	Trench	Disc	1.31317933	0.11076190	0.0001
upper	Berm-dee	Disc	1.13787117	0.11076190	0.0001
upper	Berm-sur	Disc	0.22158183	0.11076190	0.0476
upper	Hinge-de	Disc	1.31829867	0.11076190	0.0001
upper	Hinge-su	Disc	0.35548453	0.19184525	0.0662
upper	Trench	Disc	1.46620383	0.11076190	0.0001
lower	Berm-dee	Ripper	1.33824104	0.10282347	0.0001
lower	Berm-sur	Ripper	0.30672533	0.11076190	0.0065
lower	Hinge-de	Ripper	1.19048086	0.12179364	0.0001
lower	Hinge-su	Ripper	0.76947656	0.15762962	0.0001
lower	Trench	Ripper	1.18898600	0.11076190	0.0001
upper	Berm-dee	Ripper	1.19382698	0.12185100	0.0001
upper	Berm-sur	Ripper	0.68029750	0.11076190	0.0001
upper	Hinge-de	Ripper	1.22348116	0.12185100	0.0001
upper	Hinge-su	Ripper	0.62344346	0.13852336	0.0001
upper	Trench	Ripper	1.37026078	0.12185100	0.0001

Means with the same letter are not significantly different.

MICROSITE	TREATMENT	MEAN	GROUPING		
Trench	Disc	1.39	A		
Hinge-de	Disc	1.32	A		
Trench	Ripper	1.28	A		
Berm-dee	Ripper	1.27	A		
Cont-dee	Control	1.22	A		
Hinge-de	Ripper	1.21	A		
Thin	Blading	1.20	A	B	
Berm-dee	Disc	1.20	A	B	
Thick-dee	Blading	1.14	A	B	
Hinge-su	Ripper	0.70		B	C
Berm-sur	Ripper	0.49	D		C
Thick-su	Blading	0.41	D		C
Hinge-su	Disc	0.36	D		C
Berm-sur	Disc	0.[illegible]	D		C
Cont-sur	Control	0.15	D		

Appendix 1.8. Soil-moisture desorption curves.

Comparisons between different treatments and microsites were made to see if soil-moisture desorption curves were similar or different (Table 1). Only two of these comparisons are shown as an example.

Ripper ploughing: hinge deep vs. hinge surface

Nonlinear Regression Summary Statistics   Dependent Variable BAR

Source	DF	Sum of Squares	Mean Square
Regression	8	9.74784	1.21848
Residual	94	.79993	8.509911E-03
Uncorrected Total	102	10.54777	
(Corrected Total)	101	2.39306	

R squared = 1 - Residual SS / Corrected SS = .66573

Parameter	Estimate	Asymptotic Std. Error	Asymptotic 95 % Confidence Interval Lower	Upper
B0	.461612226	.017385163	.427093576	.496130874
B1	-1.540467129	.192807635	-1.923291208	-1.157643051
B2	.006506186	.017385164	-.028012464	.041024837
B3	-.270103155	.425013960	-1.113978334	.573772025
B4	.106777248	.249306578	-.388226807	.601781302
B5	2.465581565	.425013980	1.621706345	3.309456785
B6	-1.238047956	.249306592	-1.733052040	-.743043873
B7	.159757627	.192807632	-.223066446	.542581700

Asymptotic Correlation Matrix of the Parameter Estimates

	B0	B1	B2	B3	B4	B5	B6	B7
B0	1.0000	-.7042	-.1747	-.0855	.0621	.5685	-.4794	.1174
B1	-.7042	1.0000	.1174	.1271	-.0932	-.9578	.8793	-.1543
B2	-.1747	.1174	1.0000	.5685	-.4794	-.0855	.0621	-.7042
B3	-.0855	.1271	.5685	1.0000	-.9755	-.1060	.0707	-.9578
B4	.0621	-.0932	-.4794	-.9755	1.0000	.0707	-.0316	.8793
B5	.5685	-.9578	-.0855	-.1060	.0707	1.0000	-.9755	.1271
B6	-.4794	.8793	.0621	.0707	-.0316	-.9755	1.0000	-.0932
B7	.1174	-.1543	-.7042	-.9578	.8793	.1271	-.0932	1.0000

Control: deep vs. surface

Nonlinear Regression Summary Statistics   Dependent Variable BAR

Source	DF	Sum of Squares	Mean Square
Regression	8	14.65347	1.83168
Residual	130	1.41712	.01090
Uncorrected Total	138	16.07059	
(Corrected Total)	137	3.76563	

R squared = 1 - Residual SS / Corrected SS = .62367

Parameter	Estimate	Asymptotic Std. Error	Asymptotic 95 % Confidence Interval Lower	Upper
B0	.491176540	.016657366	.458221934	.524131147
B1	-1.717357034	.184395089	-2.082160664	-1.352553403
B2	-.030191854	.016657367	-.063146462	.002762754
B3	-1.249861139	.405759469	-2.052607723	-.447114556
B4	.664360711	.237026456	.195432216	1.133289207
B5	2.785080647	.405759428	1.982334145	3.587827149
B6	-1.367994944	.237026439	-1.836923406	-.899066482
B7	.597294324	.184395108	.232490655	.962097993

Asymptotic Correlation Matrix of the Parameter Estimates

	B0	B1	B2	B3	B4	B5	B6	B7
B0	1.0000	-.7040	-.0433	-.0235	.01[illegible]	.5690	-.4812	.0301
B1	-.7040	1.0000	.0301	.0383	-.0333	-.9585	.8817	-.0417
B2	-.0433	.0301	1.0000	.5690	-.4812	-.0235	.0191	-.7040
B3	-.0235	.0383	.5690	1.0000	-.9761	-.0378	.0342	-.9585
B4	.0191	-.0333	-.4812	-.9761	1.0000	.0342	-.0316	.8817
B5	.5690	-.9585	-.0235	-.0378	.0342	1.0000	-.9761	.0383
B6	-.4812	.8617	.0191	.0342	-.0316	-.9761	1.0000	-.0333
B7	.0301	-.0417	-.7040	-.9585	.8817	.0383	-.0333	1.0000

Table 1. Significant differences in slopes and intercepts of the soil-moisture desorption curves for the different treatments and microsites. d = significantly different. s = similar.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	-	d/s	s/s	s/s	s/s	s/s	d/d	s/s	d/s	s/s	s/s	d/d	s/s	s/s	d/s
2		-	s/s	s/s	d/s	d/s	s/s	d/s	s/s	d/s	d/s	s/s	d/s	d/s	s/s
3			-	s/s	s/s	s/s	d/s	s/s	s/s	s/s	s/s	s/d	s/s	s/s	d/s
4				-	s/s	s/s	s/s	s/s	s/s	d/s	s/s	s/d	s/s	s/s	s/s
5					-	s/s	d/d	s/s	d/d	s/s	s/s	d/d	s/s	s/s	d/d
6						-	d/d	s/s	d/d	s/s	s/s	d/d	s/s	s/s	d/d
7							-	d/d	s/s	d/d	d/s	s/s	d/d	d/d	s/s
8								-	d/d	s/s	s/s	d/d	s/s	s/s	d/d
9									-	d/d	d/s	s/s	d/d	d/s	s/s
10										-	s/s	d/d	s/s	s/s	d/d
11											-	d/s	s/s	s/s	d/s
12												-	d/d	d/d	s/s
13													-	s/s	d/d
14														-	d/s
15															-

1 - Riper ploughing/Berm/deep
2 - Ripper ploughing/Berm/surface
3 - Ripper ploughing/Hinge/deep
4 - Ripper ploughing/Hinge/surface
5 - Ripper ploughing/Trench
6 - Disc trenching/Berm/deep
7 - Disc trenching/Berm/surface
8 - Disc trenching/Hinge/deep
9 - Disc trenching/Hinge/surface
10 - Disc trenching/Trench
11 - Blading/Thick/deep
12 - Blading/Thick/surface
13 - Blading/Thin
14 - Control/deep
15 - Control/surface

Volumetric water content at -0.1 bar matric potential.

General Linear Models Procedure
Class Level Information

Class	Levels	Values
LOCATION	3	Ante Fox Judy
BLOCK	2	1 2
SLOPE	2	lower upper
TREAT	4	Blade Control Disc Ripper
MICROS	10	deep surface Berm-dee Berm-sur Hinge-de Hinge-su Thick-de Thick-su Thin-de Trench-d

Number of observations in data set = 165

General Linear Models Procedure

Dependent Variable: BAR01

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	37	0.31227601	0.00843995	1.90	0.0046
Error	127	0.56420923	0.00444259		
Corrected Total	164	0.87648723			

R-Square	C.V.	Root MSE	BAR01 Mean
0.356284	20.16503	0.06665277	0.33053639

Source	DF	Type I SS	Mean Square	F Value	Pr > F
BLOCK	1	0.01428294	0.01428294	3.22	0.0753
SLOPE	1	0.03231560	0.03231560	7.27	0.0079
BLOCK*SLOPE	1	0.00126778	0.00126778	0.29	0.5941
TREAT	3	0.02019282	0.00673094	1.52	0.2138
BLOCK*TREAT	3	0.00365843	0.00121948	0.27	0.8437
SLOPE*TREAT	3	0.01090977	0.00363659	0.82	0.4859
BLOCK*SLOPE*TREAT	3	0.00979129	0.00326376	0.73	0.5332
MICROS(TREAT)	11	0.20024193	0.01820381	4.10	0.0001
SLOPE*MICROS(TREAT)	11	0.01961744	0.00178340	0.40	0.9532

Source	DF	Type III SS	Mean Square	F Value	Pr > F
BLOCK	1	0.00599399	0.00599399	1.35	0.2476
SLOPE	1	0.03620386	0.03620386	8.15	0.0050
BLOCK*SLOPE	1	0.00061161	0.00061161	0.14	0.7112
TREAT	3	0.02402779	0.00800926	1.80	0.1500
BLOCK*TREAT	3	0.00457731	0.00152577	0.34	0.7939
SLOPE*TREAT	3	0.01445174	0.00481725	1.08	0.3583
BLOCK*SLOPE*TREAT	3	0.01279586	0.00426529	0.96	0.4138
MICROS(TREAT)	11	0.20062054	0.01823823	4.11	0.0001
SLOPE*MICROS(TREAT)	11	0.01961744	0.00178340	0.40	0.9532

Tests of Hypotheses using the Type III MS for BLOCK*SLOPE as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SLOPE	1	0.03620386	0.03620386	59.19	0.0823

Tests of Hypotheses using the Type III MS for BLOCK*TREAT as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F

TREAT	3	0.02402779	0.00800926	5.25	0.1033

Dependent Variable: BAR01

Tests of Hypotheses using the Type III MS for BLOCK*SLOPE*TREAT as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SLOPE*TREAT	3	0.01445174	0.00481725	1.13	0.4613

General Linear Models Procedure
Least Squares Means

Standard Errors and Probabilities calculated using the Type III MS for BLOCK*TREAT as an Error term

TREAT	BAR01 LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0
Blade	0.34954356	0.00651018	0.0001
Control	0.31146238	0.00819180	0.0001
Disc	0.32288586	0.00565050	0.0001
Ripper	0.32793169	0.00563063	0.0001

General Linear Models Procedure
Least Squares Means

MICROS	TREAT	BAR01 LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0	LSMEAN Number
Thick-de	Blade	0.38322617	0.01924100	0.0001	1
Thick-su	Blade	0.32924033	0.01924100	0.0001	2
Thin-de	Blade	0.33616417	0.01924100	0.0001	3
deep	Control	0.35986008	0.01924100	0.0001	4
surface	Control	0.26306468	0.02028179	0.0001	5
Berm-dee	Disc	0.33726067	0.01924100	0.0001	6
Berm-sur	Disc	0.27409975	0.01924100	0.0001	7
Hinge-de	Disc	0.34002600	0.01924100	0.0001	8
Hinge-su	Disc	0.30382348	0.02903911	0.0001	9
Trench-d	Disc	0.35921942	0.01924100	0.0001	10
Berm-dee	Ripper	0.37425156	0.01958452	0.0001	11
Berm-sur	Ripper	0.28582183	0.01924100	0.0001	12
Hinge-de	Ripper	0.34953414	0.02116236	0.0001	13
Hinge-su	Ripper	0.27691725	0.02577658	0.0001	14
Trench-d	Ripper	0.35313366	0.02022711	0.0001	15

Pr > |T| H0: LSMEAN(i)=LSMEAN(j)

i/j	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	.	0.0494	0.0861	0.3921	0.0001	0.0936	0.0001	0.1149	0.0243	0.3793	0.7443	0.0005	0.2410	0.0012	0.2831
2	0.0494	.	0.7996	0.2626	0.0194	0.7667	0.0448	0.6925	0.4670	0.2727	0.1036	0.1131	0.4793	0.1063	0.3937
3	0.0861	0.7996	.	0.3855	0.0100	0.9679	0.0242	0.8874	0.3550	0.3984	0.1678	0.0666	0.6410	0.0678	0.5444
4	0.3921	0.2626	0.3855	.	0.0007	0.4078	0.0020	0.4674	0.1102	0.9813	0.6011	0.0074	0.7187	0.0111	0.8100
5	0.0001	0.0194	0.0100	0.0007	.	0.0090	0.6937	0.0068	0.2520	0.0008	0.0001	0.4172	0.0038	0.6735	0.0021
6	0.0936	0.7687	0.9679	0.4078	0.0090	.	0.0219	0.9192	0.3389	0.4212	0.1803	0.0610	0.6686	0.0630	0.5706
7	0.0001	0.0448	0.0242	0.0020	0.6937	0.0219	.	0.0168	0.3951	0.0022	0.0004	0.6674	0.0094	0.9303	0.0054
8	0.1149	0.6925	0.8874	0.4674	0.0068	0.9192	0.0168	.	0.3007	0.4819	0.2148	0.0485	0.7401	0.0520	0.6395
9	0.0243	0.4670	0.3550	0.1102	0.2520	0.3389	0.3951	0.3007	.	0.1143	0.0465	0.6062	0.2056	0.4896	0.1659
10	0.3793	0.2727	0.3984	0.9813	0.0008	0.4212	0.0022	0.4819	0.1143	.	0.5850	0.0079	0.7355	0.0117	0.8278
11	0.7443	0.1036	0.1678	0.6011	0.0001	0.1803	0.0004	0.2148	0.0465	0.5850	.	0.0016	0.3912	0.0031	0.4535
12	0.0005	0.1131	0.0666	0.0074	0.4172	0.0610	0.6674	0.0485	0.6062	0.0079	0.0016	.	0.0277	0.7824	0.0173
13	0.2410	0.4793	0.6410	0.7187	0.0038	0.6686	0.0094	0.7401	0.2056	0.7355	0.3912	0.0277	.	0.0310	0.9021
14	0.0012	0.1063	0.0678	0.0111	0.6735	0.0630	0.9303	0.0520	0.4896	0.0117	0.0031	0.7824	0.0310	.	0.0210
15	0.2831	0.3937	0.5444	0.8100	0.0021	0.5706	0.0054	0.6395	0.1659	0.8278	0.4535	0.0173	0.9021	0.0210	.

NOTE: To ensure overall protection level, only probabilities associated with pre-planned comparisons should be used.

General Linear Models Procedure
Least Squares Means

Standard Errors and Probabilities calculated using the Type III MS for BLOCK*TREAT as an Error term

MICROS	TREAT	BAR01 LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0	LSMEAN Number
Thick-de	Blade	0.38322617	0.01127597	0.0001	1
Thick-su	Blade	0.32924033	0.01127597	0.0001	2
Thin-de	Blade	0.33616417	0.01127597	0.0001	3
deep	Control	0.35986008	0.01127597	0.0001	4
surface	Control	0.26306468	0.01188592	0.0001	5
Berm-dee	Disc	0.33726067	0.01127597	0.0001	6
Berm-sur	Disc	0.27409975	0.01127597	0.0002	7
Hinge-de	Disc	0.34002600	0.01127597	0.0001	8
Hinge-su	Disc	0.30382348	0.01701804	0.0004	9
Trench-d	Disc	0.35921942	0.01127597	0.0001	10
Berm-dee	Ripper	0.37425156	0.01147728	0.0001	11
Berm-sur	Ripper	0.28582183	0.01127597	0.0001	12
Hinge-de	Ripper	0.34953414	0.01240196	0.0001	13
Hinge-su	Ripper	0.27691725	0.01510607	0.0004	14
Trench-d	Ripper	0.35313366	0.01185387	0.0001	15

Pr > |T| H0: LSMEAN(i)=LSMEAN(j)

i/j	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	.	0.0429	0.0600	0.2391	0.0052	0.0634	0.0064	0.0732	0.0301	0.2293	0.6159	0.0088	0.1380	0.0110	0.1631
2	0.0429	.	0.6935	0.1506	0.0273	0.6496	0.0407	0.5473	0.3015	0.1567	0.0680	0.0724	0.3127	0.0692	0.2403
3	0.0600	0.6935	.	0.2340	0.0210	0.9495	0.0301	0.8243	0.2113	0.2440	0.0988	0.0510	0.4834	0.0515	0.3759
4	0.2391	0.1506	0.2340	.	0.0097	0.2514	0.0126	0.3019	0.0710	0.9705	0.4370	0.0188	0.5815	0.0218	0.7086
5	0.0052	0.0273	0.0210	0.0097	.	0.0201	0.5488	0.0182	0.1444	0.0099	0.0067	0.2590	0.0151	0.5232	0.0127
6	0.0634	0.6496	0.9495	0.2514	0.0201	.	0.0287	0.8734	0.2000	0.2623	0.1051	0.0484	0.5170	0.0493	0.4035
7	0.0064	0.0407	0.0301	0.0126	0.5488	0.0287	.	0.0257	0.2414	0.0129	0.0084	0.5155	0.0205	0.8907	0.0169
8	0.0732	0.5473	0.8243	0.3019	0.0182	0.8734	0.0257	.	0.1743	0.3151	0.1233	0.0425	0.6102	0.0441	0.4816
9	0.0301	0.3015	0.2113	0.0710	0.1444	0.2000	0.2414	0.1743	.	0.0729	0.0415	0.4428	0.1184	0.3222	0.0978
10	0.2293	0.1567	0.2440	0.9705	0.0099	0.2623	0.0129	0.3151	0.0729	.	0.4191	0.0193	0.6039	0.0222	0.7346
11	0.6159	0.0680	0.0988	0.4370	0.0067	0.1051	0.0084	0.1233	0.0415	0.4191	.	0.0119	0.2383	0.0142	0.2896
12	0.0088	0.0724	0.0510	0.0188	0.2590	0.0484	0.5155	0.0425	0.4428	0.0193	0.0119	.	0.0320	0.6689	0.0260
13	0.1380	0.3127	0.4834	0.5815	0.0151	0.5170	0.0205	0.6102	0.1184	0.6039	0.2383	0.0320	.	0.0338	0.8469
14	0.0110	0.0692	0.0515	0.0218	0.5232	0.0493	0.8907	0.0441	0.3222	0.0222	0.0142	0.6689	0.0338	.	0.0282
15	0.1631	0.2403	0.3759	0.7086	0.0127	0.4035	0.0169	0.4816	0.0978	0.7346	0.2896	0.0260	0.8469	0.0282	.

NOTE: To ensure overall protection level, only probabilities associated with pre-planned comparisons should be used.

Means with the same letter are not significantly different.

MICROSITE	TREATMENT	MEAN	GROUPING			
Thick-de	Blading	0.38	A			
Berm-dee	Ripper	0.37	A	B		
Deep	Control	0.36	A	B	C	
Trench-d	Disc	0.36	A	B	C	
Trench-d	Ripper	0.35	A	B	C	
Hinge-de	Ripper	0.35	A	B	C	
Hinge-de	Disc	0.34	A	B	C	
Berm-dee	Disc	0.34	A	B	C	
Thin-de	Blading	0.34	A	B	C	D
Thick-su	Blading	0.33		B	C	D
Hinge-su	Disc	0.30	E		C	D
Berm-sur	Ripper	0.29	E			D
Hinge-su	Ripper	0.28	E			D
Berm-sur	Disc	0.27	E			
Surface	Control	0.26	E			

Volumetric moisture content at -6 bar matric potential.

General Linear Models Procedure
Class Level Information

Class	Levels	Values
LOCATION	3	Ante Fox Judy
BLOCK	2	1 2
SLOPE	2	lower upper
TREAT	4	Blade Control Disc Ripper
MICROS	10	deep surface Berm-dee Berm-sur Hinge-de Hinge-su Thick-de Thick-su Thin-de Trench-d

Number of observations in data set = 165

General Linear Models Procedure

Dependent Variable: BAR6

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	37	0.19294271	0.00521467	1.01	0.4630
Error	127	0.65450156	0.00515356		
Corrected Total	164	0.84744427			

R-Square	C.V.	Root MSE	BAR6 Mean
0.227676	43.93336	0.07178827	0.16340265

Source	DF	Type I SS	Mean Square	F Value	Pr > F
BLOCK	1	0.00904222	0.00904222	1.75	0.1877
SLOPE	1	0.03897522	0.03897522	7.56	0.0068
BLOCK*SLOPE	1	0.00000803	0.00000803	0.00	0.9686
TREAT	3	0.01021608	0.00340536	0.66	0.5777
BLOCK*TREAT	3	0.00932855	0.00310952	0.60	0.6140
SLOPE*TREAT	3	0.01099467	0.00366489	0.71	0.5471
BLOCK*SLOPE*TREAT	3	0.02257298	0.00752433	1.46	0.2286
MICROS(TREAT)	11	0.05726382	0.00520580	1.01	0.4413
SLOPE*MICROS(TREAT)	11	0.03454113	0.00314010	0.61	0.8182

Source	DF	Type III SS	Mean Square	F Value	Pr > F
BLOCK	1	0.00421490	0.00421490	0.82	0.3675
SLOPE	1	0.03229913	0.03229913	6.27	0.0136
BLOCK*SLOPE	1	0.00005917	0.00005917	0.01	0.9148
TREAT	3	0.00764413	0.00254804	0.49	0.6868
BLOCK*TREAT	3	0.01068120	0.00356040	0.69	0.5592
SLOPE*TREAT	3	0.01166820	0.00388940	0.75	0.5216
BLOCK*SLOPE*TREAT	3	0.02408131	0.00802710	1.56	0.2030
MICROS(TREAT)	11	0.05868062	0.00533460	1.04	0.4197
SLOPE*MICROS(TREAT)	11	0.03454113	0.00314010	0.61	0.8182

Tests of Hypotheses using the Type III MS for BLOCK*SLOPE as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SLOPE	1	0.03229913	0.03229913	545.87	0.0272

Tests of Hypotheses using the Type III MS for BLOCK*TREAT as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	3	0.00764413	0.00254804	0.72	0.6050

Tests of Hypotheses using the Type III MS for BLOCK*SLOPE*TREAT as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SLOPE*TREAT	3	0.01166820	0.00388940	0.48	0.7165

General Linear Models Procedure
Least Squares Means

Standard Errors and Probabilities calculated using the Type III MS for BLOCK*TREAT as an Error term

TREAT	BAR6 LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0
Blade	0.17343514	0.00994485	0.0004
Control	0.17264009	0.01251366	0.0008
Disc	0.15756985	0.00863161	0.0004
Ripper	0.15998855	0.00860126	0.0003

General Linear Models Procedure
Least Squares Means

MICROS	TREAT	BAR6 LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0	LSMEAN Number
Thick-de	Blade	0.18846300	0.02072349	0.0001	1
Thick-su	Blade	0.20333417	0.02072349	0.0001	2
Thin-de	Blade	0.12850825	0.02072349	0.0001	3
deep	Control	0.17270683	0.02072349	0.0001	4
surface	Control	0.17257334	0.02184447	0.0001	5
Berm-dee	Disc	0.14528900	0.02072349	0.0001	6
Berm-sur	Disc	0.18127500	0.02072349	0.0001	7
Hinge-de	Disc	0.14659633	0.02072349	0.0001	8
Hinge-su	Disc	0.16483716	0.03127653	0.0001	9
Trench-d	Disc	0.14985175	0.02072349	0.0001	10
Berm-dee	Ripper	0.17402637	0.02109347	0.0001	11
Berm-sur	Ripper	0.15173050	0.02072349	0.0001	12
Hinge-de	Ripper	0.16907318	0.02279289	0.0001	13
Hinge-su	Ripper	0.13325108	0.02776262	0.0001	14
Trench-d	Ripper	0.17186163	0.02178558	0.0001	15

Available water-storage capacity (0.1 - 6bars).

General Linear Models Procedure
Class Level Information

Class	Levels	Values
LOCATION	3	Ante Fox Judy
BLOCK	2	1 2
SLOPE	2	lower upper
TREAT	4	Blade Control Disc Ripper
MICROS	10	deep surface Berm-dee Berm-sur Hinge-de Hinge-su Thick-de Thick-su Thin-de Trench-d

Number of observations in data set = 165

General Linear Models Procedure

Dependent Variable: AW16

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	56	0.53441996	0.00954321	3.42	0.0001
Error	108	0.30114903	0.00278842		
Corrected Total	164	0.83556899			

R-Square	C.V.	Root MSE	AW16 Mean
0.639588	31.59473	0.05280546	0.16713376

Source	DF	Type I SS	Mean Square	F Value	Pr > F
LOCATION	2	0.14888274	0.07444137	26.70	0.0001
BLOCK(LOCATION)	3	0.00671943	0.00223981	0.80	0.4947
TREAT	3	0.02580090	0.00860030	3.08	0.0304
LOCATION*TREAT	6	0.00851895	0.00141982	0.51	0.8003
BLOCK*TREAT(LOCATIO)	9	0.02748212	0.00305357	1.10	0.3726
MICROS(TREAT)	11	0.24509527	0.02228139	7.99	0.0001
LOCATI*MICROS(TREAT)	22	0.07192055	0.00326912	1.17	0.2878

Source	DF	Type III SS	Mean Square	F Value	Pr > F
LOCATION	2	0.11787474	0.05893737	21.14	0.0001
BLOCK(LOCATION)	3	0.00312633	0.00104211	0.37	0.7721
TREAT	3	0.02380634	0.00793545	2.85	0.0410
LOCATION*TREAT	6	0.00794844	0.00132474	0.48	0.8256
BLOCK*TREAT(LOCATIO)	9	0.02906415	0.00322935	1.16	0.3292
MICROS(TREAT)	11	0.23877317	0.02170665	7.78	0.0001
LOCATI*MICROS(TREAT)	22	0.07192055	0.00326912	1.17	0.2878

Tests of Hypotheses using the Type III MS for BLOCK(LOCATION) as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
LOCATION	2	0.11787474	0.05893737	56.56	0.0042

Tests of Hypotheses using the Type III MS for BLOCK*TREAT(LOCATIO) as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	3	0.02380634	0.00793545	2.46	0.1296
LOCATION*TREAT	6	0.00794844	0.00132474	0.41	0.8548

General Linear Models Procedure
Least Squares Means

Standard Errors and Probabilities calculated using the Type III MS for BLOCK*TREAT(LOCATIO) as an Error term

TREAT	AW16 LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0
Blade	0.17610853	0.00947123	0.0001
Control	0.14072846	0.01198026	0.0001
Disc	0.16188033	0.00838771	0.0001
Ripper	0.17958259	0.01093266	0.0001

General Linear Models Procedure
Least Squares Means

MICROS	TREAT	AW16 LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0	LSMEAN Number
Thick-de	Blade	0.19476325	0.01524362	0.0001	1
Thick-su	Blade	0.12590617	0.01524362	0.0001	2
Thin-de	Blade	0.20765617	0.01524362	0.0001	3
deep	Control	0.18715342	0.01524362	0.0001	4
surface	Control	0.09430350	0.01622808	0.0001	5
Berm-dee	Disc	0.19197175	0.01524362	0.0001	6
Berm-sur	Disc	0.09282458	0.01524362	0.0001	7
Hinge-de	Disc	0.19342967	0.01524362	0.0001	8
Hinge-su	Disc	0.12180815	0.02427383	0.0001	9
Trench-d	Disc	0.20936750	0.01524362	0.0001	10
Berm-dee	Ripper	0.20820435	0.01580140	0.0001	11
Berm-sur	Ripper	0.13879354	0.01580140	0.0001	12
Hinge-de	Ripper	0.19839103	0.02253600	0.0001	13
Hinge-su	Ripper	0.17218242	0.02489273	0.0001	14

Trench-d	Ripper	0.18034163	0.01878721	0.0001	15

Pr > |T| HO: LSMEAN(i)=LSMEAN(j)

i/j	1	2	3	4		6	7	8	9	10	11	12	13	14	15
1	.	0.0018	0.5510	0.7248	0.0001	0.8972	0.0001	0.9508	0.0123	0.4996	0.5417	0.0122	0.8942	0.4409	0.5524
2	0.0018	.	0.0002	0.0054	0.1587	0.0028	0.1278	0.0022	0.8866	0.0002	0.0003	0.5584	0.0089	0.1158	0.0265
3	0.5510	0.0002	.	0.3437	0.0001	0.4685	0.0001	0.5107	0.0034	0.9369	0.9801	0.0022	0.7341	0.2269	0.2614
4	0.7248	0.0054	0.3437	.	0.0001	0.8236	0.0001	0.7715	0.0246	0.3051	0.3398	0.0297	0.6804	0.6091	0.7788
5	0.0001	0.1587	0.0001	0.0001	.	0.0001	0.9472	0.0001	0.3483	0.0001	0.0001	0.0521	0.0003	0.0100	0.0008
6	0.8972	0.0028	0.4685	0.8236	0.0001	.	0.0001	0.9462	0.0160	0.4215	0.4613	0.0171	0.8139	0.4992	0.6317
7	0.0001	0.1278	0.0001	0.0001	0.9472	0.0001	.	0.0001	0.3142	0.0001	0.0001	0.0386	0.0002	0.0076	0.0005
8	0.9508	0.0022	0.5107	0.7715	0.0001	0.9462	0.0001	.	0.0140	0.4613	0.5024	0.0144	0.8556	0.4682	0.5896
9	0.0123	0.8866	0.0034	0.0246	0.3483	0.0160	0.3142	0.0140	.	0.0028	0.0035	0.5588	0.0227	0.1503	0.0592
10	0.4996	0.0002	0.9369	0.3051	0.0001	0.4215	0.0001	0.4613	0.0028	.	0.9578	0.0017	0.6874	0.2054	0.2329
11	0.5417	0.0003	0.9801	0.3398	0.0001	0.4613	0.0001	0.5024	0.0035	0.9578	.	0.0021	0.7149	0.2140	0.2428
12	0.0122	0.5584	0.0022	0.0297	0.0521	0.0171	0.0386	0.0144	0.5588	0.0017	0.0021	.	0.0282	0.2492	0.0827
13	0.8942	0.0089	0.7341	0.6804	0.0003	0.8139	0.0002	0.8556	0.0227	0.6874	0.7149	0.0282	.	0.4117	0.5094
14	0.4409	0.1158	0.2269	0.6091	0.0100	0.4992	0.0076	0.4682	0.1503	0.2054	0.2140	0.2492	0.4117	.	0.7809
15	0.5524	0.0265	0.2614	0.7788	0.0008	0.6317	0.0005	0.5896	0.0592	0.2329	0.2428	0.0827	0.5094	0.7809	.

NOTE: To ensure overall protection level, only probabilities associated with pre-planned comparisons should be used.

General Linear Models Procedure
Least Squares Means

Standard Errors and Probabilities calculated using the Type III MS for BLOCK*TREAT(LOCATIO) as an Error term

MICROS	TREAT	AW16 LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0	LSMEAN Number
Thick-de	Blade	0.19476325	0.01640465	0.0001	1
Thick-su	Blade	0.12590617	0.01640465	0.0001	2
Thin-de	Blade	0.20765617	0.01640465	0.0001	3
deep	Control	0.18715342	0.01640465	0.0001	4
surface	Control	0.09430350	0.01746408	0.0004	5
Berm-dee	Disc	0.19197175	0.01640465	0.0001	6
Berm-sur	Disc	0.09282458	0.01640465	0.0003	7
Hinge-de	Disc	0.19342967	0.01640465	0.0001	8
Hinge-su	Disc	0.12180815	0.02612264	0.0012	9
Trench-d	Disc	0.20936750	0.01640465	0.0001	10
Berm-dee	Ripper	0.20820435	0.01700491	0.0001	11
Berm-sur	Ripper	0.13879354	0.01700491	0.0001	12
Hinge-de	Ripper	0.19839103	0.02425244	0.0001	13
Hinge-su	Ripper	0.17218242	0.02678868	0.0001	14
Trench-d	Ripper	0.18034163	0.02021813	0.0001	15

Pr > |T| HO: LSMEAN(i)=LSMEAN(j)

i/j	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	.	0.0158	0.5919	0.7504	0.0023	0.9069	0.0017	0.9554	0.0422	0.5447	0.5834	0.0420	0.9041	0.4905	0.5931
2	0.0158	.	0.0065	0.0269	0.2198	0.0192	0.1876	0.0173	0.8972	0.0058	0.0069	0.5987	0.0352	0.1748	0.0661
3	0.5919	0.0065	.	0.3998	0.0011	0.5160	0.0008	0.5549	0.0213	0.9428	0.9820	0.0172	0.7589	0.2880	0.3215
4	0.7504	0.0269	0.3998	.	0.0038	0.8401	0.0028	0.7929	0.0632	0.3633	0.3962	0.0710	0.7100	0.6450	0.7995
5	0.0023	0.2198	0.0011	0.0038	.	0.0028	0.9521	0.0025	0.4042	0.0010	0.0012	0.1013	0.0069	0.0377	0.0105
6	0.9069	0.0192	0.5160	0.8401	0.0026	.	0.0021	0.9513	0.0490	0.4725	0.5094	0.0509	0.8314	0.5444	0.6657
7	0.0017	0.1876	0.0008	0.0028	0.9521	0.0021	.	0.0019	0.3720	0.0007	0.0009	0.0836	0.0057	0.0324	0.0084
8	0.9554	0.0173	0.5549	0.7929	0.0025	0.9513	0.0019	.	0.0453	0.5094	0.5473	0.0461	0.8692	0.5158	0.6273
9	0.0422	0.8972	0.0213	0.0632	0.4042	0.0490	0.3720	0.0453	.	0.0194	0.0217	0.5990	0.0602	0.2111	0.1102
10	0.5447	0.0058	0.9428	0.3633	0.0010	0.4725	0.0007	0.5094	0.0194	.	0.9618	0.0153	0.7164	0.2668	0.2938
11	0.5834	0.0069	0.9820	0.3962	0.0012	0.5094	0.0009	0.5473	0.0217	0.9618	.	0.0168	0.7414	0.2753	0.3035
12	0.0420	0.5987	0.0172	0.0710	0.1013	0.0509	0.0836	0.0461	0.5990	0.0153	0.0168	.	0.0687	0.3097	0.1381
13	0.9041	0.0352	0.7589	0.7100	0.0069	0.8314	0.0057	0.8692	0.0602	0.7164	0.7414	0.0687	.	0.4634	0.5537
14	0.4905	0.1748	0.2880	0.6450	0.0377	0.5444	0.0324	0.5158	0.2111	0.2668	0.2753	0.3097	0.4634		0.0014
15	0.5931	0.0661	0.3215	0.7995	0.0105	0.6657	0.0084	0.6273	0.1102	0.2938	0.3035	0.1381	0.5537	0.8014	.

NOTE: To ensure overall protection level, only probabilities associated with pre-planned comparisons should be used.

Means with the same letter are not significantly different.

MICROSITE	TREATMENT	MEAN	GROUPING			
Trench-d	Disc	0.21	A			
Berm-dee	Ripper	0.21	A			
Thin-de	Blading	0.21	A			
Hinge-de	Ripper	0.20	A			
Thick-de	Blading	0.19	A			
Hinge-de	Disc	0.19	A			
Berm-dee	Disc	0.19	A	B		
Deep	Control	0.19	A	B		
Trench-d	Ripper	0.18	A	B	C	
Hinge-su	Ripper	0.17	A	B	C	
Berm-sur	Ripper	0.14		B	C	D
Thick-su	Blading	0.13			C	D
Hinge-su	Disc	0.12			C	D
Surface	Control	0.09				D
Berm-sur	Disc	0.09				D

Appendix 1.9. Organic matter content of mineral layers for the K factor of the U.S.L.E.

General Linear Models Procedure
Class Level Information

Class	Levels	Values
LOCATION	3	Ante Fox Judy
BLOCK	2	I II
SLOPE	2	lower upper
TREAT	4	Blading Control Disc Ripper
MICROS	6	Berm Control Hinge Thick Thin Trench

Number of observations in data set = 112

General Linear Models Procedure

Dependent Variable: OM

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	77	95.36979726	1.23856860	1.75	0.0360
Error	34	24.06593642	0.70782166		
Corrected Total	111	119.43573368			

R-Square	C.V.	Root MSE	OM Mean
0.798503	32.32270	0.84132138	2.60288110

Source	DF	Type I SS	Mean Square	F Value	Pr > F
LOCATION	2	3.06996645	1.53498322	2.17	0.1299
BLOCK(LOCATION)	3	3.10481960	1.03493987	1.46	0.2422
SLOPE	1	4.36223129	4.36223129	6.16	0.0181
LOCATION*SLOPE	2	2.81241426	1.40620713	1.99	0.1528
BLOCK*SLOPE(LOCATIO)	3	3.75135446	1.25045149	1.77	0.1721
TREAT	3	16.36877249	5.45625750	7.71	0.0005
LOCATION*TREAT	6	7.47660573	1.24610096	1.76	0.1371
BLOCK*TREAT(LOCATIO)	9	15.69679434	1.74408826	2.46	0.0277
SLOPE*TREAT	3	2.09314889	0.69771630	0.99	0.4111
LOCATION*SLOPE*TREAT	6	3.21901677	0.53650280	0.76	0.6077
BLOC*SLOP*TREA(LOCA)	9	17.60496891	1.95610766	2.76	0.0153
MICROS(TREAT)	5	6.09245022	1.21849004	1.72	0.1563
SLOPE*MICROS(TREAT)	5	2.89780838	0.57956168	0.82	0.5448
LOCATI*MICROS(TREAT)	10	0.54766335	0.05476633	0.08	0.9999
LOCA*SLOP*MICR(TREA)	10	6.27178211	0.62717821	0.89	0.5552

Source	DF	Type III SS	Mean Square	F Value	Pr > F
LOCATION	2	2.50219484	1.25109742	1.77	0.1861
BLOCK(LOCATION)	3	3.98371495	1.32790498	1.88	0.1522
SLOPE	1	5.22362186	5.22362186	7.38	0.0103
LOCATION*SLOPE	2	3.70585671	1.85292835	2.62	0.0876
BLOCK*SLOPE(LOCATIO)	3	5.61708221	1.87236074	2.65	0.0648
TREAT	3	14.48583876	4.82861292	6.82	0.0010
LOCATION*TREAT	6	7.47452610	1.24575435	1.76	0.1372
BLOCK*TREAT(LOCATIO)	9	14.98188791	1.66465421	2.35	0.0347
SLOPE*TREAT	3	1.77786117	0.59262039	0.84	0.4829
LOCATION*SLOPE*TREAT	6	3.04577209	0.50762868	0.72	0.6384
BLOC*SLOP*TREA(LOCA)	9	17.60675048	1.95630561	2.76	0.0153
MICROS(TREAT)	5	5.82931704	1.16586341	1.65	0.1742
SLOPE*MICROS(TREAT)	5	2.94909371	0.58981874	0.83	0.5352
LOCATI*MICROS(TREAT)	10	0.65112271	0.06511227	0.09	0.9998
LOCA*SLOP*MICR(TREA)	10	6.27178211	0.62717821	0.89	0.5552

General Linear Models Procedure

Dependent Variable: OM

Tests of Hypotheses using the Type III MS for BLOCK(LOCATION) as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
LOCATION	2	2.50219484	1.25109742	0.94	0.4814

Tests of Hypotheses using the Type III MS for BLOCK*SLOPE(LOCATIO) as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SLOPE	1	5.22362186	5.22362186	2.79	0.1935
LOCATION*SLOPE	2	3.70585671	1.85292835	0.99	0.4677

Tests of Hypotheses using the Type III MS for BLOCK*TREAT(LOCATIO) as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	3	14.48583876	4.828e1292	2.90	0.0940
LOCATION*TREAT	6	7.47452610	1.24575435	0.75	0.6260

Tests of Hypotheses using the Type III MS for BLOC*SLOP*TREA(LOCA) as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SLOPE*TREAT	3	1.77786117	0.59262039	0.30	0.8227
LOCATION*SLOPE*TREAT	6	3.04577209	0.50762868	0.26	0.9427

General Linear Models Procedure
Least Squares Means

Standard Errors and Probabilities calculated using the Type III MS for BLOCK*TREAT(LOCATIO) as an Error term

TREAT	OM LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0
Blading	3.13767417	0.26336399	0.0001
Control	3.04504017	0.37245293	0.0001
Disc	2.55185883	0.21503580	0.0001
Ripper	2.23319787	0.20866969	0.0001

General Linear Models Procedure
Least Squares Means

MICROS	TREAT	OM LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0	LSMEAN Number
Thick	Blading	3.11849725	0.24286856	0.0001	1
Thin	Blading	3.15685108	0.24286856	0.0001	2
Control	Control	3.04504017	0.24286856	0.0001	3
Berm	Disc	3.03788950	0.24286856	0.0001	4
Hinge	Disc	2.44828217	0.24286856	0.0001	5
Trench	Disc	2.16940500	0.24286856	0.0001	6
Berm	Ripper	2.16987444	0.23660360	0.0001	7
Hinge	Ripper	2.06759780	0.23660360	0.0001	8
Trench	Ripper	2.46212138	0.23028680	0.0001	9

Appendix 1.10. Soil texture.

General Linear Models Procedure
Class Level Information

Class	Levels	Values
LOCATION	3	Ante Fox Judy
BLOCK	2	I II
SLOPE	2	lower upper
TREAT	4	Blading Control Disc Ripper
MICROS	6	Berm Control Hinge Thick Thin Trench

Number of observations in data set = 118

General Linear Models Procedure

Dependent Variable: CLAY

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	77	3078.58583788	39.98163426	2.55	0.0008
Error	40	627.55195873	15.68879897		
Corrected Total	117	3706.13779661			

R-Square	C.V.	Root MSE	CLAY Mean
0.830672	22.71185	3.96090886	17.43983051

Source	DF	Type I SS	Mean Square	F Value	Pr > F
LOCATION	2	324.62964116	162.31482058	10.35	0.0002
BLOCK(LOCATION)	3	90.93741411	30.31247137	1.93	0.1399
SLOPE	1	30.71462442	30.71462442	1.96	0.1695
LOCATION*SLOPE	2	92.18773175	46.09386587	2.94	0.0645
BLOCK*SLOPE(LOCATIO)	3	712.67214237	237.55738079	15.14	0.0001
TREAT	3	92.78739343	30.92913114	1.97	0.1337
LOCATION*TREAT	6	121.46095964	20.24349327	1.29	0.2837
BLOCK*TREAT(LOCATIO)	9	283.94806325	31.54978481	2.01	0.0634
SLOPE*TREAT	3	323.05053602	107.68351201	6.86	0.0008
LOCATION*SLOPE*TREAT	6	166.26089440	27.71014907	1.77	0.1309
BLOC*SLOP*TREA(LOCA)	9	108.14104487	12.01567165	0.77	0.6479
MICROS(TREAT)	5	179.38856734	35.87771347	2.29	0.0642
SLOPE*MICROS(TREAT)	5	170.31322601	34.06264520	2.17	0.0766
LOCATI*MICROS(TREAT)	10	149.95695513	14.99569551	0.96	0.4953
LOCA*SLOP*MICR(TREA)	10	232.13664398	23.21366440	1.48	0.1829

Source	DF	Type III SS	Mean Square	F Value	Pr > F
LOCATION	2	254.05333769	127.02666884	8.10	0.0011
BLOCK(LOCATION)	3	64.95586644	21.65195548	1.38	0.2628
SLOPE	1	70.17742232	70.17742232	4.47	0.0407
LOCATION*SLOPE	2	51.35454650	25.67727325	1.64	0.2074
BLOCK*SLOPE(LOCATIO)	3	479.66272320	159.88757440	10.19	0.0001
TREAT	3	100.88061328	33.62687109	2.14	0.1099
LOCATION*TREAT	6	118.54344527	19.75724088	1.26	0.2978
BLOCK*TREAT(LOCATIO)	9	282.54635471	31.39403941	2.00	0.0646
SLOPE*TREAT	3	314.13913003	104.71304334	6.67	0.0009
LOCATION*SLOPE*TREAT	6	162.24782486	27.04130414	1.72	0.1406
BLOC*SLOP*TREA(LOCA)	9	105.84943897	11.76104877	0.75	0.6619
MICROS(TREAT)	5	175.81084052	35.16216810	2.24	0.0688
SLOPE*MICROS(TREAT)	5	177.11583050	35.42316610	2.26	0.0671
LOCATI*MICROS(TREAT)	10	151.40348909	15.14034891	0.97	0.4878
LOCA*SLOP*MICR(TREA)	10	232.13664398	23.21366440	1.48	0.1829

General Linear Models Procedure

Dependent Variable: CLAY

Tests of Hypotheses using the Type III MS for BLOCK(LOCATION) as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
LOCATION	2	254.05333769	127.02666884	5.87	0.0919

Tests of Hypotheses using the Type III MS for BLOCK*SLOPE(LOCATIO) as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SLOPE	1	70.17742232	70.17742232	0.44	0.5550
LOCATION*SLOPE	2	51.35454650	25.67727325	0.16	0.8585

Tests of Hypotheses using the Type III MS for BLOCK*TREAT(LOCATIO) as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F

TREAT	3	100.88261328	33.62687109	1.07	0.4089
LOCATION*TREAT	6	118.54384527	19.75724088	0.63	0.7050

Tests of Hypotheses using the Type III MS for BLOC*SLOP*TREA(LOCA) as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SLOPE*TREAT	3	314.13913003	104.71304334	8.90	0.0047
LOCATION*SLOPE*TREAT	6	162.24782486	27.04130414	2.30	0.1260

General Linear Models Procedure

Dependent Variable: SILT

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	77	8259.12184618	107.26132268	2.36	0.0019
Error	40	1821.79687240	45.54492181		
Corrected Total	117	10080.91871857			

R-Square	C.V.	Root MSE	SILT Mean
0.819283	12.71073	6.74869779	53.09448220

Source	DF	Type I SS	Mean Square	F Value	Pr > F
LOCATION	2	2641.36013223	1320.68006612	29.00	0.0001
BLOCK(LOCATION)	3	216.58146549	72.19382163	1.59	0.2080
SLOPE	1	71.34902460	71.34902460	1.57	0.2180
LOCATION*SLOPE	2	33.26465018	16.63232509	0.37	0.6964
BLOCK*SLOPE(LOCATIO)	3	1659.21721549	553.07240516	12.14	0.0001
TREAT	3	22.12082142	7.37360714	0.16	0.9214
LOCATION*TREAT	6	154.88221603	25.81370267	0.57	0.7541
BLOCK*TREAT(LOCATIO)	9	526.86899421	58.54099936	1.29	0.2749
SLOPE*TREAT	3	259.34921595	86.44973865	1.90	0.1454
LOCATION*SLOPE*TREAT	6	94.31549826	15.71924971	0.35	0.9085
BLOC*SLOP*TREA(LOCA)	9	750.48552400	83.38728044	1.83	0.0924
MICROS(TREAT)	5	537.59421172	107.51884234	2.36	0.0573
SLOPE*MICROS(TREAT)	5	151.90537633	30.38107527	0.67	0.6506
LOCATI*MICROS(TREAT)	10	678.24235116	67.82423512	1.49	0.1793
LOCA*SLOP*MICR(TREA)	10	461.58514911	46.15851491	1.01	0.4494

Source	DF	Type III SS	Mean Square	F Value	Pr > F
LOCATION	2	2544.93833509	1272.46916754	27.94	0.0001
BLOCK(LOCATION)	3	101.18313665	33.72771222	0.74	0.5342
SLOPE	1	4.59209129	4.59209129	0.10	0.7525
LOCATION*SLOPE	2	43.34002210	21.67001105	0.48	0.6249
BLOCK*SLOPE(LOCATIO)	3	1277.50309239	425.83436413	9.35	0.0001
TREAT	3	31.19205721	10.39735240	0.23	0.8762
LOCATION*TREAT	6	166.48749170	27.74791528	0.61	0.7214
BLOCK*TREAT(LOCATIO)	9	558.45491065	62.05054563	1.36	0.2374
SLOPE*TREAT	3	273.95077064	91.31692355	2.00	0.1287
LOCATION*SLOPE*TREAT	6	82.73125036	13.78854173	0.30	0.9318
BLOC*SLOP*TREA(LOCA)	9	748.04380502	83.11597834	1.82	0.0936
MICROS(TREAT)	5	607.19968509	121.43993702	2.67	0.0359
SLOPE*MICROS(TREAT)	5	176.49820929	35.29964186	0.78	0.5735
LOCATI*MICROS(TREAT)	10	725.88847464	72.58884746	1.59	0.1439
LOCA*SLOP*MICR(TREA)	10	461.58514911	46.15851491	1.01	0.4494

General Linear Models Procedure

Dependent Variable: SILT

Tests of Hypotheses using the Type III MS for BLOCK(LOCATION) as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
LOCATION	2	2544.93833509	1272.46916754	37.73	0.0075

Tests of Hypotheses using the Type III MS for BLOCK*SLOPE(LOCATIO) as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SLOPE	1	4.59209129	4.59209129	0.01	0.9238
LOCATION*SLOPE	2	43.34002210	21.67001105	0.05	0.9512

Tests of Hypotheses using the Type III MS for BLOCK*TREAT(LOCATIO) as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	3	31.19205721	10.39735240	0.17	0.9156
LOCATION*TREAT	6	166.48749170	27.74791528	0.45	0.8302

Tests of Hypotheses using the Type III MS for BLOC*SLOP*TREA(LOCA) as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SLOPE*TREAT	3	273.95077064	91.31692355	1.10	0.3988
LOCATION*SLOPE*TREAT	6	82.73125036	13.78854173	0.17	0.9798

General Linear Models Procedure

Dependent Variable: SAND

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	77	6387.81998436	82.95870110	2.79	0.0003
Error	40	1189.75683811	29.74392095		
Corrected Total	117	7577.57682247			

R-Square	C.V.	Root MSE	SAND Mean
0.842990	18.50890	5.45379876	29.46566729

Source	DF	Type I SS	Mean Square	F Value	Pr > F
LOCATION	2	2762.93502272	1381.46751136	46.45	0.0001
BLOCK(LOCATION)	3	79.60866859	26.53622286	0.89	0.4535
SLOPE	1	195.68968158	195.68968158	6.58	0.0142
LOCATION*SLOPE	2	90.74894085	45.37447042	1.53	0.2299
BLOCK*SLOPE(LOCATIO)	3	309.22835313	103.07611771	3.47	0.0249
TREAT	3	61.61701844	20.53900615	0.69	0.5632
LOCATION*TREAT	6	110.98438146	18.49739691	0.62	0.7116
BLOCK*TREAT(LOCATIO)	9	361.40550428	40.15616714	1.35	0.2431
SLOPE*TREAT	3	65.31007119	21.77002373	0.73	0.5391
LOCATION*SLOPE*TREAT	6	187.09202511	31.18200419	1.05	0.4092
BLOC*SLOP*TREA(LOCA)	9	653.68973607	72.63219290	2.44	0.0255
MICROS(TREAT)	5	399.40101580	79.88020316	2.69	0.0348
SLOPE*MICROS(TREAT)	5	132.87968836	26.57593767	0.89	0.4947
LOCATI*MICROS(TREAT)	10	609.38975948	60.93897595	2.05	0.0533
LOCA*SLOP*MICR(TREA)	10	367.84011729	36.78401173	1.24	0.2983

Source	DF	Type III SS	Mean Square	F Value	Pr > F
LOCATION	2	2504.21890465	1252.10945232	42.10	0.0001
BLOCK(LOCATION)	3	43.63287583	14.54429194	0.49	0.6919
SLOPE	1	110.67277977	110.67277977	3.72	0.0609
LOCATION*SLOPE	2	52.21439243	26.10719621	0.88	0.4236
BLOCK*SLOPE(LOCATIO)	3	363.92998842	121.30999614	4.08	0.0128
TREAT	3	48.23050640	16.07683547	0.54	0.6573
LOCATION*TREAT	6	109.60458085	18.26743014	0.61	0.7176
BLOCK*TREAT(LOCATIO)	9	394.21532493	43.80170277	1.47	0.1915
SLOPE*TREAT	3	68.77539146	22.92513049	0.77	0.5172
LOCATION*SLOPE*TREAT	6	203.14961290	33.85826882	1.14	0.3582
BLOC*SLOP*TREA(LOCA)	9	647.52458646	71.94717627	2.42	0.0268
MICROS(TREAT)	5	481.36988023	96.27397605	3.24	0.0151
SLOPE*MICROS(TREAT)	5	185.99658501	37.19931700	1.25	0.3041
LOCATI*MICROS(TREAT)	10	636.81633306	63.68163331	2.14	0.0434
LOCA*SLOP*MICR(TREA)	10	367.84011729	36.78401173	1.24	0.2983

General Linear Models Procedure

Dependent Variable: SAND

Tests of Hypotheses using the Type III MS for BLOCK(LOCATION) as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
LOCATION	2	2504.21890465	1252.10945232	86.09	0.0022

Tests of Hypotheses using the Type III MS for BLOCK*SLOPE(LOCATIO) as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SLOPE	1	110.67277977	110.67277977	0.91	0.4100
LOCATION*SLOPE	2	52.21439243	26.10719621	0.22	0.8178

Tests of Hypotheses using the Type III MS for BLOCK*TREAT(LOCATIO) as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	3	48.23050640	16.07683547	0.37	0.7[illegible]
LOCATION*TREAT	6	109.60458085	18.26743014	0.42	0.8[illegible]

Tests of Hypotheses using the Type III MS for BLOC*SLOP*TREA(LOCA) as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SLOPE*TREAT	3	68.77539146	22.92513049	0.32	0.8118
LOCATION*SLOPE*TREAT	6	203.14961290	33.85826882	0.47	0.8144

General Linear Models Procedure
Multivariate Analysis of Variance

Characteristic Roots and Vectors of: E Inverse * H, where
H = Type III SS&CP Matrix for TREAT   E = Type III SS&CP Matrix for BLOCK*TREAT(LOCATIO)

Characteristic Root	Percent	Characteristic Vector V'EV=1 CLAY	SILT	SAND
0.3979173511	92.48	0.06959698	0.01711293	0.00000000
0.0323624322	7.52	0.01823875	0.04822973	0.00000000

Manova Test Criteria and F Approximations for the Hypothesis of no Overall TREAT Effect
H = Type III SS&CP Matrix for TREAT   E = Type III SS&CP Matrix for BLOCK*TREAT(LOCATIO)

S=2 M=0 N=3

Statistic	Value	F	Num DF	Den DF	Pr > F
Wilks' Lambda	0.69292513	0.5368	6	16	0.7727
Pillai's Trace	0.31599806	0.5629	6	18	0.7542
Hotelling-Lawley Trace	0.43027978	0.5020	6	14	0.7968
Roy's Greatest Root	0.39741735	1.1936	3	9	0.3661

NOTE: F Statistic for Roy's Greatest Root is an upper bound.
NOTE: F Statistic for Wilks' Lambda is exact.

General Linear Models Procedure
Least Squares Means

Standard Errors and Probabilities calculated using the Type III MS for BLOCK*TREAT(LOCATIO) as an Error term

TREAT	CLAY LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0
Blading	19.0523810	1.1300177	0.0001
Control	16.7083333	1.6174579	0.0001
Disc	17.4194444	0.9338397	0.0001
Ripper	16.5733889	0.8751898	0.0001

Standard Errors and Probabilities calculated using the Type III MS for BLOCK*TREAT(LOCATIO) as an Error term

TREAT	SILT LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0
Blading	[illegible].7901190	1.5886728	0.0001
Control	[illegible].2832417	2.2739566	0.0001
Disc	5[illegible]8450000	1.3128695	0.0001
Ripper	53.6752944	1.2304139	0.0001

Standard Errors and Probabilities calculated using the Type III MS for BLOCK*TREAT(LOCATIO) as an Error term

TREAT	SAND LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0
Blading	28.1575000	1.3347722	0.0001
Control	29.0084250	1.9105345	0.0001
Disc	29.7355556	1.1030476	0.0001
Ripper	29.7513167	1.0337700	0.0001

General Linear Models Procedure
Least Squares Means

MICROS	TREAT	SILT LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0	LSMEAN Number
Thick	Blading	52.1466667	1.9481812	0.0001	1
Thin	Blading	53.4335714	1.9012302	0.0001	2
Control	Control	54.2832417	1.9481812	0.0001	3
Berm	Disc	52.6658333	1.9481812	0.0001	4
Hinge	Disc	49.5608333	1.9481812	0.0001	5
Trench	Disc	56.3083333	1.9481812	0.0001	6
Berm	Ripper	56.8969852	1.7939808	0.0001	7
Hinge	Ripper	50.2409130	1.7703177	0.0001	8
Trench	Ripper	53.8879852	1.8461142	0.0001	9

Pr > |T| H0: LSMEAN(i)=LSMEAN(j)

i/j	1	2	3	4	5	6	7	8	9
1	.	0.6390	0.4426	0.8515	0.3536	0.1388	0.0804	0.4733	0.5202
2	0.6390	.	0.7566	0.7794	0.1626	0.2973	0.1927	0.2263	0.8647
3	0.4426	0.7566	.	0.5605	0.0943	0.4666	0.3296	0.1325	0.8837
4	0.8515	0.7794	0.5605	.	0.2665	0.1937	0.1180	0.3625	0.6513
5	0.3536	0.1626	0.0943	0.2665	.	0.0188	0.0085	0.7975	0.1148
6	0.1388	0.2973	0.4666	0.1937	0.0188	.	0.8252	0.0264	0.3726
7	0.0804	0.1927	0.3296	0.1180	0.0085	0.8252	.	0.0112	0.2469
8	0.4733	0.2263	0.1325	0.3625	0.7975	0.0264	0.0112	.	0.1590
9	0.5202	0.8647	0.8837	0.6513	0.1148	0.3726	0.2469	0.1590	.

General Linear Models Procedure
Least Squares Means

MICROS	TREAT	SAND LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0	LSMEAN Number
Thick	Blading	27.6700000	1.5743761	0.0001	1
Thin	Blading	28.6450000	1.5364337	0.0001	2
Control	Control	29.0084250	1.5743761	0.0001	3
Berm	Disc	29.5091667	1.5743761	0.0001	4
Hinge	Disc	31.0725000	1.5743761	0.0001	5
Trench	Disc	28.6250000	1.5743761	0.0001	6
Berm	Ripper	26.7115519	1.4497627	0.0001	7
Hinge	Ripper	34.1254574	1.4306399	0.0001	8
Trench	Ripper	28.4169407	1.4918931	0.0001	9

Pr > |T| H0: LSMEAN(i)=LSMEAN(j)

i/j	1	2	3	4	5	6	7	8	9
1	.	0.6600	0.5511	0.4137	0.1343	0.6703	0.6567	0.0042	0.7324
2	0.6600	.	0.8696	0.6965	0.2764	0.9928	0.3655	0.0127	0.9157
3	0.5511	0.8696	.	0.8232	0.3595	0.8641	0.2896	0.0209	0.7865
4	0.4137	0.6965	0.8232	.	0.4867	0.6934	0.1986	0.0360	0.6173

i/j	1	2	3	4	5	6	7	8	9
5	0.1343	0.2764	0.3595	0.4867	.	0.2782	0.0482	0.1590	0.2280
6	0.6703	0.9928	0.8641	0.6934	0.2782	.	0.3766	0.0135	0.9241
7	0.6567	0.3655	0.2896	0.1986	0.0482	0.3766	.	0.0007	0.4148
8	0.0042	0.0127	0.0209	0.0360	0.1590	0.0135	0.0007	.	0.0082
9	0.7324	0.9157	0.7865	0.6173	0.2280	0.9241	0.4148	0.0082	.

NOTE: To ensure overall protection level, only probabilities associated with pre-planned comparisons should be used.

General Linear Models Procedure
Least Squares Means

Standard Errors and Probabilities calculated using the Type III MS for BLOCK*TREAT(LOCATIO) as an Error term

MICROS	TREAT	SILT LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0	LSMEAN Number
Thick	Blading	52.1466667	2.2739566	0.0001	1
Thin	Blading	53.4335714	2.2191545	0.0001	2
Control	Control	54.2832417	2.2739566	0.0001	3
Berm	Disc	52.6658333	2.2739566	0.0001	4
Hinge	Disc	49.5608333	2.2739566	0.0001	5
Trench	Disc	56.3083333	2.2739566	0.0001	6
Berm	Ripper	56.8969852	2.0939708	0.0001	7
Hinge	Ripper	50.2409130	2.0663507	0.0001	8
Trench	Ripper	53.8879852	2.1548220	0.0001	9

Pr > |T| H0: LSMEAN(i)=LSMEAN(j)

i/j	1	2	3	4	5	6	7	8	9
1	.	0.6949	0.5231	0.8753	0.4421	0.2278	0.1587	0.5505	0.5919
2	0.6949	.	0.7952	0.8145	0.2539	0.3892	0.2856	0.3198	0.8864
3	0.5231	0.7952	.	0.6271	0.1760	0.5445	0.4197	0.2208	0.9024
4	0.8753	0.8145	0.6271	.	0.3595	0.2866	0.2043	0.4503	0.7055
5	0.4421	0.2539	0.1760	0.3595	.	0.0653	0.0417	0.8298	0.2005
6	0.2278	0.3892	0.5445	0.2866	0.0653	.	0.8532	0.0797	0.4596
7	0.1587	0.2856	0.4197	0.2043	0.0417	0.8532	.	0.0487	0.3404
8	0.5505	0.3198	0.2209	0.4503	0.8298	0.0797	0.0487	.	0.2500
9	0.5919	0.8864	0.9024	0.7055	0.2005	0.4596	0.3404	0.2500	.

General Linear Models Procedure
Least Squares Means

Standard Errors and Probabilities calculated using the Type III MS for BLOCK*TREAT(LOCATIO) as an Error term

MICROS	TREAT	SAND LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0	LSMEAN Number
Thick	Blading	27.6700000	1.9105345	0.0001	1
Thin	Blading	28.6450000	1.8644907	0.0001	2
Control	Control	29.0084250	1.9105345	0.0001	3
Berm	Disc	29.5091667	1.9105345	0.0001	4
Hinge	Disc	31.0725000	1.9105345	0.0001	5
Trench	Disc	28.6250000	1.9105345	0.0001	6
Berm	Ripper	26.7115519	1.7593138	0.0001	7
Hinge	Ripper	34.1254574	1.7361080	0.0001	8
Trench	Ripper	28.4169407	1.8104398	0.0001	9

Pr > |T| H0: LSMEAN(i)=LSMEAN(j)

i/j	1	2	3	4	5	6	7	8	9
1	.	0.7234	0.6322	0.5132	0.2396	0.7319	0.7206	0.0338	0.7830
2	0.7234	.	0.8947	0.7536	0.3869	0.9942	0.4700	0.0599	0.9320
3	0.6322	0.8947	.	0.8571	0.4645	0.8903	0.3995	0.0788	0.8272
4	0.5132	0.7536	0.8571	.	0.5770	0.7510	0.3094	0.1074	0.6879
5	0.2396	0.3869	0.4645	0.5770	.	0.3886	0.1274	0.2673	0.3394
6	0.7319	0.9942	0.8903	0.7510	0.3886	.	0.4800	0.0619	0.9387
7	0.7206	0.4700	0.3995	0.3094	0.1274	0.4800	.	0.0145	0.5142
8	0.0338	0.0599	0.0788	0.1074	0.2673	0.0619	0.0145	.	0.0477
9	0.7830	0.9320	0.8272	0.6879	0.3394	0.9387	0.5142	0.0477	.

NOTE: To ensure overall protection level, only probabilities associated with pre-planned comparisons should be used.

General Linear Models Procedure
Least Squares Means

SLOPE	MICROS	TREAT	CLAY LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0
lower	Thick	Blading	17.0666667	1.6170343	0.0001
lower	Thin	Blading	18.1428571	1.5381064	0.0001
upper	Thick	Blading	23.3000000	1.6170343	0.0001
upper	Thin	Blading	17.7000000	1.6170343	0.0001
lower	Control	Control	18.9500000	1.6170343	0.0001
upper	Control	Control	14.4666667	1.6170343	0.0001
lower	Berm	Disc	21.9500000	1.6170343	0.0001
lower	Hinge	Disc	20.0666667	1.6170343	0.0001
lower	Trench	Disc	18.4833333	1.6170343	0.0001
upper	Berm	Disc	13.7000000	1.6170343	0.0001

upper	Hinge	Disc	18.6666667	1.6170343	0.0001
upper	Trench	Disc	11.6500000	1.6170343	0.0001
lower	Berm	Ripper	15.6420000	1.5321583	0.0001
lower	Hinge	Ripper	16.7663333	1.4035013	0.0001
lower	Trench	Ripper	17.2086667	1.5321583	0.0001
upper	Berm	Ripper	17.1409259	1.4446445	0.0001
upper	Hinge	Ripper	14.5009259	1.5324743	0.0001
upper	Trench	Ripper	18.1814815	1.5324743	0.0001

SLOPE	MICROS	TREAT	SILT LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0
lower	Thick	Blading	54.8766667	2.7551443	0.0001
lower	Thin	Blading	54.7321429	2.6206650	0.0001
upper	Thick	Blading	49.4166667	2.7551443	0.0001
upper	Thin	Blading	52.1350000	2.7551443	0.0001
lower	Control	Control	51.6083333	2.7551443	0.0001
upper	Control	Control	56.9581500	2.7551443	0.0001
lower	Berm	Disc	51.1416667	2.7551443	0.0001
lower	Hinge	Disc	51.1416667	2.7551443	0.0001
lower	Trench	Disc	54.0583333	2.7551443	0.0001
upper	Berm	Disc	54.1900000	2.7551443	0.0001
upper	Hinge	Disc	47.9800000	2.7551443	0.0001
upper	Trench	Disc	58.5583333	2.7551443	0.0001
lower	Berm	Ripper	58.8372667	2.6105306	0.0001
lower	Hinge	Ripper	53.0175667	2.3913214	0.0001
lower	Trench	Ripper	53.7139333	2.6105306	0.0001
upper	Berm	Ripper	54.9567037	2.4614222	0.0001
upper	Hinge	Ripper	47.4642593	2.6110690	0.0001
upper	Trench	Ripper	54.0620370	2.6110690	0.0001

SLOPE	MICROS	TREAT	SAND LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0
lower	Thick	Blading	28.0566667	2.2265040	0.0001
lower	Thin	Blading	27.1250000	2.1178278	0.0001
upper	Thick	Blading	27.2833333	2.2265040	0.0001
upper	Thin	Blading	30.1650000	2.2265040	0.0001
lower	Control	Control	29.4416667	2.2265040	0.0001
upper	Control	Control	28.5751833	2.2265040	0.0001
lower	Berm	Disc	26.9083333	2.2265040	0.0001
lower	Hinge	Disc	28.7916667	2.2265040	0.0001
lower	Trench	Disc	27.4583333	2.2265040	0.0001
upper	Berm	Disc	32.1100000	2.2265040	0.0001
upper	Hinge	Disc	33.3533333	2.2265040	0.0001
upper	Trench	Disc	29.7916667	2.2265040	0.0001
lower	Berm	Ripper	25.5207333	2.1096379	0.0001
lower	Hinge	Ripper	30.2161000	1.9324892	0.0001
lower	Trench	Ripper	29.0774000	2.1096379	0.0001
upper	Berm	Ripper	27.9023704	1.9891395	0.0001
upper	Hinge	Ripper	38.0348148	2.1100730	0.0001
upper	Trench	Ripper	27.7564815	2.1100730	0.0001

Appendix 1.11. Potential soil erosion: K*C factor.

General Linear Models Procedure
Class Level Information

Class	Levels	Values
LOCATION	3	Ante Fox Judy
BLOCK	2	I II
SLOPE	2	lower upper
TREAT	4	Blading Control Disc Ripper

Number of observations in data set = 48

General Linear Models Procedure

Dependent Variable: KCW

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	38	0.10095096	0.00265660	2.40	0.0822
Error	9	0.00997560	0.00110840		
Corrected Total	47	0.11092655			

R-Square	C.V.	Root MSE	KCW Mean
0.910070	76.80763	0.03329263	0.04334548

Source	DF	Type I SS	Mean Square	F Value	Pr > F
LOCATION	2	0.01589021	0.00794510	7.17	0.0137
BLOCK(LOCATION)	3	0.00213718	0.00071239	0.64	0.6066
SLOPE	1	0.00005551	0.00005551	0.05	0.8279
LOCATION*SLOPE	2	0.00125497	0.00062749	0.57	0.5867
BLOCK*SLOPE(LOCATIO)	3	0.00520901	0.00173634	1.57	0.2642
TREAT	3	0.05045111	0.01681704	15.17	0.0007
LOCATION*TREAT	6	0.01998770	0.00333128	3.01	0.0674
BLOCK*TREAT(LOCATIO)	9	0.00398014	0.00044224	0.40	0.9064
SLOPE*TREAT	3	0.00135289	0.00045096	0.41	0.7519
LOCATION*SLOPE*TREAT	6	0.00063225	0.00010537	0.10	0.9952

Source	DF	Type III SS	Mean Square	F Value	Pr > F
LOCATION	2	0.01589021	0.00794510	7.17	0.0137
BLOCK(LOCATION)	3	0.00213718	0.00071239	0.64	0.6066
SLOPE	1	0.00005551	0.00005551	0.05	0.8279
LOCATION*SLOPE	2	0.00125497	0.00062749	0.57	0.5867
BLOCK*SLOPE(LOCATIO)	3	0.00520901	0.00173634	1.57	0.2642
TREAT	3	0.05045111	0.01681704	15.17	0.0007
LOCATION*TREAT	6	0.01998770	0.00333128	3.01	0.0674
BLOCK*TREAT(LOCATIO)	9	0.00398014	0.00044224	0.40	0.9064
SLOPE*TREAT	3	0.00135289	0.00045096	0.41	0.7519
LOCATION*SLOPE*TREAT	6	0.00063225	0.00010537	0.10	0.9952

Tests of Hypotheses using the Type III MS for BLOCK(LOCATION) as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
LOCATION	2	0.01589021	0.00794510	11.15	0.0408

Tests of Hypotheses using the Type III MS for BLOCK*SLOPE(LOCATIO) as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SLOPE	1	0.00005551	0.00005551	0.03	0.8695
LOCATION*SLOPE	2	0.00125497	0.00062749	0.36	0.7234

Tests of Hypotheses using the Type III MS for BLOCK*TREAT(LOCATIO) as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	3	0.05045111	0.01681704	38.03	0.0001
LOCATION*TREAT	6	0.01998770	0.00333128	7.53	0.0041

General Linear Models Procedure
Least Squares Means

Standard Errors and Probabilities calculated using the Type III MS for BLOCK*SLOPE(LOCATIO) as an Error term

SLOPE	KCW LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0

lower	0.04227006	0.00850572	0.0157
upper	0.04442087	0.00850572	0.0137

General Linear Models Procedure
Least Squares Means

Standard Errors and Probabilities calculated using the Type III MS for BLOCK*TREAT(LOCATIO) as an Error term

TREAT	KCW LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0
Blading	0.09024125	0.00607068	0.0001
Control	0.00132250	0.00607068	0.8324
Disc	0.03024975	0.00607068	0.0008
Ripper	0.05156842	0.00607068	0.0001

General Linear Models Procedure
Least Squares Means

SLOPE	TREAT	KCW LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0
lower	Blading	0.09741517	0.01359166	0.0001
lower	Control	0.00122500	0.01359166	0.9302
lower	Disc	0.02379817	0.01359166	0.1139
lower	Ripper	0.04664200	0.01359166	0.0075
upper	Blading	0.08306733	0.01359166	0.0002
upper	Control	0.00142000	0.01359166	0.9191
upper	Disc	0.03670133	0.01359166	0.0244
upper	Ripper	0.05649463	0.01359166	0.0025

General Linear Models Procedure
Least Squares Means

Standard Errors and Probabilities calculated using the Type III MS for BLOCK(LOCATION) as an Error term

LOCATION	KCW LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0	Pr > |T| H0: LSMEAN(i)=LSMEAN(j) i/j	1	2	3
Ante	0.05784069	0.00667267	0.0032	1	.	0.7474	0.0238
Fox	0.05450944	0.00667267	0.0036	2	0.7474	.	0.0299
Judy	0.01768631	0.00667267	0.0770	3	0.0238	0.0299	.

NOTE: To ensure overall protection level, only probabilities associated with pre-planned comparisons should be used.

Means with the same letter are not significantly different.

LOCATION	MEAN	GROUPING	
Ante	0.058	A	
Fox	0.055	A	
Judy	0.018		B

Appendix 1.12. Bulk density of selected microsites.

General Linear Models Procedure
Class Level Information

Class	Levels	Values
LOCATION	3	A B C
BLOCK	2	1 2
SLOPE	2	lower upper
TREAT	4	Blade Control Disc Ripper
MICROS	6	Control Exposed Screef Shaded Thick Thin

Number of observations in data set = 96

General Linear Models Procedure

Dependent Variable: AVEDENS

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	71	13.32990850	0.18774519	9.18	0.0001
Error	24	0.49093127	0.02045547		
Corrected Total	95	13.82083977			

R-Square	C.V.	Root MSE	AVEDENS Mean
0.964479	18.65256	0.14302262	0.76677226

Source	DF	Type I SS	Mean Square	F Value	Pr > F
LOCATION	2	0.97352408	0.48676204	23.80	0.0001
BLOCK(LOCATION)	3	0.20149450	0.06716483	3.28	0.0381
SLOPE	1	0.01184647	0.01184647	0.58	0.4541
LOCATION*SLOPE	2	0.11042510	0.05521255	2.70	0.0876
BLOCK*SLOPE(LOCATIO)	3	0.04063418	0.01354473	0.66	0.5834
TREAT	3	6.06873211	2.02291070	98.89	0.0001
LOCATION*TREAT	6	0.71330793	0.11888465	5.81	0.0007
BLOCK*TREAT(LOCATIO)	9	0.50473331	0.05608148	2.74	0.0234
SLOPE*TREAT	3	0.11667235	0.03889078	1.90	0.1564
LOCATION*SLOPE*TREAT	6	0.33088198	0.05514700	2.70	0.0382
BLOC*SLOP*TREA(LOCA)	9	0.29773397	0.03308155	1.62	0.1665
MICROS(TREAT)	4	3.15599137	0.78899784	38.57	0.0001
SLOPE*MICROS(TREAT)	4	0.12409945	0.03102486	1.52	0.2289
LOCATI*MICROS(TREAT)	8	0.46452899	0.05806612	2.84	0.0227
LOCA*SLOP*MICR(TREA)	8	0.21530271	0.02691284	1.32	0.2829

Source	DF	Type III SS	Mean Square	F Value	Pr > F
LOCATION	2	0.97352408	0.48676204	23.80	0.0001
BLOCK(LOCATION)	3	0.20149450	0.06716483	3.28	0.0381
SLOPE	1	0.01184647	0.01184647	0.58	0.4541
LOCATION*SLOPE	2	0.11042510	0.05521255	2.70	0.0876
BLOCK*SLOPE(LOCATIO)	3	0.04063418	0.01354473	0.66	0.5834
TREAT	3	6.06873211	2.02291070	98.89	0.0001
LOCATION*TREAT	6	0.71330793	0.11888465	5.81	0.0007
BLOCK*TREAT(LOCATIO)	9	0.50473331	0.05608148	2.74	0.0234
SLOPE*TREAT	3	0.11667235	0.03889078	1.90	0.1564
LOCATION*SLOPE*TREAT	6	0.33088198	0.05514700	2.70	0.0382
BLOC*SLOP*TREA(LOCA)	9	0.29773397	0.03308155	1.62	0.1665
MICROS(TREAT)	4	3.15599137	0.78899784	38.57	0.0001
SLOPE*MICROS(TREAT)	4	0.12409945	0.03102486	1.52	0.2289
LOCATI*MICROS(TREAT)	8	0.46452899	0.05806612	2.84	0.0227
LOCA*SLOP*MICR(TREA)	8	0.21530271	0.02691284	1.32	0.2829

General Linear Models Procedure

Dependent Variable: AVEDENS

Tests of Hypotheses using the Type III MS for BLOCK(LOCATION) as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
LOCATION	2	0.97352408	0.48676204	7.25	0.0710

Tests of Hypotheses using the Type III MS for BLOCK*SLOPE(LOCATIO) as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SLOPE	1	0.01184647	0.01184647	0.87	0.4167
LOCATION*SLOPE	2	0.11042510	0.05521255	4.08	0.1395

Tests of Hypotheses using the Type III MS for BLOCK*TREAT(LOCATIO) as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F

TREAT	3	6.06873211	2.02291070	36.07	0.0001
LOCATION*TREAT	6	0.71330793	0.11888465	2.12	0.1496

Tests of Hypotheses using the Type III MS for BLOC*SLOP*TREA(LOCA) as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SLOPE*TREAT	3	0.11667235	0.03889078	1.18	0.3721
LOCATION*SLOPE*TREAT	6	0.33088198	0.05514700	1.67	0.2354

General Linear Models Procedure
Least Squares Means

Standard Errors and Probabilities calculated using the Type III MS for BLOCK*SLOPE(LOCATIO) as an Error term

SLOPE	AVEDENS LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0
lower	0.75566367	0.01679827	0.0001
upper	0.77788085	0.01679827	0.0001

General Linear Models Procedure
Least Squares Means

Standard Errors and Probabilities calculated using the Type III MS for BLOCK*TREAT(LOCATIO) as an Error term

TREAT	AVEDENS LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0
Blade	0.81021956	0.04833972	0.0001
Control	0.34378332	0.04833972	0.0001
Disc	0.95263217	0.04833972	0.0001
Ripper	0.96045401	0.04833972	0.0001

General Linear Models Procedure
Least Squares Means

MICROS	TREAT	AVEDENS LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0	Pr > |T| H0: LSMEAN(i)=LSMEAN(j) i/j	1	2	3	4	5	6	7	8
Thick	Blade	0.46559111	0.04128707	0.0001	1	.	0.0001	0.0008	0.7505	0.0001	0.0001	0.0001	0.0001
Thin	Blade	1.15484800	0.04128707	0.0001	2	0.0001	.	0.0001	0.0001	0.0005	0.0077	0.0107	0.0007
Control	Control	0.24075683	0.04128707	0.0001	3	0.0008	0.0001	.	0.0017	0.0001	0.0001	0.0001	0.0001
Screef	Control	0.44680981	0.04128707	0.0001	4	0.7505	0.0001	0.0017	.	0.0001	0.0001	0.0001	0.0001
Exposed	Disc	0.92026108	0.04128707	0.0001	5	0.0001	0.0005	0.0001	0.0001	.	0.2785	0.2240	0.8988
Shaded	Disc	0.98500325	0.04128707	0.0001	6	0.0001	0.0077	0.0001	0.0001	0.2785	.	0.8903	0.3367
Exposed	Ripper	0.99314242	0.04128707	0.0001	7	0.0001	0.0107	0.0001	0.0001	0.2240	0.8903	.	0.2739
Shaded	Ripper	0.92776561	0.04128707	0.0001	8	0.0001	0.0007	0.0001	0.0001	0.8988	0.3367	0.2739	.

NOTE: To ensure overall protection level, only probabilities associated with pre-planned comparisons should be used.

General Linear Models Procedure
Least Squares Means

Standard Errors and Probabilities calculated using the Type III MS for BLOCK*TREAT(LOCATIO) as an Error term

MICROS	TREAT	AVEDENS LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0	Pr > |T| H0: LSMEAN(i)=LSMEAN(j) i/j	1	2	3	4	5	6	7	8
Thick	Blade	0.46559111	0.06836268	0.0001	1	.	0.0001	0.0451	0.8503	0.0011	0.0004	0.0004	0.0010
Thin	Blade	1.15484800	0.06836268	0.0001	2	0.0001	.	0.0001	0.0001	0.0382	0.1128	0.1287	0.0434
Control	Control	0.24075683	0.06836268	0.0001	3	0.0451	0.0001	.	0.0619	0.0001	0.0001	0.0001	0.0001
Screef	Control	0.44680981	0.06836268	0.0001	4	0.8503	0.0001	0.0619	.	0.0009	0.0003	0.0003	0.0008
Exposed	Disc	0.92026108	0.06836268	0.0001	5	0.0011	0.0382	0.0001	0.0009	.	0.5199	0.4702	0.9398
Shaded	Disc	0.98500325	0.06836268	0.0001	6	0.0004	0.1128	0.0001	0.0003	0.5199	.	0.9348	0.5684
Exposed	Ripper	0.99314242	0.06836268	0.0001	7	0.0004	0.1287	0.0001	0.0003	0.4702	0.9348	.	0.5159
Shaded	Ripper	0.92776561	0.06836268	0.0001	8	0.0010	0.0434	0.0001	0.0008	0.9398	0.5684	0.5159	.

NOTE: To ensure overall protection level, only probabilities associated with pre-planned comparisons should be used.

Means with the same letter are not significantly different.

MICROSITE	TREATMENT	MEAN	GROUPING	
Thin	Blading	1.15	A	
Exposed	Ripper	0.99	A	B
Shaded	Disc	0.99	A	B
Shaded	Ripper	0.93		B
Exposed	Disc	0.92		B
Thick	Blading	0.47	C	
Screef	Control	0.45	C	
Control	Control	0.24		

Appendix 1.13. Soil moisture content of selected microsites.

General Linear Models Procedure
Class Level Information

Class	Levels	Values
LOCATION	3	A B C
BLOCK	2	1 2
SLOPE	2	lower upper
TREAT	4	Blade Control Disc Ripper
MICROS	6	Control Exposed Screef Shaded Thick Thin

Number of observations in data set = 96

General Linear Models Procedure

Dependent Variable: AVEWATER

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	71	10007.05272085	140.94440452	3.69	0.0004
Error	24	917.64225451	38.23509394		
Corrected Total	95	10924.69497536			

R-Square	C.V.	Root MSE	AVEWATER Mean
0.916003	21.25418	6.18345324	29.09287958

Source	DF	Type I SS	Mean Square	F Value	Pr > F
LOCATION	2	2151.69090119	1075.84545059	26.14	0.0001
BLOCK(LOCATION)	3	417.01484022	139.00494674	3.64	0.0271
SLOPE	1	372.38970997	372.38970997	9.74	0.0046
LOCATION*SLOPE	2	761.39249614	380.69624807	9.96	0.0007
BLOCK*SLOPE(LOCATIO)	3	646.01040000	215.33680000	5.63	0.0045
TREAT	3	1249.78023689	416.59341230	10.90	0.0001
LOCATION*TREAT	6	996.33731091	166.05621848	4.34	0.0042
BLOCK*TREAT(LOCATIO)	9	320.80942500	35.64549167	0.93	0.5158
SLOPE*TREAT	3	36.46346955	12.15448985	0.32	0.8123
LOCATION*SLOPE*TREAT	6	245.35140654	40.89190109	1.07	0.4078
BLOC*SLOP*TREA(LOCA)	9	306.34978966	34.03886552	0.89	0.5479
MICROS(TREAT)	4	1079.97591661	269.99397915	7.06	0.0007
SLOPE*MICROS(TREAT)	4	146.25370363	36.56342591	0.96	0.4492
LOCATI*MICROS(TREAT)	8	930.56261475	116.32032684	3.04	0.0164
LOCA*SLOP*MICR(TREA)	8	346.67049979	43.33381247	1.13	0.3774

Source	DF	Type III SS	Mean Square	F Value	Pr > F
LOCATION	2	2151.69090119	1075.84545059	28.14	0.0001
BLOCK(LOCATION)	3	417.01484022	139.00494674	3.64	0.0271
SLOPE	1	372.38970997	372.38970997	9.74	0.0046
LOCATION*SLOPE	2	761.39249614	380.69624807	9.96	0.0007
BLOCK*SLOPE(LOCATIO)	3	646.01040000	215.33680000	5.63	0.0045
TREAT	3	1249.78023689	416.59341230	10.90	0.0001
LOCATION*TREAT	6	996.33731091	166.05621848	4.34	0.0042
BLOCK*TREAT(LOCATIO)	9	320.80942500	35.64549167	0.93	0.5158
SLOPE*TREAT	3	36.46346955	12.15448985	0.32	0.8123
LOCATION*SLOPE*TREAT	6	245.35140654	40.89190109	1.07	0.4078
BLOC*SLOP*TREA(LOCA)	9	306.34978966	34.03886552	0.89	0.5479
MICROS(TREAT)	4	1079.97591661	269.99397915	7.06	0.0007
SLOPE*MICROS(TREAT)	4	146.25370363	36.56342591	0.96	0.4492
LOCATI*MICROS(TREAT)	8	930.56261475	116.32032684	3.04	0.0164
LOCA*SLOP*MICR(TREA)	8	346.67049979	43.33381247	1.13	0.3774

General Linear Models Procedure

Dependent Variable: AVEWATER

Tests of Hypotheses using the Type III MS for BLOCK(LOCATION) as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
LOCATION	2	2151.69090119	1075.84545059	7.74	0.0654

Tests of Hypotheses using the Type III MS for BLOCK*SLOPE(LOCATIO) as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SLOPE	1	372.38970997	372.38970997	1.73	0.2800
LOCATION*SLOPE	2	761.39249614	380.69624807	1.77	0.3110

Tests of Hypotheses using the Type III MS for BLOCK*TREAT(LOCATIO) as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	3	1249.78023689	416.59341230	11.69	0.0019
LOCATION*TREAT	6	996.33731091	166.05621848	4.66	0.0199

Tests of Hypotheses using the Type III MS for BLOC*SLOP*TREA(LOCA) as an error term

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SLOPE*TREAT	3	36.46346955	12.15448985	0.36	0.7854
LOCATION*SLOPE*TREAT	6	245.35140654	40.89190109	1.20	0.3860

General Linear Models Procedure
Least Squares Means

Standard Errors and Probabilities calculated using the Type III MS for BLOCK*SLOPE(LOCATIO) as an Error term

SLOPE	AVEWATER LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0
lower	31.0624124	2.1180612	0.0007
upper	27.1233468	2.1180612	0.0010

General Linear Models Procedure
Least Squares Means

Standard Errors and Probabilities calculated using the Type III MS for BLOCK*TREAT(LOCATIO) as an Error term

TREAT	AVEWATER LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0
Blade	23.8235248	1.2186996	0.0001
Control	32.1641372	1.2186996	0.0001
Disc	32.6878886	1.2186996	0.0001
Ripper	27.6959677	1.2186996	0.0001

General Linear Models Procedure
Least Squares Means

MICROS	TREAT	AVEWATER LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0	Pr > |T| H0: LSMEAN(i)=LSMEAN(j) i/j	1	2	3	4	5	6	7	8
Thick	Blade	27.7617339	1.7850092	0.0001	1	.	0.0047	0.7631	0.0040	0.4000	0.0056	0.2451	0.2657
Thin	Blade	19.8853156	1.7850092	0.0001	2	0.0047	.	0.0022	0.0001	0.0006	0.0001	0.0657	0.0003
Control	Control	28.5312742	1.7850092	0.0001	3	0.7631	0.0022	.	0.0083	0.5860	0.0114	0.1476	0.4121
Screef	Control	35.7970003	1.7850092	0.0001	4	0.0040	0.0001	0.0083	.	0.0288	0.8921	0.0002	0.0521
Exposed	Disc	29.9248025	1.7850092	0.0001	5	0.4000	0.0006	0.5860	0.0288	.	0.0386	0.0516	0.7799
Shaded	Disc	35.4509747	1.7850092	0.0001	6	0.0056	0.0001	0.0114	0.8921	0.0386	.	0.0003	0.0686
Exposed	Ripper	24.7536614	1.7850092	0.0001	7	0.2451	0.0657	0.1476	0.0002	0.0516	0.0003	.	0.0285
Shaded	Ripper	30.6382740	1.7850092	0.0001	8	0.2657	0.0003	0.4121	0.0521	0.7799	0.0686	0.0285	.

NOTE: To ensure overall protection level, only probabilities associated with pre-planned comparisons should be used.

General Linear Models Procedure
Least Squares Means

Standard Errors and Probabilities calculated using the Type III MS for BLOCK*TREAT(LOCATIO) as an Error term

MICROS	TREAT	AVEWATER LSMEAN	Std Err LSMEAN	Pr > |T| H0:LSMEAN=0	Pr > |T| H0: LSMEAN(i)=LSMEAN(j) i/j	1	2	3	4	5	6	7	8
Thick	Blade	27.7617339	1.7235016	0.0001	1	.	0.0103	0.7594	0.0093	0.3979	0.0116	0.2484	0.2682
Thin	Blade	19.8853156	1.7235016	0.0001	2	0.0103	.	0.0062	0.0001	0.0026	0.0001	0.0769	0.0017
Control	Control	28.5312742	1.7235016	0.0001	3	0.7594	0.0062	.	0.0154	0.5815	0.0194	0.1556	0.4098
Screef	Control	35.7970003	1.7235016	0.0001	4	0.0093	0.0001	0.0154	.	0.0393	0.8902	0.0014	0.0634
Exposed	Disc	29.9248025	1.7235016	0.0001	5	0.3979	0.0026	0.5815	0.0393	.	0.0496	0.0629	0.7764
Shaded	Disc	35.4509747	1.7235016	0.0001	6	0.0116	0.0001	0.0194	0.8902	0.0496	.	0.0017	0.0798
Exposed	Ripper	24.7536614	1.7235016	0.0001	7	0.2484	0.0769	0.1556	0.0014	0.0629	0.0017	.	0.0390
Shaded	Ripper	30.6382740	1.7235016	0.0001	8	0.2682	0.0017	0.4098	0.0634	0.7764	0.0798	0.0390	.

NOTE: To ensure overall protection level, only probabilities associated with pre-planned comparisons should be used.

Means with the same letter are not significantly different.

MICROSITE	TREATMENT	MEAN	GROUPING		
Screef	Control	35.80	A		
Shaded	Disc	35.45	A		
Shaded	Ripper	30.64	A	B	
Exposed	Disc	29.92		B	C
Control	Control	28.53		B	C
Thick	Blading	27.76		B	C
Exposed	Ripper	24.75	D		C
Thin	Blading	19.89	D		