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Associations among glacial landforms, soils, and vegetation in northeastern Lower Michigan

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ASSOCIATIONS AMONG GLACIAL LANDFORMS, SOILS, AND VEGETATION IN NORTHEASTERN LOWER MICHIGAN

by

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ABSTRACT

ASSOCIATIONS AMONG GLACIAL LANDFORMS, SOILS, AND VEGETATION IN NORTHEASTERN LOWER MICHIGAN

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Relationships among ecosystem components were studied on 24 upland forested sites in northeastern Lower Michigan. The objectives of this study were to investigate relationships among ecosystem components and discuss approaches to ecosystem classification of the area.

Sites were grouped based on depositional environment as indicated by soil morphology. Principal component analyses (PCA) of soils data did not contradict site groupings based on depositional environment, although sites formed in loamy textured till deposited by two different glacial substages were not consistently separated. PCA produced similar site groupings from laboratory or field data.

Individual comparisons of variables among depositional environment groups found significant differences among sites formed in outwash, outwash with till inclusions, and loamy tills. The tills of different deposition were different only with respect to a few variables.

First-dimensional site ordinations obtained by reciprocal averaging of ground flora data, overstory basal area, and PCA of soils data were all significantly correlated with each other. Differences in overstory

composition occurred on till sites of different glacial depositions, on soils which were texturally and chemically similar. Nitrogen mineralized during anaerobic incubation was correlated with the ordination of ground flora, and was significantly different for sites of different overstory composition. Composition differences and nitrogen mineralization may be related to historic patterns of disturbance.

Weights of Oe forest floor layers were similar among ecosystems. Production and nutrient quality of autumn litterfall was similar to that reported for other studies in the region. Return of potassium, phosphorous, and magnesium in autumn litterfall was associated with litter production, and was greatest for mixed oak-northern hardwood sites. Return of nitrogen and calcium was associated with species composition.

Glacial landforms mapped in the area do not provide divisions of sufficient detail to serve as a basis for ecosystem mapping. Separations based on localized depositional environments are required. Ground flora are effective in making these separations, and also distinguish depositionally similar sites of different successional potential. Six ecosystem groups were identified among the study sites, with divisions based on depositional environment, flora, and soil properties important in land management.

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CHAPTER I

INTRODUCTION

Land classification systems have been developed based on various features of the earth's surface, including soils, vegetation, landforms, and geology, either individually or in combination. Historically, controversy has existed regarding the relative merit of various systems. A discussion of the beliefs inherent in these classification systems, and their shortcomings, leads to a description of ecological classification. Ecological classification attempts to incorporate the best aspects of other classification systems, and avoid their pitfalls.

Soil Survey

Land mapping in the U.S. has been the primary responsibility of the Soil Conservation Service throughout this century. The current system of classification, documented in Soil Taxonomy (Soil Survey Staff 1975), is based primarily on soil morphology in the belief that morphological features express information regarding soil development, including biotic and abiotic factors over time. The system was intended to enable a mapper to describe and classify soils without knowledge of the processes which formed them. The basis for the system has been criticized primarily because a range of soil forming factors may be expressed similarly in soil morphology.

Forest managers became dissatisfied some years ago with land classification by Soil Survey methods because it lacked applicability to management concerns. The sentiments were expressed in 1963 by Rennie, who wrote that for "adult forest growth the use of soil criteria satisfactory for agricultural advisory work has proved only partly successful". Similarly, Jones (1969) wrote that the "utility of soil maps in ... wildland management depends on whether the units are sufficiently uniform ecologically. This uniformity of units depends on the degree of coincidence of classification criteria with characteristics of greatest relevance to problems of soil management". Carmean (1975) felt that the modal concept of soils introduced bias, because it did not express the variability of mapped units. Much of the variation in tree growth within mapped units was attributed to soil and topographic variations which were not well described in soil unit definitions. Additionally, soil taxonomic features used to describe map units may not be those features associated with tree growth. Grigal (1984) expressed the sentiment strongly, stating that there was "widespread and deep dissatisfaction with soil surveys in many forested areas", because tree growth is affected by site history, landform, and climate. These features are commonly recognized in the field but inadequately communicated in Soil Survey reports.

Another shortcoming of traditional soil surveys in forest management was its reliance on Site Index (SI) as a measure of site productivity. One commonly reported objection was to the use of regionwide SI data, which were not applicable to most sites on a scale useful to land management (Carmean 1968). Also, there were problems in finding trees suitable for determining SI, including stand density influences on height growth, the effect of genetic factors, suppression, damage from disease or weather, root sprouting, and the inability to measure plantations, uneven aged stands, and deforested areas (Jones 1969, Carmean 1975). Additionally, SI does not provide information on forest management issues other than production, such as wood quality, regenerative capability, species composition and diversity, or wildlife habitat (Jones 1969, Carmean 1975). Because of the wide variation of SI within soil units and similar averages between units, productivity interpretations based only on SI were not considered meaningful by forest managers (Carmean 1975).

Habitat Types

Land classifications based solely on plant community designations are known as habitat types. A rationale for the use of vegetative indicators is that potential plant communities are the expression of an integration of climate, physiography, and soils, so that vegetative species or species groups occupy discrete localities with characteristics which are dependent on the availability of resources (Cajander 1926, Rowe 1956, Pfister and Arno 1980).

Classifications of forested lands based on vegetation were first developed by Cajander (1926) in Finland, and were subsequently used in Europe, Canada, and in the northwestern U.S. Classifications based on vegetation were more successful in northern regions, where plant communities were organized simply, with relatively few species and associations. In areas further south, the complexity of understory flora made classification more difficult (Carmean 1975).

Vegetative gradients in various areas have been related to gradients of topography, soil moisture, soil texture, nutrient supply, SI, basal area (BA), and abundance of regeneration (Rowe 1956, Pluth and Arneman 1963, Waring and Major 1964). In some cases, herbaceous vegetation is associated with different soil characteristics than overstory vegetation (Dunn and Stearns 1987). Other studies have found poor relationships of vegetation with soil and physiographic site components, and it appears that vegetation is not a useful indicator of environmental conditions in all cases (Grigal and Arneman 1970). Barnes (1984) has noted that areas of similar vegetation are not necessarily the same ecosystem type, and Pregitzer and Ramm (1984) have mentioned geographic specificity of species ranges as a difficulty with the use of indicator plants. The variation in patterns of vegetation makes its use valuable only when information about its relationship to other environmental components is known.

Multifactor, or Ecological, Classification

Carmean (1975) suggested that land classification "should not continue segregated along strict mensurational, soil, and ecological lines, but instead should have integrated and coordinated methods for landscape inventories and site quality classifications". Ecological, or integrated multifactor classification, is such a system. The basic ecosystem unit is defined as an area of uniform vegetative structure, soil, geology, and topography, with consistent internal functions and external associations (Leefers et al. 1987). Ecosystem units can be distinguished from each other by observable differences in physiography, soils, and vegetation; these components and their interrelationships characterize the local ecosystem. Ecological classification systems use characteristics of the three major components to classify and map the ecosystem units (Barnes et al. 1982).

Landforms, defined as surficial substance plus topography, are believed to be a meaningful delineation for the study of ecosystem processes at a regional hierarchical level. At this level, landforms direct the expression of soil, vegetation, and local climate (Rowe 1984, Bailey 1987). Landforms, through their effects on climate and soil moisture and nutrient supplies, also control the temporal trends of succession, partly through influences on frequency and degree of disturbance (Whitney 1986, Host et al. 1987, Leefers et al. 1987).

Classification systems which incorporate a variety of ecosystem components to aid in identification of ecologically equivalent areas have been implemented in parts of Canada and in Europe throughout most of this century (Barnes 1984, Jones 1984, Moon 1984). They have been introduced to the U.S. more recently. Studies of integrated land classification systems, comparing the use of single components to combinations of components, showed that combinations of physiographic, soil, and vegetation data provided better classifications than any single component (Pregitzer and Barnes 1984, Spies and Barnes 1985). Recently, there have been suggestions that a nationwide ecological survey should be initiated to describe the biotic component of the environment and the processes which formed it (Roughgarden 1989).

Background, objectives, and overall hypotheses of the study

The U.S. Forest Service initiated development of an Ecological Classification System (ECS) on the Huron-Manistee National Forests in 1980. Field work began in 1983 on the Manistee, and in 1985 on the Huron National Forest. This study uses data collected on the Huron National Forest during 1985 and 1986, and employs quantitative techniques to describe ecological units and relationships for the area. A relatively small data set was used for this study, so that other ecological units may exist in the area in addition to those described herein.

The general objective of my study is to determine whether sites may be classified into groups of ecologically equivalent units. Site ordinations based on separate site components are developed, and the smallest equivalent unit is eventually derived.

Relationships among site components are also investigated. An ECS requires knowledge of the relationships between ecosystem components for several reasons. Climate and site history can alter forest growth on sites with similar soil and physiography; these influences must be recognized when predicting response. Different soil forming processes may produce similar soil morphologies; in such instances a combination of soil and flora must be used to define the unit. Local variation in ground flora species amplitude may alter the information provided by indicator plant species; these variations must be known to correctly map new areas. Information on components of a landscape ecosystem may be used to make inferences about other components which may be difficult to observe or which may be absent because of disturbance. Knowledge of these relationships will allow accurate mapping of ecological units, which in turn will allow forest managers to predict the influences of site characteristics on silvicultural treatments and other multiple-use management practices.

The overall hypotheses to be tested by this study, stated as alternative hypotheses (as opposed to null hypotheses), are: 1) there are groups into which sites can be classified across the landscape which are of utility in forest management; all sites are not the same, 2) site classifications, or ordinations, separately derived from soils data, ground flora data, and overstory data are significantly different, and 3) there are associations among individual site characteristics believed important to growth.

Detailed objectives and hypotheses, together with reviews of the literature and methodologies employed, are presented in Chapters 2 and 3. Chapter 2 discusses the summarization and analysis of soils data collected from laboratory and field work, and relates soils data to site groupings based on depositional environment. Chapter 3 presents an ordination of sites using ranked ground flora species cover-abundance values, and discusses its relationship with soils, geology, and overstory composition. The ordination based on ground flora is compared with ordinations based on overstory basal area by species, and ordinations based on soil properties. Additionally, soil and forest floor properties are compared among site groups developed from overstory composition. A summary of study conclusions is presented in Chapter 4, and implications for definition of ecological units are discussed.

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CHAPTER II

ASSOCIATIONS AMONG CHEMICAL AND MORPHOLOGICAL SOIL FEATURES, DEPOSITIONAL ENVIRONMENTS, AND GLACIAL LANDFORMS

INTRODUCTION

Soils are not "separate from and independent of the landform" in which they occur; rather, soils occur within landforms, and together they quantify most environmental factors within a designated macroclimatic area. (Grigal 1984). Soil properties are known to be attributable in part to parent material, topography, climate, and time (Jenny 1941), all of which can be directly or indirectly associated with landform characteristics (Barnes et al. 1982, Grigal 1984, Rowe 1984, Bailey 1987).

Landforms influence the development of ecosystem patterns by modifying regional climatic conditions, supplying plant nutrients from geologic material (Barnes et al. 1982, Rowe 1984, Bailey 1987), and influencing types and frequencies of disturbance (Zak et al. 1986, Host et al. 1987, Host et al. 1988).

The landform, therefore, is believed to be a meaningful delineation for the study and mapping of both soil and ecosystem units (Rowe 1984, Bailey 1987). A definition of precisely what land area comprises a landform can be more elusive. Pregitzer and Ramm (1984) have stated that landform, broadly defined, includes "physiography, geomorphology, terrain, and topography". The Soil Science Society of America defines landform as "a three-dimensional part of the land surface, formed of soil, sediment, or rock that is distinctive because of its shape, that is significant for land use or to landscape genesis, that repeats in various landscapes" (Soil Sci. Soc. Am. 1987), while a geomorphologic description of landform is simply "portions of the Earth's surface relief" (Pitty 1984). Landform has been described by Rowe (1984) as "surficial substance plus its surface shape or topography", representing "the stable morphological-structural component of landscape ecosystems". He further states that "repetitive patterns in vegetation can be traced directly to repetitive patterns of topography associated with specific kinds of surficial materials", so that the "best correlate of vegetation patterns and soil patterns is landform". This implies that a landform as defined by Rowe consists of a topographic mass with a relatively homogenous surficial deposit, which seems a reasonable definition for purposes of soil and ecosystem mapping.

Definitions of landform generally depend on the spatial scale of interest and the terrain of the region in question, whether it be glacial drift, aeolian deposits, erosional surfaces, or others. Bailey (1984) describes three spatial scales which are of interest in ecological land mapping. The macroscale is largely controlled by climate, while the mesoscale is characterized by landform control of climate due to geologic substrate, surface shape, and relief. The microscale is related to local slope and aspect differences, and has a uniform soil series and plant association. In her study of the geomorphology of northeastern lower Michigan, Burgis (1977) defined landforms as glacial features, which would roughly correspond with Bailey's mesoscale. These features include moraines, till plains, outwash plains, outwash channels, deltas, beach complexes, lake plains, islands, kamic masses, and bedrock topography. Field observations in this area indicate that some of these landforms, notably moraines, contain several different types of surficial deposit owing to localized variations in depositional environment. The landform unit as defined geomorphologically may be too heterogeneous to be useful in determining ecosystem boundaries for this area.

My study provides information on associations of mapped glacial features with surficial deposits, and with soil properties. The information will be vital to the development of an ecosystem classification and for studies of ecosystem processes in the area. An understanding of the ecological meaning of coincident landscape features will increase the usefulness of data obtained from geographic information systems. Ultimately, knowledge regarding soil-landform relationships may provide inputs to modeling of environmental systems.

Glacial geology and climate of the study area

The study was located in the Huron National Forest in northeastern lower Michigan (Figure 2.1). The glacial geology of the area has been extensively studied and its glacial features mapped by Burgis (1977, 1981). The region was most recently glaciated by the Laurentide Ice Sheet during the Late Wisconsinan period. Several readvances of the Huron Lobe occurred during the Port Bruce and Port Huron substages of the Late Wisconsinan period to form the surficial topography of the area. The two largest morainal features are the West Branch moraine and the Glennie moraine (Figure 2.1). The West Branch moraine was formed at about 13,800 years before present (B.P.) during the retreat of Port Bruce ice. An area designated as the Maltby Kames is an ice-disintegration feature located at the southwest margin of the West Branch moraine. The Maltby Kames are not truly kames, which are conical hills formed in glacial drainages by water deposition of coarse-textured materials. This area instead exhibits a kettle topography indicative of melting of stranded ice blocks subsequent to glacial retreat. The Glennie moraine formed after a readvance of the northwest sublobe of the Huron Lobe, which reached its maximum southwest extent at approximately 12,500 years B.P., and is believed to have overridden the eastern portion of the West Branch moraine (Burgis 1977, 1981). The smaller features located at the westernmost edge of the study area

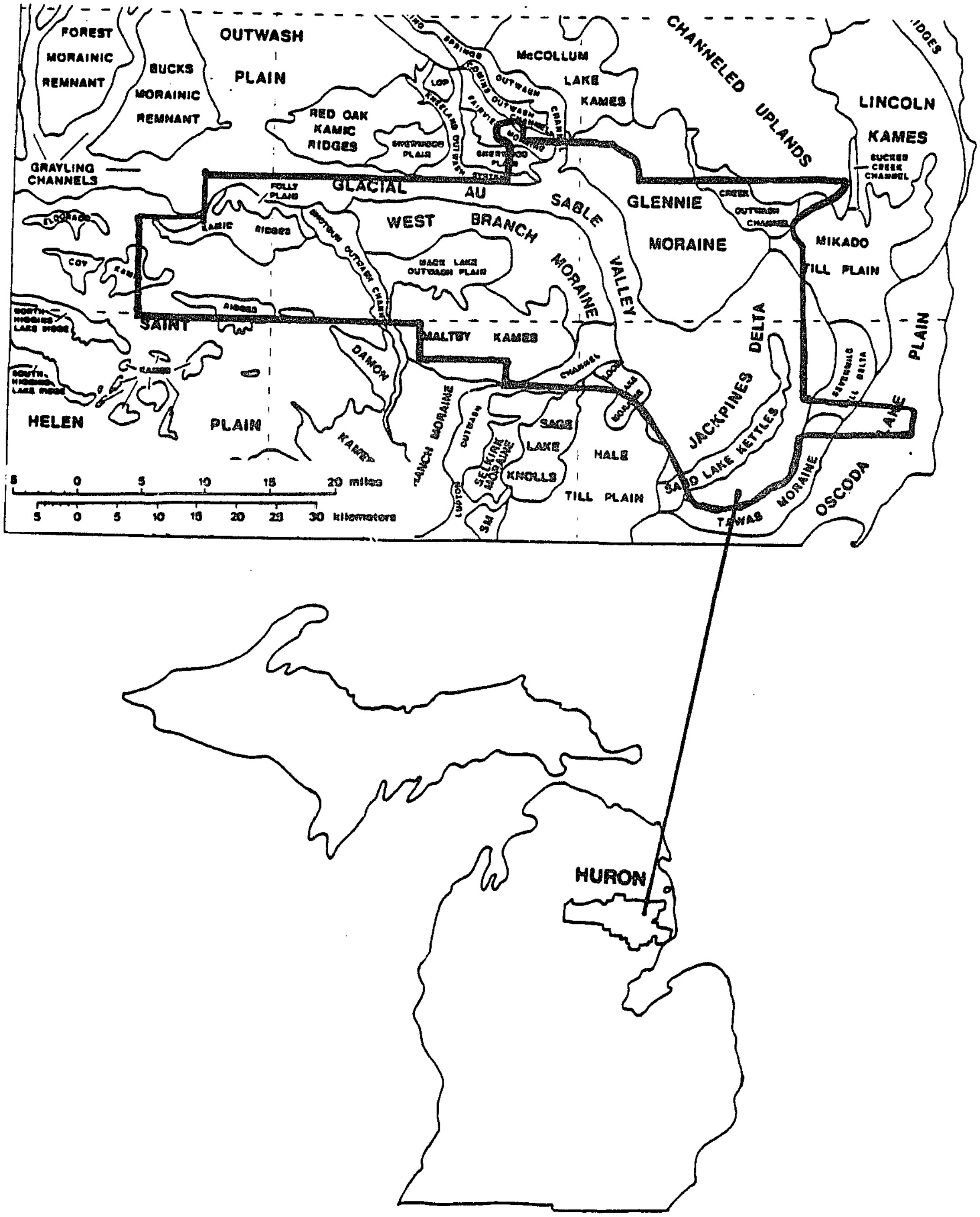


Figure 2.1. Location of the Huron National Forest in northeastern lower Michigan, and glacial landform features of the study area (Burgis 1981).

are the Eldorado Kamic Ridges. These remnant features were deposited at the same time as the West Branch moraine, during Port Bruce time at about 13,800 years B.P.

Moraines in the study area are comprised of a reddish brown loamy textured till, reworked in places by locally ponded water, or overridden by localized outwash. Dune-like formations are common atop the moraines, indicating wind reworking following glaciation. Kettles are also common in parts of both the West Branch and Glennie moraines, indicating ice-disintegration at these locations. Associated with the moraines in the landscape are drainage and outwash features, largely comprised of coarse-textured sandy materials. Thus, the landscape of northeastern lower Michigan exhibits a pattern of uneven topography and variable soil parent materials as a result of repeated glacial advances and postglacial reworking of surface materials by wind and water.

The climate of the area is cool and moist, with a mean annual temperature of 6.7 degrees Centigrade. Local climate is moderated near Lake Huron, so that temperatures range from 6.1 degrees at the western edge of the study area to 7.2 near the lake. Mean annual rainfall averages 71.1 cm, ranging from 68.6 cm in the central part of the study area to 73.7 cm at the southeastern edge. The growing season averages 115 days, ranging from 100 days at the west edge to 140 days at the east edge. Growing season lengths are also extremely variable temporally. Winter snowfall ranges from

114 cm on the southeast to 228 cm on the northwest. Variation in snowfall is due to prevailing wind directions and local topography. The mean annual extreme minimum temperature is -29 degrees Centigrade (Michigan Department of Agriculture 1974). Albert et al. (1986), in their regional landscape ecosystem map of Michigan, have placed most of the study site in the Highplains District of Region II. This district is large and climatically diverse, but variation in recorded weather data precluded division of the area into homogeneous subdistricts. The local variation in climate appeared to be related to topography, with cold air masses settling in low-lying outwash plains.

Relationships of soil and landscape features

Development of soils has been associated with landforms at both the microscale and mesoscale levels. On a calcareous till soil in Denmark, the thickness of the B horizon, presence of an E horizon, and depth of decalcification were all related to slope inclination and position (Dalsgaard et al. 1981). A similar study in Florida related thickness of the A horizon, color, sand percentage, pH and organic C content to summit, shoulder, and backslope positions (Ovalles and Collins 1986). Elevation, slope, and aspect were strongly related to field observed soil properties on an area of mixed loess and glacial drift in Iowa (Walker et al. 1968).

Geologic material has been associated with soil features in a number of studies. Vertical and horizontal grain size distributions in a soil catena in Alberta were found to be related to four geomorphic episodes, including a till deposit, two colluvial deposits, and an aeolian deposit (Pennock and Vreeken 1986). Crum and Rust (1986) found that samples of till parent materials in Minnesota could be classified into four groups by discriminant functions which used texture, coarse fragment, and carbonate values. Soil taxonomic differences were related to till composition at the family level. Discriminant analysis was applied to groups based on soils derived from seven different sedimentary rock formations in Virginia based on ranks of 34 field and laboratory determined properties (Edmonds and Lentner 1987). Discriminant functions were successfully developed for soil groups from two of the seven formations; the other soil groups could not be discriminated by any of the measured properties. Soil properties were found to differ between two types of similarly aged ground moraines in Wisconsin, one of which featured drumlin topography (Pavlik and Hole 1977). Soils on the drumlin terrain had deeper profiles, with greater development of B horizons.

Numerical analysis of soils data

Studies reported in the literature have most often used soil data which were summed by horizons, but some studies have used depth sums. The rationale for using horizon groupings is that comparisons are made among soil layers on which similar pedogenetic processes have occurred. Alternatively, horizon summaries have been criticized because they use varying depths and thicknesses, and reflect a subjective decision by the soil describer in determining the location of horizon boundaries. Depth sums are considered more objective (Grigal and Arneman 1969).

Numerical analysis has been used to demonstrate differences and similarities among soil observations at single points, and among groups of observations. Principal component analysis (PCA) has been useful in a number of studies. The technique does not provide a statistical significance test, but can reduce the dimensionality of a data set to allow a visual examination of relationships among points. Ovalles and Collins (1988) used PCA simply to identify major sources of variability in Florida soils, finding that it was related primarily to texture and organic carbon content. Webster and Burrough (1972) followed up a PCA of soils in south central England by creating an isarithm map of the first principal component (PC). They compared changes in soil properties identified by the numerical procedure with a traditional soil survey map and found good agreement generally. Plots of site locations with respect to the first two PCA dimensions were used by Norris (1971) to determine that groupings based on field data corresponded well with groupings based on laboratory data for sets of soils from Australia and England.

Nortcliff (1978) used PCA to examine soil variability patterns at different areal scales, and also used analysis of variance (ANOVA) to identify the particular areal scale at which certain components of the variability were most important.

Clustering methods were compared by Cuanalo and Webster (1970), who found that for Brown Earth soils in England there was good agreement among methods, and between the numerical classifications and a prior intuitive biophysical classification. For Gley soils, there was no agreement between clustering methods, or between clusters and the intuitive classification. The authors concluded that Gleys are inherently difficult to classify either by numerical or intuitive methods because they are quite different from each other. In Minnesota, a weighted-pair group cluster analysis gave classifications which were subjectively accurate at lower levels of the hierarchy (Grigal and Arneman 1969). Numerical classifications did not correspond well with non-numerical classifications except when variables in the numerical classification were limited to horizon texture and thickness, and variables in the non-numerical classification was limited to family textural class. Cluster analysis of observation scores derived from PCA was used to compare taxonomic and numerical classifications of three soil mapping units in Virginia (Edmonds et al. 1985). They found that cluster groupings did not correspond with classifications by Soil Taxonomy (Soil Survey Staff 1975), indicating that soil variability within 7 m was too great for effective description by the taxonomic units. The use of PCA scores in cluster analysis was thought to be useful because there were a large number of variables with similar weights in a PC, so that no single variable could be associated with the PC (Edmonds et al. 1985). A similar method was employed by Denton and Barnes (1988), where climatic data was summarized into a few variables using PCA, and these variables were used in cluster analysis in combination with original variables of greater biological significance. This approach was intended also to make classifications less dependent on characteristics of cluster analyses methods.

Discriminant analysis was applied to some gley soils in Scotland to determine whether numerical techniques could be used to classify four taxonomic units (Henderson and Ragg 1980). There was good agreement between the numerical and taxonomic (non-numerical) classifications, but some criteria used in the taxonomic classification system were found to be poor discriminators. Discriminant analysis functions developed from ranked soil variables in Virginia were only partly successful in classifying soils into their parent rock formations, but the authors concluded that classifications produced by the discriminant analysis provided more accurate estimations of soil response than classification at the series level (Edmonds and Lentner

1987). Glacially derived loess, siltstone residua, and lacustrine silt were successfully discriminated from each other using Zr, Ti, and K contents of the silt fraction (Norton and Hall 1985). Other textural and mineralogical variables were less effective in discrimination. Two types of ground moraine in Wisconsin, one with drumlins and one without, were described by discriminant functions using 29 field-observed variables, including texture, structure, and thickness of soil horizons (Pavlik and Hole 1977).

Principal component analysis and cluster analysis were generally effective in identifying groups of similar soil individuals. Groupings derived from numerical analysis sometimes failed to correspond with classifications based on subjective taxonomic criteria, largely due to soil variability. For these situations, the numerical classifications were deemed better predictors of soil response, particularly at the local level, because the numerical classification was derived from a larger number of objectively determined variables.

OBJECTIVES AND HYPOTHESES

The objective of this chapter is to examine associations among soil features, depositional environment, and mapped glacial landforms or physiographic regions. Information regarding relationships among these ecosystem components will aid in development of an ecological classification system for northeastern lower Michigan.

The general questions addressed are: 1) are glacial landform units as mapped by Burgis (1981) homogenous enough to serve as a basis for an ecological classification system in this region, 2) are soil characteristics homogenous among the sampled sites, and if not, 3) are there differences in soils developed in loamy till dating from different ages of glacial deposition, 4) can these sites be ordinated by numerical techniques using soils data to represent a gradient of site quality, 5) does the ordination of sites obtained from soils data correspond with landform unit designations as used by Burgis (1981), or with localized depositional environments, and 6) which field or laboratory determined soil characteristics are important in developing site ordinations and should be emphasized in future sampling?

The assumptions to be evaluated are: 1) physiographic land areas, or glacial features mapped by Burgis (1981), are equivalent to parent material/depositional environment designations, 2) site ordinations obtained from soil laboratory data summed by horizons or by depth categories, or field data, are equivalent, 3) site ordinations obtained from soils data reflect a gradient of depositional environments ranging from outwash to ground moraines, 5) some soil variables are of greater importance than others in distinguishing among sites, and 6) time of till deposit does not influence soil characteristics.

Evaluating the assumptions will entail: 1) determining the mode of deposition of parent material from soil and site physiographic descriptions, and comparing depositional environment designations with mapped glacial features, 2) comparison of soil characteristics among the depositional environment designations, 3) ordination of sites by PCA using laboratory horizon summed data, depth summed data, and field data, 4) determination of whether all sites occupy the same position on the ordination, 5) comparison of the ordinations with each other and with depositional environment types, and 6) identification of soil variables which contain a large amount of information for distinguishing between sites of different depositional types.

METHODS AND MATERIALS

The approach to the study was to sample mature second-growth forested sites which were representative of the range of upland ecosystem types found in the study area. Soil morphology was described in the field and samples were collected for laboratory analyses of major soil and forest floor nutrients. Laboratory analyses, and subsequent numerical analyses, were performed to address hypotheses regarding ecological relationships within and among these sites.

Field sampling design

Sites selected for sampling were required to have homogenous vegetative cover and a minimum size of 1 ha. The sites also had to be at least 50 years in age, with no evidence of recent disturbance. At each site, a central subplot was located by throwing an object while standing in the approximate center of the site. Three other subplots were located around the central subplot using random distances and azimuths. Soil pits at each of the four subplots were described and sampled by horizon to a depth of 450 cm or until a layer 60 cm or thicker of sandy clay loam or heavier textured soil was encountered. All soils were described and sampled to at least 150 cm, a depth which included most rooting activity in these loamy till soils.

Forest floor samples were collected during the two weeks immediately following autumn litterfall in early

November of 1987. Figure 2.2 shows the arrangement of soil pits and forest floor samples on a hypothetical site. At each of the 24 study sites, 12 forest floor samples were obtained by removing material inside a 0.25 m^2 template. Three templates were located randomly around each of the four soil pits. Current year's litter was separated from the remainder of the forest floor material based on obvious differences in degree of decomposition.

Laboratory analyses

Samples were analyzed in the Soils Laboratory of the Department of Forestry at Michigan State University. Soils were air dried, crushed, and passed through a sieve with 2 mm openings. Soil analyses were performed on the less than 2 mm fraction. Analyses included pH in water and in 0.01 M $CaCl_2$ solution, Ca, Mg, and K extracted in 1 N NH_4OAc solution at pH 7.00 (U.S.D.A. 1972), Kjeldahl nitrogen (N) and phosphorous (P) determinations (Technicon 1977), and Bray's #1 solution extractable P (Bray and Kurtz 1945) with a modification for calcareous soils (Smith et al. 1957). Forest floor samples were oven dried at 80°C, and weights obtained. The three samples obtained near each soil pit were combined, so that there were four composite samples per site. Current year's litter was ground in a stainless steel Wiley mill. Old forest floor material, which was comprised partly of woody litter, was coarsely ground in a hammermill and finely homogenized in a Melita coffee grinder (Model No.

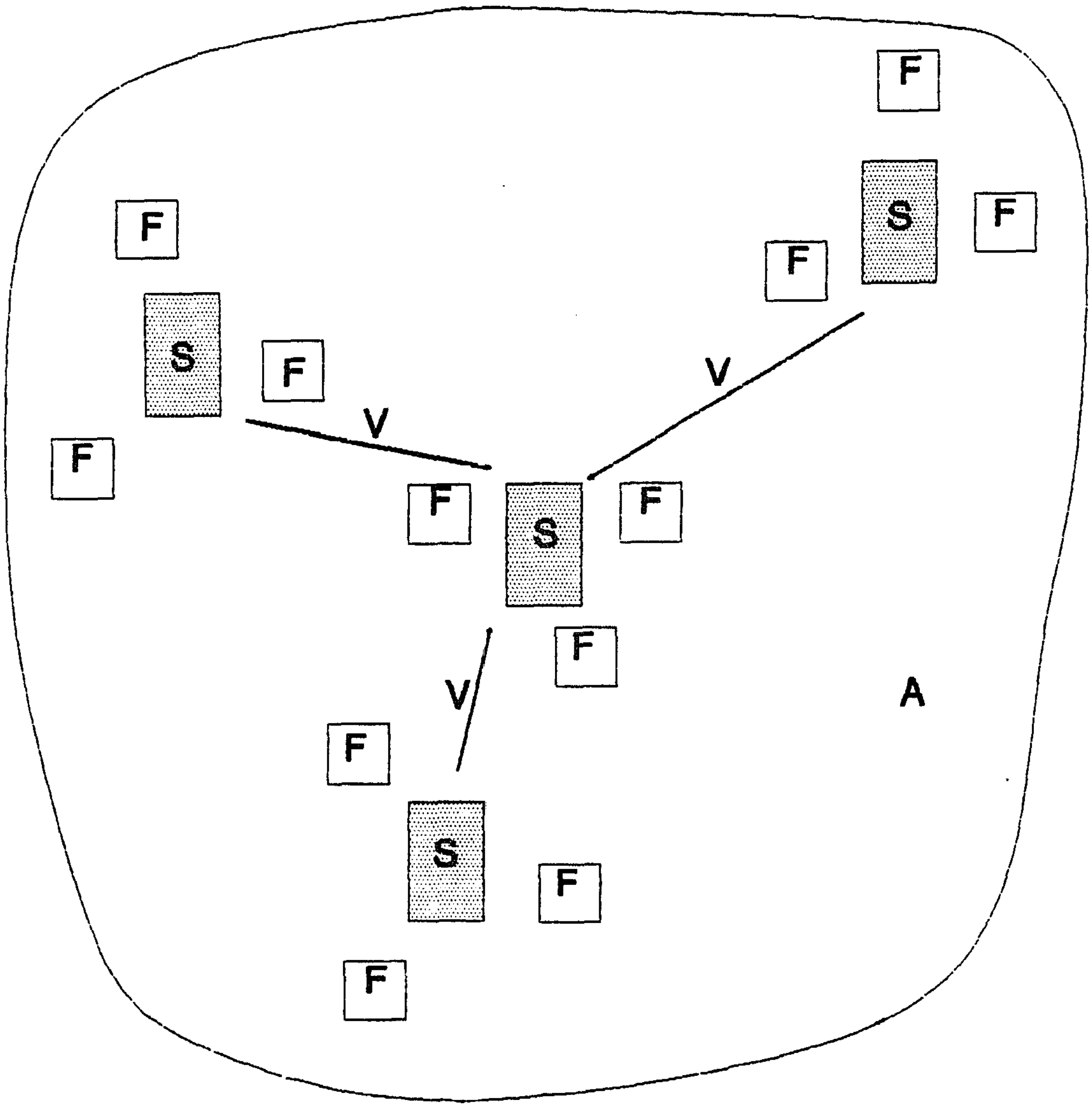


Figure 2.2. Diagram of sample collection locations at a hypothetical site.

A = area of homogenous vegetative cover, at least 1 ha in size, with 50 or more years since major disturbance.

S = soil pit.

F = forest floor sample.

V = vectors at random azimuth and distance to subplots.

CG-1). Forest floor samples were analyzed for Kjeldahl N and P (Technicon 1977), and were also dry-ashed for subsequent DC argon plasma spectrophotometric analysis of Ca, Mg, K, Al, Zn, Cu, and Mn (Likens and Bormann 1970, Isaac and Kerber 1971). The length of time required for complete ashing at 480^{o}C was extended up to as much as 24 hours for forest floor samples containing charcoal, and samples containing large amounts of oak litter and woody material (Lea et al. 1980, Melillo et al. 1982). Quality control was maintained through sample replication and analysis of standard soil and tissue samples.

Calculations were performed to place soil nutrients on a content basis, in kg/ha, for the thickness of the horizon or depth increment used. Values were corrected for coarse fragment volume and for the ratio of air dry to oven dry weight. Bulk densities were estimated using data from a set of 200 soil samples collected in northern Michigan (Soil Survey Laboratory 1982, Soil Survey Laboratory 1983, Padley and Trettin 1983a, Padley and Trettin 1983b, LeMasters et al 1984, Padley et al. 1984a, Padley et al. 1984b, Padley et al. 1984c, Trettin et al. 1984). Bulk densities had been measured by the Saran-coated clod method (U.S.D.A. 1972), and these were used in developing my prediction equations. Bulk density has been predicted in other studies from soil organic carbon, texture, and depth variables (Curtis and Post 1964, Reigner and Phillips 1964, Dawud and Gray 1979, Alexander 1980, Rawls 1983). In my study, fragipan and dense till layers were assigned group mean values. Bulk densities of other soil layers were predicted with multiple regression equations which used TKN, texture, and depth. Table 2.1 presents the equations and mean values used for the various depth, texture, and horizon groups.

Data analyses

Principal component analyses were used to reduce the dimensionality of the soils data and to display two-dimensional plots of site locations (Morrison 1976, Chatfield and Collins 1980). Separate and combined data sets of laboratory and field determined soils variables (Tables 2.2, 2.3) were used. Non-numerical values from field soil descriptions were converted to numerical variables prior to analysis. Soil textures were assigned percentage values for sand, silt, and clay which corresponded with a central value for that soil textural class. Physiographic designations and soil drainage classes were assigned ordinal numerical values (Table 2.3).

Results of PCA using the correlation matrix, rather than the covariance matrix, are reported here, although both techniques were tried. Many of the soil variables were measured on different scales, with the result that those variables with larger variances dominate PCA's of the covariance matrix (Morrison 1976, Chatfield and Collins 1980). Use of the covariance matrix in PCA is recommended

Table 2.1 Equations and mean values used for estimation of bulk density.

Soil characteristic	Regression equation[1]
Bs horizons with 40-70% sand.	-0.422+(0.00715SAND)+(0.0589PH) +(0.898TRANSTKN) Std. error 0.0784 at mean 1.394
Bs horizons with greater than 70% sand.	1.748+(-0.000315TKN)+(0.00216MID)+ (-0.00394SAND)+(0.0204CLAY) Std. error 0.0941 at mean 1.434
Less than 40% sand	1.582+(-0.000185*TKN)+ (-0.000696MID)+(-0.00421*CLAY) Std. error 0.105 at mean 1.549
Greater than 40% sand, depth between 60 and 150 cm.	-3.558+(0.00402*TKN)+(-0.0141MID)+ (0.0194TRANSTKN)+(3.260*LOGMID) Std. error 0.0939 at mean 1.578
Others[2]	lnBD=0.38061+(-0.05964*lnOC%)+ (-0.058147*OC%)

Soil horizon	Mean value	
Bt, or combination of E and Bt.	1.618	Std. dev. 0.0945
Bx, Ex, or combination.	1.816	Std. dev. 0.0706
Bm, Em, or combination.	1.70	(assigned value)

[1] Variable codes represent the following values:
TKN=Total Kjeldahl nitrogen, concentration %.
TRANSTKN=(100/TKN)+1.
MID=Horizon midpoint, cm.
LOGMID=Logarithm of horizon midpoint, cm.
CLAY=Clay %.
SAND=Sand %.
PH=pH measured in $CaCl_2$ solution.
BD=Bulk density, g cm^{-3}.
OC=Organic carbon %, here estimated by 0.03535+17.4627TKN.

[2] M.R. Gale, personal communication.

Table 2.2. Laboratory determined soil variables.

Laboratory determined variables	
	------------- Organic layers -------------------
OITKN	Kjeldahl nitrogen content of the Oi, kg/ha.
OITKP	Kjeldahl phosphorous content of the Oi, kg/ha.
OIZN	Zinc (Zn) content of the Oi, kg/ha.
OIMN	Manganese (Mn) content of the Oi, kg/ha.
OICU	Copper (Cu) content of the Oi, kg/ha.
OIAL	Aluminum (Al) content of the Oi, kg/ha.
OIMG	Magnesium (Mg) content of the Oi, kg/ha.
OICA	Calcium (Ca) content of the Oi, kg/ha.
OIK	Potassium (K) content of the Oi, kg/ha.
OETKN	Kjeldahl nitrogen content of the Oe, kg/ha.
OETKP	Kjeldahl phosphorous content of the Oe, kg/ha.
OEZN	Zinc content of the Oe, kg/ha.
OEMN	Manganese content of the Oe, kg/ha.
OECU	Copper content of the Oe, kg/ha.
OEAL	Aluminum content of the Oe, kg/ha.
OEMG	Magnesium content of the Oe, kg/ha.
OECA	Calcium content of the Oe, kg/ha.
OEK	Potassium content of the Oe, kg/ha.
	------------------ A horizons -------------------
ATKN	Kjeldahl nitrogen content of the A, kg/ha.
ATKP	Kjeldahl phosphorous content of the A, kg/ha.
AMG	Magnesium content of the A, kg/ha.
ACA	Calcium content of the A, kg/ha.
AK	Potassium content of the A, kg/ha.
ABRAYP	Bray's P content of the A, kg/ha.
AHBUF	Hydrogen content of the A, kg/ha, measured in 0.01 $\underline{M}$ $CaCl_2$ solution.
	------------------ B horizons -------------------
BTKN	Kjeldahl nitrogen content of the B, kg/ha.
BTKP	Kjeldahl phosphorous content of the B, kg/ha.
BMG	Magnesium content of the B, kg/ha.
BCA	Calcium content of the B, kg/ha.
BK	Potassium content of the B, kg/ha.
BBRAYP	Bray's P content of the B, kg/ha.
BHBUF	Hydrogen content of the B, kg/ha, measured in 0.01 $\underline{M}$ $CaCl_2$ solution.

Table 2.2. (continued).

------------------ C horizons --------------------

CTKN	Kjeldahl nitrogen content of the C, kg/ha.
CTKP	Kjeldahl phosphorous content of the C, kg/ha.
CMG	Magnesium content of the C, kg/ha.
CCA	Calcium content of the C, kg/ha.
CK	Potassium content of the C, kg/ha.
CBRAYP	Bray's P content of the C, kg/ha.
CHBUF	Hydrogen content of the C, kg/ha, measured in 0.01 M $CaCl_2$ solution.

------------------ Depth sums --------------------

TKN10	Kjeldahl nitrogen content of 0-10 cm depth, kg/ha.
TKN30	Kjeldahl nitrogen content of 10-30 cm depth, kg/ha.
TKN70	Kjeldahl nitrogen content of 30-70 cm depth, kg/ha.
TKN150	Kjeldahl nitrogen content of 70-150 cm depth, kg/ha.
TKP10	Kjeldahl phosphorous content of 0-10 cm depth, kg/ha.
TKP30	Kjeldahl phosphorous content of 10-30 cm depth, kg/ha.
TKP70	Kjeldahl phosphorous content of 30-70 cm depth, kg/ha.
TKP150	Kjeldahl phosphorous content of 70-150 cm depth, kg/ha.
CA10	Calcium content of 0-10 cm depth, kg/ha.
CA30	Calcium content of 10-30 cm depth, kg/ha.
CA70	Calcium content of 30-70 cm depth, kg/ha.
CA150	Calcium content of 70-150 cm depth, kg/ha.
MG10	Magnesium content of 0-10 cm depth, kg/ha.
MG30	Magnesium content of 10-30 cm depth, kg/ha.
MG70	Magnesium content of 30-70 cm depth, kg/ha.
MG150	Magnesium content of 70-150 cm depth, kg/ha.
K10	Potassium content of 0-10 cm depth, kg/ha.
K30	Potassium content of 10-30 cm depth, kg/ha.
K70	Potassium content of 30-70 cm depth, kg/ha.
K150	Potassium content of 70-150 cm depth, kg/ha.
TKNSUM	Kjeldahl nitrogen content of 0-150 cm depth, kg/ha.
TKPSUM	Kjeldahl phosphorous content of 0-150 cm depth, kg/ha.
CASUM	Calcium content of 70-150 cm depth, kg/ha.
MGSUM	Magnesium content of 0-150 cm depth, kg/ha.
KSUM	Potassium content of 0-150 cm depth, kg/ha.
NMIN	Ammonium-N mineralized from 0-10 cm depth during a 1 week incubation, g/kg.

Table 2.3. Field determined soil variables.

Field determined variables	
------ Textural variables from field estimates ------	
ASAND	Sand % in A horizon.
ASILT	Silt % in A horizon.
ACLAY	Clay % in A horizon.
BSAND	Sand % in B horizon.
BSILT	Silt % in B horizon.
BCLAY	Clay % in B horizon.
CSAND	Sand % in C horizon above 150 cm.
CSILT	Silt % in C horizon above 150 cm.
CCLAY	Clay % in C horizon above 150 cm.
ACSFR	Coarse fragment volume % of A horizon.
BCSFR	Coarse fragment volume % of B horizon.
CCSFR	Coarse fragment volume % of C horizon above 150 cm.
CSFRSUM	Coarse fragment volume % of upper 150 cm depth.
SAND30	Sand % of 0-30 cm depth.
SILT30	Silt % of 0-30 cm depth.
CLAY30	Clay % of 0-30 cm depth.
SLT150	Sand % of 0-150 cm depth.
SILT150	Silt % of 0-150 cm depth.
CLT150	Clay % of 0-150 cm depth.
SGT150	Sand % of 150-450 cm depth.
SIGT150	Silt % of 150-450 cm depth.
CGT150	Clay % of 150-450 cm depth.
SAND450	Sand % of 0-450 cm depth.
SILT450	Silt % of 0-450 cm depth.
CLAY450	Clay % of 0-450 cm depth.
HEAVS	Sand % of heaviest textural layer.
HEAVSI	Silt % of heaviest textural layer.
HEAVC	Clay % of heaviest textural layer.
DEPVFS	Depth to vfs accumulations 15 cm thick, cm.*
DEPLS	Depth to ls accumulations 15 cm thick, cm.*
DEPSL	Depth to sl accumulations 15 cm thick, cm.*
DEPSCL	Depth to scl or heavier textural accumulations 15 cm thick, cm.*
DEPTEX	Depth to uppermost heavy textural layer, cm.*
TEXS	Sand % of uppermost heavy textural layer.
TEXSI	Silt % of uppermost heavy textural layer.
TEXC	Clay % of uppermost heavy textural layer.
BIC	Textural banding intensity code, 0 to 5 based on thickness and texture of heavy soil layers.

* Value of '500' entered if none present.

Table 2.3. (continued).

	------------- Horizon variables ---------------
OIWT	Weight of Oi, kg/ha.
OEWT	Weight of Oe, kg/ha.
ATHICK	Thickness of A, cm.
ETHICK	Thickness of E, cm.
BTHICK	Thickness of B, cm.
BSTHICK	Thickness of Bs, cm.
BTTHICK	Thickness of Bt, cm.
AVALUE	Munsell color value of A.
BVALUE	Munsell color value of B.
EDC	E horizon development code, based on color, thickness, and continuity.
	---- Reaction, drainage, and physiographic variables ----
DEPPH7	Depth to soil of pH 7, cm.
DEPCO3	Depth to carbonates, cm.
ROOTDEP	Rooting depth of major root system, cm.
SLOPE	Slope in %.
ASPECT	Aspect in degrees from true north.
ELEV	Elevation in meters.
PHYSFORM	Physiographic designation: 1=low flat, 2=lower slope, 3=mid-level flat, 4=mid-slope, 5=bench, 6=upper slope, 7=high flat, 8=ridge.
DRCLASS	Drainage class: 1=excessively drained, 2=somewhat excessively drained, 3=well drained, 4=moderately well drained, 5=somewhat poorly drained, 6=poorly drained, 7=very poorly drained.*
MOTTDEP	Depth to mottling, cm.*

* Value of '500' entered if none present.

whenever possible because the theory is less complex, and because PC's explain variance within a data set and variances of standardized scores are somewhat artificial. In practice, the correlation matrix has been used more frequently, although it avoids rather than solving the problem of standardized variances. Use of the correlation matrix is considered satisfactory if all the variables used are of similar importance (Morrison 1976, Chatfield and Collins 1980). Not all variables used in this study appear to be of exactly the same importance; however, it is difficult to predict their importance prior to performing a PCA, and the utility of a PCA is lessened if the importance of variables is already known. PCA of the covariance matrix inevitably identifies variables with the largest variance as the most important, even if the variables are log-transformed so that the differences in variance are very small. Thus, the correlation matrix was deemed the only possible choice for these data analyses despite the chance of spurious correlations.

PCA's were performed on site-level data in which values from the four pedons at each site were averaged. Variables were removed from analysis if they contributed little to the structure of the data set. Variables of lesser importance were identified by their low communality estimates, or correlations of the variables with the PC's.

A Kruskal-Wallis test of identical distributions was used for comparing groups based on depositional environment.

The Kruskal-Wallis test may be used to determine that different distributions exist, but does not establish which groups or variables differ. For this reason, the Kruskal-Wallis test was followed by individual t-tests with reduced degrees of freedom for comparisons of groups with significantly different variances (Steel and Torrie 1980). Site ranks in the first dimension of different PCA's were compared using Spearman's coefficient of rank correlation (Steel and Torrie 1980). Site scores in the first dimension of the PCA's were compared using simple linear correlations. The Statistical Analysis System (SAS) (SAS Institute Inc. 1985) was used for all soil data analyses.

RESULTS AND DISCUSSION

Correspondence of mapped glacial features with parent materials and mode of deposition

Glacial landform features have been mapped at a local scale in the study area by Burgis (1981) (Figure 2.1). Sites sampled as part of my study are located within the boundaries of areas which Burgis mapped and designated as the Eldorado Kamic Ridges, the Maltby Kames, the West Branch and Glennie Moraines, the AuSable River valley, and the Fletcher Pond Channeled Uplands. Figure 2.3 shows the locations of sampled sites among the Burgis landforms.

Mode of deposition was determined for the soils of each site based on descriptions of soil textures and stratification, and on descriptions of the physiography of each site. Soils with loamy till in the solum were additionally separated into two groups based on their location within the boundaries of the Port Huron or Port Bruce tills. Table 2.4 describes the types of depositional environments which formed the 24 sites used in this study.

When the depositional environment designations in Table 2.4 are compared with Burgis' previously mapped landforms, there is a definite lack of correspondence, particularly within the boundaries of the Glennie and West Branch moraines. The Glennie moraine contains sites occurring on outwash sand, outwash sand with ice-rafted inclusions, and till. The West Branch moraine, including the Maltby

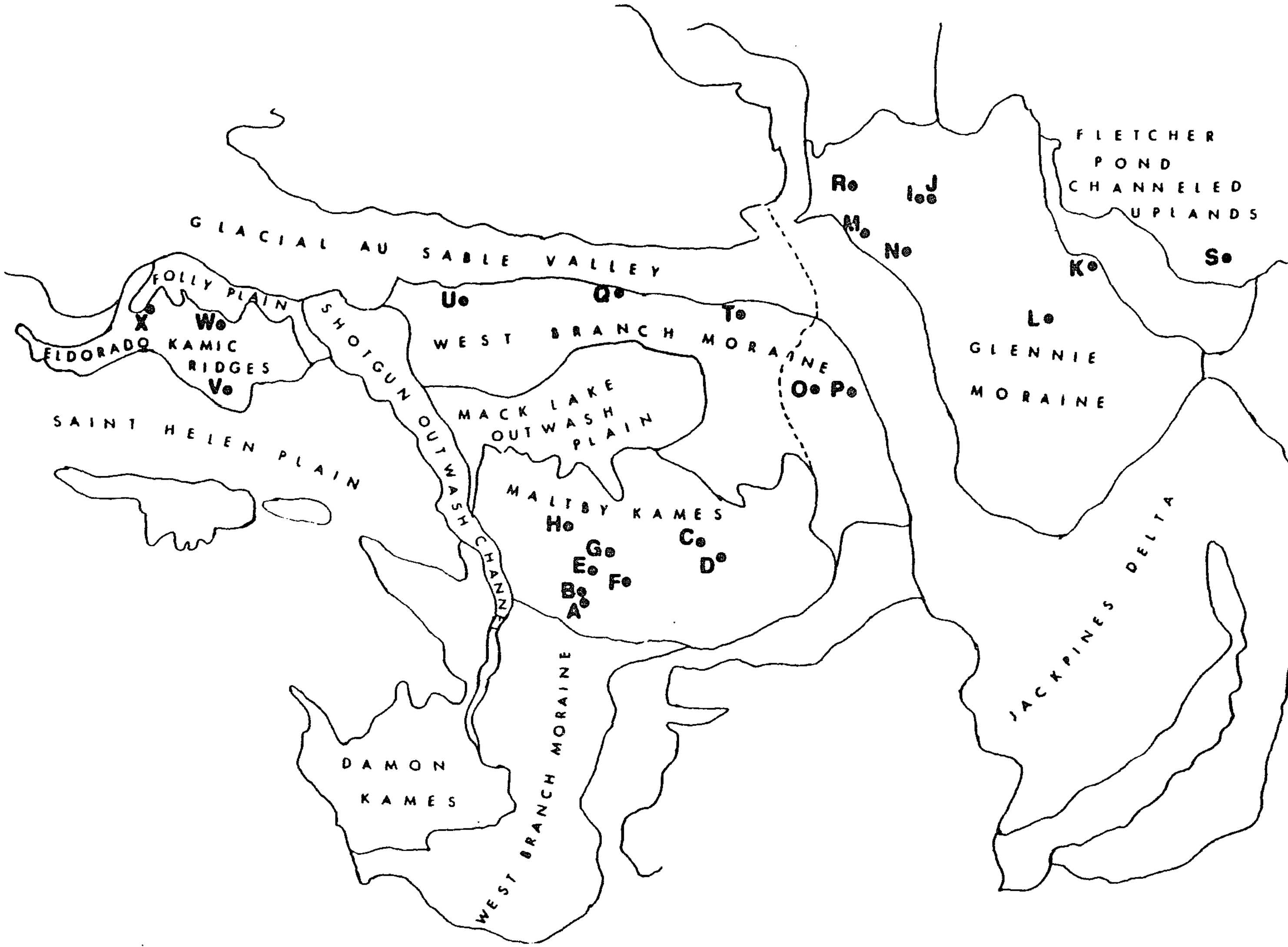


Figure 2.3. Location of study sites among glacial landforms identified by Burgis (1977, 1981). Dotted line indicates western boundary of Port Huron till.

Table 2.4 Depositional environment characteristics of sample sites.

Outwash sand: Areas of small undulating hills with sand textures to a depth of 450 cm; minimal stratification of gravel and thin loamy sand layers in substratum. Sites H, L, T.

Outwash sand with ice-rafted loamy inclusions: Sand or loamy sand surface textures; gravel and loamy textural pockets occurring below a depth of 100 cm. Sites K, M, P, Q, R, V, W, X.

Port Bruce till: Loamy sand or sandy loam surface textures; loamy till layer present above 100 cm. Port Bruce till was deposited at more than 13,000 years B.P. Sites A, B, D, E, F, G.

Port Huron till: Loamy sand or sandy loam surface texture; loamy till layer present above 100 cm. Port Huron till was deposited at about 12,000 years B.P. Sites I, J, N, O, S.

Lacustrine: Silts and fine sands in thin strata predominating throughout the pedon. Sites C, U.

Kames, contains outwash sand, outwash sand with ice-rafted inclusions, lacustrine, and till sites of both Port Huron and Port Bruce deposition. Other Burgis landforms were not intensively sampled. Sites on the Eldorado Kamic Ridges were all formed in outwash sand with ice-rafted inclusions, and the one site on the Fletcher Pond Channeled Uplands was formed in Port Huron till, although it may have been subsequently eroded.

Landforms identified and mapped by Burgis (1977, 1981) are relatively large areas, and they do not correspond well with localized depositional environments or, as will be shown later, with other ecosystem characteristics on a scale useful to forest management. In essence, the scale at which the landforms are mapped is too small to be of use in ecosystem classification, although at higher levels of a hierarchical classification they may be useful in determining the climatic influences of large physiographic masses. For my study, depositional environment designations corresponding with Rowe's (1984) definition of landform as "surficial substance plus its surface shape" were used to provide a basis for development of ecosystem groups.

Principal component analyses

A large number of variables were obtained from the field description and laboratory analyses of soils. Site mean values of these variables are presented in Tables 2.5 and 2.6. Principal component analysis (PCA) is a technique for exploratory data analysis which reduces the dimensionality of a large data set and identifies variables or linear combinations of variables which contain the greatest variation. PCA may also be used to plot site locations with respect to each other along axes of maximum variation. PCA was used to determine whether plots of site locations would contradict groupings based on previously identified depositional environments. Additionally, these analyses were designed to identify nutrients, horizons, depths, or morphological features which were most useful in separating sites along an ecological gradient. PCA was also performed to determine whether depth or horizon sums of

Table 2.5. Mean site level values of laboratory determined soil variables.

SITE	OITKN	OITKP	OIZN	OIMN	OICU	OIAL	OIMG	OICA	OIK	OETKN	OETKP	OEZN	OEMN	OECU	OEAL	OEMG	OECA	OEK
	<---------- kg/ha ---------->																	
A	25.2	2.9	0.072	1.99	0.018	0.735	6.0	86.9	6.4	102.1	8.6	0.533	9.58	0.089	16.48	13.6	370.4	11.9
B	26.1	3.0	0.143	0.87	0.021	0.268	5.4	74.1	6.6	153.2	12.0	0.933	6.73	0.138	18.04	19.8	239.3	17.5
C	35.9	4.3	0.192	1.55	0.022	0.205	5.9	86.5	7.9	282.2	20.9	1.585	21.38	0.226	15.22	25.6	451.3	22.2
D	24.1	2.5	0.146	1.30	0.015	0.258	4.1	69.2	4.5	133.1	11.1	1.055	10.27	0.125	20.00	14.0	240.7	12.9
E	27.8	3.2	0.132	1.42	0.020	0.268	5.6	75.7	6.8	138.5	10.7	0.785	6.79	0.119	14.88	13.9	219.4	13.4
F	27.6	2.9	0.091	1 39	0.019	0.295	4.9	77.7	6.1	214.7	15.6	0.955	14.43	0.171	17.39	21.5	308.9	19.0
G	29.6	3.3	0.170	1.65	0.018	0.300	4.7	86.6	6.9	121.4	9.7	0.823	9.35	0.107	11.36	11.2	204.6	11.9
H	21.8	2.2	0.097	13.90	0.013	0.328	3.9	31.6	5.1	151.5	10.1	0.670	59.90	0.107	11.95	8.6	106.6	12.2
I	35.2	5.3	0.224	3.11	0.021	0.288	6.1	77.0	12.2	202.7	15.8	1.210	23.33	0.157	20.86	20.0	258.4	21.2
J	26.2	3.7	0.155	2.70	0.016	0.293	5.9	64.1	8.9	90.6	7.5	0.593	10.09	0.071	13.33	10.0	129.6	10.5
K	21.4	3.4	0.156	5.05	0.014	0.153	5.1	44.1	9.2	154.3	11.7	1.058	29.62	0.115	10.60	13.1	191.0	16.3
L	23.6	2.3	0.111	12.73	0.013	0.275	3.6	29.3	4.5	143.0	9.3	0.588	48.93	0.130	9.55	8.8	123.7	12.9
M	25.2	2.4	0.126	8.69	0.018	0.210	5.5	46.5	6.7	251.8	16.0	1.288	60.13	0.328	20.89	17.8	217.6	20.1
N	36.0	4.5	0.175	2.29	0.026	0.283	7.8	84.9	10.8	307.5	21.5	1.508	19.85	0.269	18.35	33.2	464.0	26.1
O	31.2	4.9	0.190	1.58	0.026	0.305	6.4	83.7	9.2	199.4	15.3	0.960	10.20	0.177	14.19	23.4	273.3	19.8
P	32.2	3.6	0.121	7.16	0.019	0.260	6.8	68.2	10.6	183.0	12.0	0.635	26.75	0.113	7.84	14.4	243.3	16.5
Q	25.1	2.7	0.168	7.05	0.025	0.310	4.4	50.0	6.6	174.9	12.7	1.038	40.95	0.132	10.45	12.8	203.0	17.9
R	21.8	2.5	0.113	8.38	0.012	0.233	4.5	33.8	5.3	119.3	8.1	0.568	32.22	0.097	10.42	12.0	125.0	12.1
S	22.3	2.8	0.111	1.04	0.017	0.428	4.9	54.2	6.9	46.8	4.5	0.285	2.21	0.047	5.64	6.3	79.1	7.8
T	18.1	1.5	0.103	10.51	0.009	0.228	3.3	23.3	3.1	143.0	8.9	0.690	41.41	0.094	10.30	7.3	101.3	10.9
U	32.4	2.9	0.119	1.41	0.016	0.445	5.4	66.5	7.0	207.1	14.3	1.105	16.49	0.161	18.33	21.0	351.0	18.1
V	22.3	2.2	0.126	11.46	0.015	0.278	3.2	34.8	5.3	230.9	16.8	1.103	75.57	0.166	20.42	11.9	147.4	21.2
W	22.6	2.4	0.107	10.27	0.014	0.255	3.7	35.8	5.3	224.1	15.3	0.958	68.46	0.142	18.45	13.4	183.2	19.1
X	23.3	2.3	0.087	9.23	0.034	0.270	3.7	33.7	4.6	225.2	16.2	0.850	72.26	0.142	16.24	13.8	201.3	20.7
Mean	26.5	3.1	0.135	5.28	0.018	0.299	5.0	59.1	6.9	175.0	12.7	0.907	29.95	0.143	14.63	15.3	226.4	16.3
S.D.	5.0	0.9	0.038	4.34	0.005	0.112	1.2	21.7	2.3	62.0	4.2	0.313	23.03	0.062	4.43	6.4	103.6	4.6

Table 2.5. (continued).

SITE	ATKN	ATKP	AMG	ACA	AK	ABRAYP	AHBUF	BTKN	BTKP	BMG	BCA	BK	BBRAYP	BHBUF	CTKN	CTKP
	<------------								kg/ha							------------>
A	2603.5	335.3	101.8	2565.4	54.2	66.9	1.03E-6	4562.2	2684.8	894.2	17264.0	503.4	139.1	1.46E-5	444.2	507.2
B	1426.2	140.7	65.0	805.9	34.5	7.5	2.10E-6	6461.1	3921.1	3898.7	23058.6	1283.4	133.3	3.16E-4	2951.7	2569.5
C	914.8	74.6	34.8	579.2	31.9	4.9	1.75E-7	3987.4	3806.4	977.2	6990.7	600.0	640.8	7.04E-5	893.5	1155.6
D	1887.0	245.2	103.7	1508.8	52.1	19.1	7.25E-7	4843.9	2658.5	1208.0	16830.0	463.0	165.5	3.39E-5	105.3	573.2
E	1754.8	175.9	88.3	1508.8	43.0	9.3	2.75E-7	5112.3	2424.6	1209.2	10820.4	457.6	106.4	1.02E-4	960.7	994.6
F	2425.4	506.5	105.2	1607.1	58.9	20.8	1.48E-6	5460.2	3865.1	3258.6	32528.1	1000.0	167.5	1.74E-4	655.8	848.7
G	1802.9	242.2	72.0	1312.3	49.9	12.8	2.13E-6	5271.3	5461.2	2777.2	30081.2	1259.9	745.3	2.64E-4	551.4	597.3
H	859.1	85.0	21.9	145.3	33.5	6.2	2.20E-4	1615.5	948.1	18.9	71.3	54.3	264.8	4.03E-4	692.6	679.1
I	1183.5	182.6	70.0	817.6	46.6	13.9	5.03E-6	5413.1	5580.8	4084.9	18688.4	1311.6	713.9	6.77E-5	1669.0	2170.8
J	1549.1	193.6	81.8	900.8	48.5	12.7	4.08E-6	3769.8	2518.0	2820.6	12938.3	1218.1	217.0	8.81E-5	1855.9	1963.2
K	1463.4	101.4	73.0	666.2	91.5	13.3	5.83E-6	3892.5	2913.8	3377.3	13493.5	1233.8	422.6	2.11E-4	1123.5	1168.2
L	932.0	110.7	15.4	86.1	26.7	4.2	1.41E-4	1169.7	823.5	100.3	472.6	76.0	223.7	3.04E-4	548.7	691.4
M	1230.8	87.5	45.0	255.1	25.6	7.8	1.22E-4	2882.3	1001.8	849.3	4545.8	248.4	227.6	2.70E-4	2196.9	1794.5
N	1757.9	151.8	177.8	1389.1	83.5	9.7	1.58E-5	3850.3	1734.8	2780.3	11856.4	892.5	75.8	2.59E-5	5025.6	4082.2
O	1956.1	167.0	240.2	2622.2	134.8	19.9	9.50E-7	4334.0	2518.2	2542.8	13494.2	629.6	175.8	1.25E-4	1268.5	1178.8
P	2005.7	107.2	132.3	1414.2	78.7	12.9	3.77E-5	2323.1	725.8	187.2	2307.5	81.0	106.4	2.93E-4	1732.3	1050.1
Q	636.4	50.6	26.5	154.3	32.5	4.9	1.75E-4	1139.0	617.7	45.7	205.2	116.0	182.1	3.53E-4	1531.2	1768.9
R	628.2	73.3	23.0	191.9	15.7	6.5	1.37E-4	1218.1	747.7	57.3	311.7	60.4	206.4	1.90E-4	1356.3	1538.4
S	2512.9	264.3	182.8	2011.6	76.3	17.7	1.41E-5	4433.6	3290.8	4227.4	32857.4	1136.3	45.2	9.01E-5	1089.2	1839.2
T	711.7	48.5	13.6	40.1	24.8	3.6	1.47E-4	1356.5	615.8	16.2	63.3	58.1	159.0	2.19E-4	504.7	701.5
U	904.1	79.0	70.5	904.3	39.8	6.1	9.55E-6	3195.4	1122.1	1704.0	6756.6	5987.0	30.5	1.25E-4	3673.2	3444.6
V	480.8	37.6	18.6	70.3	33.2	5.9	1.01E-4	1529.4	967.5	93.7	345.8	115.5	242.2	2.82E-4	746.1	876.5
W	800.1	54.7	30.9	146.3	38.9	6.2	2.31E-4	1104.8	334.1	40.5	155.4	63.9	40.6	2.24E-4	1078.5	880.4
X	536.9	44.4	17.5	111.7	20.1	3.1	1.24E-4	2547.5	1304.2	495.2	3237.4	335.4	264.6	5.15E-4	454.2	586.4
Mean	1373.5	148.3	75.5	908.9	49.0	12.3	6.25E-5	3394.7	2191.1	1569.4	10807.2	574.8	237.3	1.98E-4	1379.5	1402.52
S.D.	651.0	110.2	59.6	790.8	27.3	12.8	7.84E-5	1662.6	1534.4	1491.2	10678.0	472.6	198.7	1.30E-4	1136.6	926.7

Table 2.5 (continued).

SITE	CMG	CCA	CK	CBRAYP	CHBUF	TKN10	TKN30	TKN70	TKN150	TKP10	TKP30	TKP70	TKP150	CA10	CA30
	<------							kg/ha							------>
A	178.3	6907.1	44.8	10.3	3.03E-7	2654.5	873.5	1704.3	1794.3	363.0	482.6	930.6	1317.6	2663.4	1778.2
B	3395.8	33695.1	750.2	31.0	1.46E-5	2136.0	1481.3	2780.1	4441.5	463.1	686.0	1725.1	3757.0	1347.1	2013.7
C	824.4	6148.6	348.9	64.0	1.40E-5	1601.6	1063.6	1354.0	1790.3	393.6	1057.8	1182.9	2405.3	1130.3	1011.3
D	151.2	5711.6	22.1	3.0	1.55E-7	2566.9	1766.0	1145.3	1328.1	509.6	914.0	610.0	1416.3	2134.9	3321.8
E	488.2	9414.5	183.1	26.6	3.47E-6	2629.2	1580.1	1505.4	2154.0	374.3	711.0	807.8	1711.5	2107.3	1718.7
F	892.9	16775.2	201.3	5.9	2.23E-7	2199.1	1764.7	1819.4	2762.9	434.1	773.6	1218.8	2797.5	1281.4	2019.7
G	494.3	5536.8	132.8	14.3	1.28E-5	2310.3	1193.2	1438.6	2429.6	482.5	1076.1	1558.8	2828.7	1734.5	1004.8
H	107.9	659.2	71.4	215.5	1.67E-4	1054.9	766.2	855.5	490.6	156.3	357.6	660.0	538.4	153.1	30.5
I	2746.8	20796.5	675.5	36.4	2.85E-6	1767.9	1522.4	2319.8	2655.5	546.8	1511.3	2556.2	3319.8	1578.4	2802.0
J	3741.9	16811.8	532.3	45.0	1.88E-5	1954.4	1053.9	1901.7	2273.9	368.5	652.3	1300.2	2356.8	1202.8	1615.6
K	1174.7	15212.7	361.3	49.7	4.05E-5	1771.0	875.8	1391.5	1603.6	212.9	625.4	960.3	1612.0	838.1	884.2
L	418.6	8482.5	122.3	141.5	7.20E-5	1144.0	542.1	599.0	367.9	211.2	401.8	512.2	500.7	106.4	65.9
M	2282.0	21590.6	526.8	28.0	1.81E-5	1590.8	974.0	1329.1	2422.2	152.6	310.8	565.5	1855.6	312.0	432.1
N	4031.0	37242.0	950.5	58.6	1.40E-5	2128.6	1259.9	2222.6	5007.4	293.8	452.5	1190.7	4030.9	1873.7	2478.2
O	1392.5	14348.9	223.7	28.7	3.43E-6	2281.3	1104.6	2010.6	2142.2	308.0	679.1	1152.9	1723.8	2944.8	1872.7
P	662.7	6601.4	186.1	93.9	1.93E-5	2008.1	958.1	1610.3	1474.5	143.9	242.9	544.1	951.9	1443.8	975.2
Q	2496.1	29429.2	550.6	92.1	8.37E-5	788.7	519.9	654.2	1343.7	103.1	248.5	513.8	1571.8	166.2	89.1
R	1935.1	10145.3	350.0	196.4	9.25E-5	773.1	550.8	759.6	1119.1	146.6	311.0	590.9	1310.8	239.5	136.8
S	1800.2	29119.7	469.9	0	2.28E-7	2302.7	1284.0	1785.6	2663.4	230.3	404.3	1282.0	3477.7	1823.5	2107.7
T	301.0	7990.6	73.0	188.7	8.42E-5	982.6	626.2	611.6	352.4	109.4	268.6	443.5	544.3	51.7	29.4
U	3808.3	25843.7	551.5	26.2	1.60E-5	1363.4	1241.6	2116.5	3051.2	210.4	339.5	1073.5	3022.4	1381.8	2198.6
V	655.7	5594.3	255.6	105.0	1.49E-4	856.0	718.4	597.5	584.4	163.6	514.6	523.9	679.4	112.5	100.2
W	560.9	4545.9	190.0	148.9	1.04E-4	1084.4	762.8	677.8	458.4	126.7	278.2	392.7	471.6	176.1	145.5
X	525.8	7063.6	301.5	118.9	5.10E-5	908.7	1017.3	1044.5	568.1	175.0	512.6	581.7	665.7	184.7	178.5
Mean	1461.1	14402.8	336.5	72.0	4.09E-5	1702.4	1062.5	1426.5	1886.6	278.3	575.5	953.3	1869.5	1124.5	1208.8
S.D.	1286.9	10316.2	243.7	65.4	4.89E-5	631.6	372.2	622.5	1215.8	140.3	316.0	508.7	1116.0	882.8	1014.1

Table 2.5 (continued).

SITE	CA70	CA150	MG10	MG30	MG70	MG150	K10	K30	K70	K150	TKNSUM	TKPSUM	CASUM	MGSUM	KSUM
	<------							kg/ha							------>
A	5975.0	13585.8	105.0	61.0	273.5	659.7	57.2	60.3	153.3	228.1	7609.8	3527.3	26736.4	1174.3	602.3
B	10842.0	43356.8	119.8	332.7	1891.3	5015.7	76.3	190.3	660.2	1141.5	10838.9	6631.2	57559.6	7359.4	2068.2
C	1868.1	9717.7	78.3	77.7	211.1	1469.9	70.8	96.1	171.0	643.3	5795.7	5036.5	13718.5	1836.4	980.7
D	4165.8	14144.2	139.9	136.0	269.6	893.8	70.3	71.5	153.2	235.7	6836.2	3476.9	24050.4	1462.9	537.2
E	2302.9	15644.0	136.0	103.7	159.1	1389.1	64.7	66.8	114.0	439.1	7827.8	3595.0	21743.6	1785.7	683.7
F	9302.0	38329.6	94.3	264.4	1150.5	2747.7	62.3	119.2	387.0	691.9	8541.4	5220.2	50910.4	4256.6	1260.1
G	2326.7	26344.3	96.6	86.0	499.1	2366.8	67.7	77.2	334.5	835.9	7625.6	6300.7	36930.3	3343.5	1442.7
H	59.0	633.2	24.4	8.2	12.5	103.7	39.9	24.0	32.8	62.5	3167.1	1712.3	875.8	148.7	159.2
I	7492.7	28429.4	155.0	390.8	1687.6	4668.4	110.7	285.2	620.7	1017.1	8265.6	7934.2	40302.5	6901.7	2033.7
J	7927.3	19910.6	126.6	306.2	1872.1	4340.2	84.1	181.7	752.9	780.9	7174.9	4674.7	30650.8	6644.2	1798.9
K	5325.1	16970.4	104.5	136.6	1168.5	1665.2	116.8	107.7	399.4	573.9	6479.9	4183.3	29372.5	4625.0	1686.5
L	749.7	8119.5	19.8	13.7	137.5	363.4	36.6	30.7	59.3	98.5	2650.3	1625.6	9041.2	534.4	225.0
M	2724.4	22923.5	59.0	78.5	497.4	2541.4	36.5	45.8	135.9	582.7	6310.0	2883.9	26391.6	3176.3	800.8
N	9827.0	36283.9	261.3	466.1	2216.4	4042.2	116.2	196.3	671.2	941.5	10633.8	5968.8	50487.4	6989.1	1926.4
O	8872.7	16740.5	289.7	323.7	1550.8	2009.0	152.9	107.4	383.8	341.7	7558.6	3864.0	30465.4	4175.6	988.1
P	1635.3	6265.4	137.9	88.1	114.6	641.2	81.6	30.7	59.6	173.4	6061.1	1883.1	10323.1	982.2	345.8
Q	1290.2	28243.3	30.5	18.6	145.8	2373.5	42.0	44.6	107.6	504.8	3306.6	2437.2	29788.7	2568.3	699.1
R	389.3	9883.3	31.2	25.7	54.0	1904.5	24.7	28.3	43.7	329.4	3202.6	2359.3	10648.9	2015.4	426.1
S	12145.7	47911.8	164.5	289.8	1661.3	4095.0	68.0	136.3	476.0	1002.2	8035.7	5394.3	63988.7	6210.5	1682.4
T	286.8	7724.1	17.5	7.2	18.5	287.6	34.9	26.6	35.7	58.7	2572.8	1365.7	8094.0	330.8	155.8
U	5721.1	24203.2	135.7	467.8	1690.2	3289.2	72.3	208.1	437.0	471.9	7772.7	4645.8	33504.6	5582.9	1189.3
V	448.6	5349.1	31.2	26.8	119.3	590.6	53.9	46.1	90.6	213.8	2756.3	1881.6	6010.4	767.9	404.3
W	704.0	3821.9	38.5	33.9	161.9	397.9	53.1	44.0	80.2	115.5	2983.4	1269.2	4847.6	632.2	292.8
X	1042.3	9007.2	29.4	33.8	240.6	734.7	40.0	61.5	182.2	373.2	3538.6	1935.0	10412.8	1038.4	656.9
Mean	4309.4	18897.6	101.1	157.4	741.8	2024.6	68.1	95.3	272.6	494.0	6147.7	3741.9	26119.0	3105.9	960.3
S.D.	3861.0	12983.5	72.3	153.3	758.0	1532.6	31.0	70.6	230.3	329.0	2540.5	1876.0	17558.5	2426.3	634.4

Table 2.6. Site level values of field determined soil variables.

SITE	ASAND	ASILT	ACLAY	BSAND	BSILT	BCLAY	CSAND	CSILT	CCLAY	ACSFR	BCSFR	CCSFR	SAND30	SILT30	CLAY30	SLT150
	<------------------								%							------------------>
A	63.3	25.8	11.0	69.0	19.4	11.6	67.2	3.8	4.1	4.4	20.7	15.9	83	12	5	65
B	53.0	32.8	14.3	38.3	37.5	24.3	44.8	18.4	36.8	1.6	1.5	0.9	63	26	11	10
C	72.8	19.0	8.3	80.2	11.6	8.2	40.0	23.7	36.3	0.5	1.7	1.1	83	12	5	83
D	59.3	28.8	12.0	68.6	21.2	10.3	67.5	3.8	3.8	0.5	17.1	8.2	65	25	10	57
E	59.3	28.8	12.0	72.1	16.1	11.9	75.3	7.6	17.0	2.5	9.8	8.7	65	25	10	57
F	63.8	25.8	10.5	56.7	21.0	22.4	72.6	16.8	10.6	2.2	1.9	1.6	65	25	10	57
G	64.5	25.3	10.3	63.4	21.6	15.1	22.6	10.6	16.6	2.3	1.8	0.2	65	25	10	57
H	83.0	12.0	5.0	90.0	5.0	5.0	90.0	5.0	5.0	0.4	2.0	0.1	90	5	5	90
I	68.3	22.3	9.5	43.0	34.4	22.6	49.1	21.2	29.7	0.7	2.9	5.6	42	40	18	57
J	68.3	22.3	9.5	54.2	27.1	18.8	61.9	14.8	23.3	1.8	6.3	2.1	65	25	10	42
K	48.3	19.0	7.8	68.0	18.6	13.5	59.0	8.2	7.8	0.0	2.4	0.0	65	25	10	65
L	90.0	5.0	5.0	89.0	6.0	5.0	90.0	5.0	5.0	0.2	1.6	0.1	90	5	5	90
M	90.0	5.0	5.0	78.0	13.5	8.6	59.5	16.3	24.2	0.2	2.2	0.3	90	5	5	57
N	41.8	23.0	10.3	40.8	39.2	20.0	32.4	22.7	44.9	0.6	2.1	0.1	42	40	18	10
O	48.3	19.0	7.8	57.8	21.6	20.7	59.9	15.6	24.5	0.2	1.6	4.6	65	25	10	57
P	20.8	3.0	1.3	86.5	8.6	5.0	88.3	5.3	6.5	0.3	0.4	0.1	83	12	5	90
Q	90.0	5.0	5.0	90.0	5.0	5.0	66.2	8.5	25.3	0.0	4.9	0.3	90	5	5	90
R	90.0	5.0	5.0	90.0	5.0	5.0	89.5	5.3	5.3	0.1	6.4	1.0	90	5	5	90
S	75.3	17.0	7.8	62.9	16.1	21.0	10.0	35.0	55.0	1.0	0.8	1.0	65	25	10	57
T	90.0	5.0	5.0	90.0	5.0	5.0	90.0	5.0	5.0	0.0	2.9	0.3	90	5	5	90
U	56.0	32.8	11.3	54.4	29.0	16.7	73.2	8.9	18.0	1.2	2.3	0.1	65	25	10	10
V	90.0	5.0	5.0	87.2	7.9	5.0	89.1	5.0	5.9	0.6	10.5	2.0	90	5	5	83
W	86.5	8.5	5.0	85.1	10.0	5.0	87.5	5.0	7.5	0.4	9.1	2.5	83	12	5	90
X	90.0	5.0	5.0	83.1	10.0	6.9	85.5	5.0	9.5	0.4	7.6	1.8	83	12	5	57
Mean	69.3	16.7	7.8	70.7	17.1	12.2	65.5	11.5	17.8	0.9	5.0	2.4	74.0	17.8	8.2	63.0
S.D.	19.0	10.2	3.2	16.9	10.5	7.0	22.9	8.2	14.4	1.1	5.2	3.8	14.9	11.1	3.9	25.6

Table 2.6. (continued).

SITE	SILT150	CLT150	SGT150	CGT150	CGT150	SAND450	SILT450	CLAY450	HEAVS	HEAVSI	HEAVC	DEPVFS	DEPLS	DEPSL	DEPSCL	DEPTEX
	<------	------	------	------	------	%	------	------	------	------	------>	<------	------	cm	------	------>
A	25	10	57	15	28	57	15	28	57	15	28	500	15	70	50	45
B	55	35	10	55	35	10	55	35	57	15	28	500	15	25	49	43
C	12	5	20	65	15	57	15	28	57	15	28	500	15	142	185	179
D	15	28	57	15	28	57	15	28	57	15	28	500	500	15	98	15
E	15	28	57	15	28	57	15	28	57	15	28	500	500	17	137	105
F	15	28	57	15	28	57	15	28	57	15	28	500	500	18	57	52
G	15	28	57	15	28	57	15	28	57	15	28	500	500	30	93	88
H	5	5	90	5	5	90	5	5	90	5	5	500	500	500	500	500
I	15	28	33	35	32	33	35	32	33	35	32	500	15	33	64	49
J	40	18	57	15	28	57	15	28	57	15	28	500	47	18	43	39
K	25	10	57	15	28	57	15	28	57	15	28	307	63	52	173	135
L	5	5	90	5	5	90	5	5	83	12	5	500	220	500	500	500
M	15	28	10	55	35	10	55	35	10	55	35	500	83	48	115	100
N	55	35	10	55	35	10	55	35	10	55	35	500	379	22	60	48
O	15	28	57	15	28	57	15	28	57	15	28	500	500	18	59	40
P	5	5	65	25	10	65	25	10	33	35	32	177	49	198	244	125
Q	5	5	33	35	32	33	35	32	33	35	32	167	198	154	205	87
R	5	5	20	65	15	20	65	15	20	65	15	299	500	274	500	259
S	15	28	10	55	35	10	55	35	10	55	35	500	15	20	58	43
T	5	5	83	12	5	83	12	5	83	12	5	500	500	500	500	500
U	55	35	10	55	35	10	55	35	33	35	32	146	106	110	40	21
V	12	5	65	25	10	65	25	10	65	25	10	500	134	335	500	183
W	5	5	65	25	10	65	25	10	65	25	10	500	24	500	500	244
X	15	28	57	15	28	57	15	28	57	15	28	500	72	185	52	37
Mean	18.7	18.3	47.0	29.5	23.6	48.5	27.4	24.1	49.8	25.6	24.6	441.5	227.1	157.7	199.3	143.2
S.D.	16.2	12.2	26.0	20.1	10.8	25.4	18.8	10.7	22.5	16.8	10.1	120.9	213.2	178.8	185.6	153.0

Table 2.6. (continued).

SITE	TEXS	TEXSI	TEXC	BIC	OIWT	OEWT	ATHICK	ETHICK	BTHICK	BSTHICK	BTTHICK	AVALUE	BVALUE	EDC	DEPPH7	DEPCO3
	<-------- % ------->				<---- kg/ha ---->		<------------- cm ----------------->								<---- cm ---->	
A	57	15	28	4.25	3028.7	10400.0	9.0	0.0	97.8	18.0	0.0	2.0	4.0	0.0	51	103
B	10	55	35	5.00	2562.7	10396.3	3.3	3.3	89.0	13.3	0.0	2.0	3.8	1.8	67	67
C	57	15	28	5.00	3048.3	14921.3	2.3	4.3	123.5	40.8	0.0	2.3	3.8	2.3	121	358
D	65	25	10	4.50	2361.3	11550.0	4.8	2.5	122.3	29.8	0.0	2.0	4.0	1.3	64	114
E	57	15	28	5.00	2856.7	10605.0	4.5	4.0	104.8	28.8	0.0	3.0	4.0	0.5	107	107
F	57	15	28	5.00	2844.3	13685.7	7.8	5.1	104.3	11.0	0.0	2.0	4.5	1.0	68	68
G	57	15	28	5.00	2943.7	9375.0	5.5	2.8	140.3	43.5	0.0	2.3	4.3	0.8	99	99
H	90	5	5	1.00	2786.3	11226.3	5.5	5.5	49.0	46.3	0.0	2.8	4.5	1.8	237	328
I	33	35	32	5.00	3531.3	11608.0	3.3	1.8	95.5	13.5	55.5	2.3	4.0	1.0	73	112
J	57	15	28	4.50	3067.3	7326.0	4.0	1.3	70.3	10.5	33.0	2.0	3.8	1.0	77	85
K	60	28	12	4.75	2808.3	11412.0	3.3	5.5	114.3	25.8	0.0	2.0	4.0	3.5	107	127
L	90	5	5	0.75	2682.7	11632.0	4.0	1.0	43.0	34.3	0.0	2.5	4.8	0.5	92	170
M	10	55	35	3.75	3170.7	15722.3	4.3	5.5	65.8	37.3	0.0	2.0	3.8	1.0	98	112
N	10	55	35	5.00	3516.3	16247.3	4.3	8.5	65.0	0.0	24.3	2.3	4.3	2.5	44	69
O	57	15	28	5.00	2989.7	11404.0	5.3	3.3	77.3	0.0	29.8	2.0	4.5	1.3	61	103
P	65	25	10	4.00	3745.0	12270.3	6.0	9.8	54.8	43.8	0.0	2.0	3.3	3.5	112	218
Q	65	25	10	3.25	3251.0	12060.0	5.0	4.8	50.0	47.8	0.0	2.0	4.3	3.8	74	114
R	20	65	15	1.50	2640.3	8712.7	5.0	6.3	45.3	39.5	0.0	2.8	4.8	2.3	201	253
S	57	15	28	5.00	2584.7	5691.0	10.8	3.3	94.0	0.0	47.3	2.8	4.5	1.3	48	55
T	90	5	5	0.25	2174.7	10152.3	4.0	1.0	45.3	45.3	0.0	3.0	4.3	2.0	123	123
U	10	55	35	4.50	2540.0	12490.3	3.5	6.5	52.0	16.8	31.0	2.5	4.0	2.0	101	109
V	65	25	10	2.25	2815.3	14685.0	1.8	4.3	47.5	33.8	0.0	2.0	4.8	4.0	199	298
W	65	25	10	1.25	2805.0	13903.3	3.8	4.5	28.8	40.5	0.0	2.0	5.0	2.5	143	143
X	57	15	28	2.50	2520.7	14457.7	2.3	3.5	80.5	35.3	14.3	2.0	3.8	4.0	187	202
Mean	52.5	26.0	21.5	3.67	2886.5	11747.3	4.7	4.1	77.5	27.3	9.8	2.3	4.2	1.9	106.3	147.2
S.D.	24.6	17.9	11.1	1.63	374.2	2558.5	2.1	2.3	30.7	15.9	17.1	0.4	0.4	1.2	52.6	84.9

Table 2.6. (continued).

SITE	ROOTDEP cm	SLOPE %	ASPECT °	ELEV m	PHYSFORM	DRCLASS	MOTTDEP cm
A	127	18.5	190	372	4	3	500
B	84	17.8	8	375	4	4	24
C	93	2.3	0	408	7	4	94
D	127	4.3	0	387	7	4	36
E	133	11.3	286	396	4	3	168
F	121	7.8	285	378	4	4	23
G	118	7.3	40	378	5	4	45
H	151	12.8	146	408	4	3	290
I	141	4.0	45	366	7	5	30
J	125	5.0	90	341	5	5	129
K	148	7.5	337	280	7	5	37.5
L	127	10.0	280	335	4	2	500
M	98	3.7	0	323	5	4	90
N	156	9.0	270	317	1	3	111
O	128	15.0	140	347	4	3	500
P	122	14.5	108	323	4	3	135
Q	103	15.0	111	335	4	1	175
R	233	16.3	358	335	4	1	290
S	115	2.0	0	256	7	5	29
T	185	9.5	195	369	8	1	500
U	83	4.8	0	335	7	3	374
V	135	6.5	20	390	4	3	500
W	122	0.8	0	387	3	3	500
X	137	4.8	205	372	7	3	59.5
Mean	129.7	8.8	129.8	355	5.0	3.3	214.2
S.D.	31.8	5.3	122.5	38	1.7	1.2	191.3

soil nutrient contents gave more interpretable results. PCA's were performed on laboratory data sets summed by master horizon groups with and without the inclusion of organic horizons, and on laboratory data summed by depths. A separate PCA was performed on field data, and on a combination of laboratory and field data.

PCA of soil and forest floor laboratory data summed by horizons

PCA was performed on laboratory determined soil and forest floor variables which had been summed by the horizon groups Oi, Oe, A, B, and C above a 150 cm depth (Table 2.5). Because there were 24 observations, the number of variables used in PCA was limited to 23. Tables presenting regression coefficients of the variables with the PC's all use the first four PC's for consistency; four were used because in most of the analyses presented they have meaningful interpretations and eigenvalues greater than 1.0, whereas the fifth and higher PC's usually do not. Ranks of the eight coefficients with the highest absolute values in each PC have been included in the tables for ease of viewing and interpretation; eight were selected to include a third of the variables used in the analyses, and because variables with lower ranks are less important to the interpretation of the PC. Eight ranks were also used to maintain consistency in those tables which present results of analyses which used fewer than 23 variables. Plots of site locations with respect to the first three PC axes are presented; plots of the fourth axis contributed little pertinent information and are not included.

Regression coefficients of variables and the first four PC's are presented in Table 2.7, and the correlation matrix used in the PCA is presented in Table 2.8. Correlations in Table 2.8 which are greater than or equal to an absolute value of 0.404 are statistically significant at alpha=0.05 for n=24. The first PC summarized 45% of the variability in the data set, and emphasized Oi (undecomposed forest floor litter layer) nutrients, with the highest coefficients placed on Oi magnesium (Mg) and P. The coefficients are all positive, and values range only from 0.033 to 0.085, so this component shows only a relative size trend. Sites arrayed along this PC axis range from those with low amounts of nutrients to those with high amounts. The second PC, with an additional 23% of the variability, emphasized Oe nutrients with positive coefficients and some A and B horizon nutrients with negative coefficients. The third PC contained 13% of the variability, and placed large negative coefficients on C horizon variables. The fourth PC placed positive coefficients on B horizon variables and negative coefficients on A horizon variables, accounting for 7% of the total variability in the data set. None of the PC's placed large coefficients on a single nutrient or group of nutrients across all the horizons, but rather, sequentially emphasized master horizon groupings of all nutrients in the

Table 2.7. Correlations between laboratory determined soil variables and the first four principal components, with ranks of the eight highest correlations for each PC. Data are summed by horizon groups.

Variable	PC 1(Rank)	PC 2(Rank)	PC 3(Rank)	PC 4(Rank)
Eigenvalue	10.40	5.23	3.00	1.65
Percent	45.2	22.7	13.0	7.2
OITKN	0.8234(4)	0.1960	0.3129	0.0697
OITKP	0.8483(2)	-0.0555	0.2136	0.0461
OIMG	0.8815(1)	-0.0312	0.1036	-0.2832(8)
OICA	0.8118(5)	-0.3003	0.3078	0.1021
OIK	0.8275(3)	0.0068	0.0332	-0.0907
OETKN	0.3382	0.7880(1)	0.4184(7)	0.1181
OETKP	0.4435	0.6974(4)	0.4562(6)	0.2098
OEMG	0.8037(6)	0.4306	0.2938	0.0414
OECA	0.7082(8)	0.2708	0.4592(5)	0.0459
OEK	0.4893	0.7160(3)	0.3329	0.1574
ATKN	0.4980	-0.7435(2)	0.1500	-0.2114
AMG	0.6909	-0.4459	0.1245	-0.4597(2)
ACA	0.5721	-0.6617(6)	0.2697	-0.3008(7)
AK	0.5908	-0.4051	0.2296	-0.4194(4)
BTKP	0.5491	-0.5124(7)	0.0463	0.6406(1)
BMG	0.7234(7)	-0.4344	-0.3418	0.3104(6)
BCA	0.5256	-0.6948(5)	-0.1191	0.3479(5)
BK	0.6862	-0.4314	-0.3048	0.4399(3)
CTKN	0.6743	0.4879(8)	-0.4037(8)	-0.2650
CTKP	0.6882	0.4157	-0.5296(4)	-0.1595
CMG	0.6375	0.3359	-0.6445(1)	-0.0704
CCA	0.6512	0.1818	-0.6239(2)	-0.0908
CK	0.6735	0.4347	-0.5626(3)	0.0650

Table 2.8. Simple linear correlations among variables used in principal component analysis of laboratory determined variables summed by horizons, including organic layers.

	OITKN	OITKP	OIMG	OICA	OIK	OETKN	OETKP	OEMG	OECA	OEK	ATKN	AMG
OITKN	1.000	0.835	0.781	0.787	0.754	0.504	0.581	0.791	0.782	0.560	0.250	0.438
OITKP	0.835	1.000	0.809	0.738	0.902	0.275	0.396	0.652	0.560	0.423	0.351	0.597
OIMG	0.781	0.809	1.000	0.768	0.849	0.236	0.295	0.686	0.670	0.331	0.548	0.682
OICA	0.787	0.738	0.768	1.000	0.601	0.115	0.257	0.629	0.741	0.224	0.668	0.624
OIK	0.754	0.902	0.849	0.601	1.000	0.250	0.324	0.548	0.457	0.401	0.351	0.554
OETKN	0.504	0.275	0.236	0.115	0.250	1.000	0.976	0.754	0.610	0.946	-0.336	-0.063
OETKP	0.581	0.396	0.295	0.257	0.324	0.976	1.000	0.813	0.685	0.969	-0.250	0.019
OEMG	0.791	0.652	0.686	0.629	0.548	0.754	0.813	1.000	0.878	0.806	0.146	0.404
OECA	0.782	0.560	0.670	0.741	0.457	0.610	0.685	0.878	1.000	0.633	0.279	0.339
OEK	0.560	0.423	0.331	0.224	0.401	0.946	0.969	0.806	0.633	1.000	-0.255	0.051
ATKN	0.250	0.351	0.548	0.668	0.351	-0.336	-0.250	0.146	0.279	-0.255	1.000	0.781
AMG	0.438	0.597	0.682	0.624	0.554	-0.063	0.019	0.404	0.339	0.051	0.781	1.000
ACA	0.385	0.493	0.605	0.759	0.395	-0.254	-0.138	0.276	0.404	-0.141	0.908	0.874
AK	0.343	0.608	0.579	0.483	0.597	-0.005	0.074	0.336	0.263	0.116	0.644	0.893
BTKP	0.440	0.577	0.342	0.689	0.425	-0.145	0.020	0.251	0.286	-0.003	0.495	0.310
BMG	0.356	0.575	0.478	0.553	0.559	-0.151	-0.022	0.319	0.190	0.039	0.559	0.563
BCA	0.233	0.342	0.311	0.632	0.266	-0.319	-0.185	0.151	0.183	-0.183	0.768	0.546
BK	0.374	0.572	0.457	0.594	0.545	-0.166	-0.024	0.285	0.231	0.013	0.506	0.431
CTKN	0.521	0.384	0.621	0.286	0.524	0.414	0.386	0.642	0.459	0.472	-0.001	0.299
CTKP	0.502	0.407	0.566	0.285	0.516	0.309	0.309	0.588	0.402	0.395	-0.008	0.294
CMG	0.415	0.407	0.516	0.254	0.510	0.174	0.187	0.466	0.257	0.300	-0.035	0.223
CCA	0.309	0.305	0.471	0.276	0.416	0.130	0.153	0.452	0.264	0.283	0.175	0.370
CK	0.447	0.449	0.517	0.235	0.561	0.343	0.369	0.550	0.318	0.487	-0.082	0.183

	ACA	AK	BTKP	BMG	BCA	BK	CTKN	CTKP	CMG	CCA	CK
OITKN	0.385	0.343	0.440	0.356	0.233	0.374	0.521	0.502	0.415	0.309	0.447
OITKP	0.493	0.608	0.577	0.575	0.342	0.572	0.384	0.407	0.407	0.305	0.449
OIMG	0.605	0.579	0.342	0.478	0.311	0.457	0.621	0.566	0.516	0.471	0.517
OICA	0.759	0.483	0.689	0.553	0.632	0.594	0.286	0.285	0.254	0.276	0.235
OIK	0.395	0.597	0.425	0.559	0.266	0.545	0.524	0.516	0.510	0.416	0.561
OETKN	-0.254	-0.005	-0.145	-0.151	-0.319	-0.166	0.414	0.309	0.174	0.130	0.343
OETKP	-0.138	0.074	0.020	-0.022	-0.185	-0.024	0.386	0.309	0.187	0.153	0.369
OEMG	0.276	0.336	0.251	0.319	0.151	0.285	0.642	0.588	0.466	0.452	0.550
OECA	0.404	0.263	0.286	0.190	0.183	0.231	0.459	0.402	0.257	0.264	0.318
OEK	-0.141	0.116	-0.003	0.039	-0.183	0.013	0.472	0.395	0.300	0.283	0.487
ATKN	0.908	0.644	0.495	0.559	0.768	0.506	-0.001	-0.008	-0.035	0.175	-0.082
AMG	0.874	0.893	0.310	0.563	0.546	0.431	0.299	0.294	0.223	0.370	0.183
ACA	1.000	0.738	0.464	0.501	0.667	0.439	0.042	0.048	0.004	0.156	-0.076
AK	0.738	1.000	0.263	0.505	0.408	0.402	0.177	0.140	0.088	0.213	0.066
BTKP	0.464	0.263	1.000	0.788	0.834	0.851	-0.071	0.041	0.101	0.162	0.166
BMG	0.501	0.505	0.788	1.000	0.847	0.959	0.319	0.435	0.487	0.585	0.508
BCA	0.667	0.408	0.834	0.847	1.000	0.831	-0.004	0.098	0.134	0.333	0.137
BK	0.439	0.402	0.851	0.959	0.831	1.000	0.265	0.372	0.456	0.483	0.468
CTKN	0.042	0.177	-0.071	0.319	-0.004	0.265	1.000	0.957	0.863	0.775	0.846
CTKP	0.048	0.140	0.041	0.435	0.098	0.372	0.957	1.000	0.932	0.856	0.909
CMG	0.004	0.088	0.101	0.487	0.134	0.456	0.863	0.932	1.000	0.853	0.920
CCA	0.156	0.213	0.162	0.585	0.333	0.483	0.775	0.856	0.853	1.000	0.880
CK	-0.076	0.066	0.166	0.508	0.137	0.468	0.846	0.909	0.920	0.880	1.000

order Oi, Oe, C, and AB.

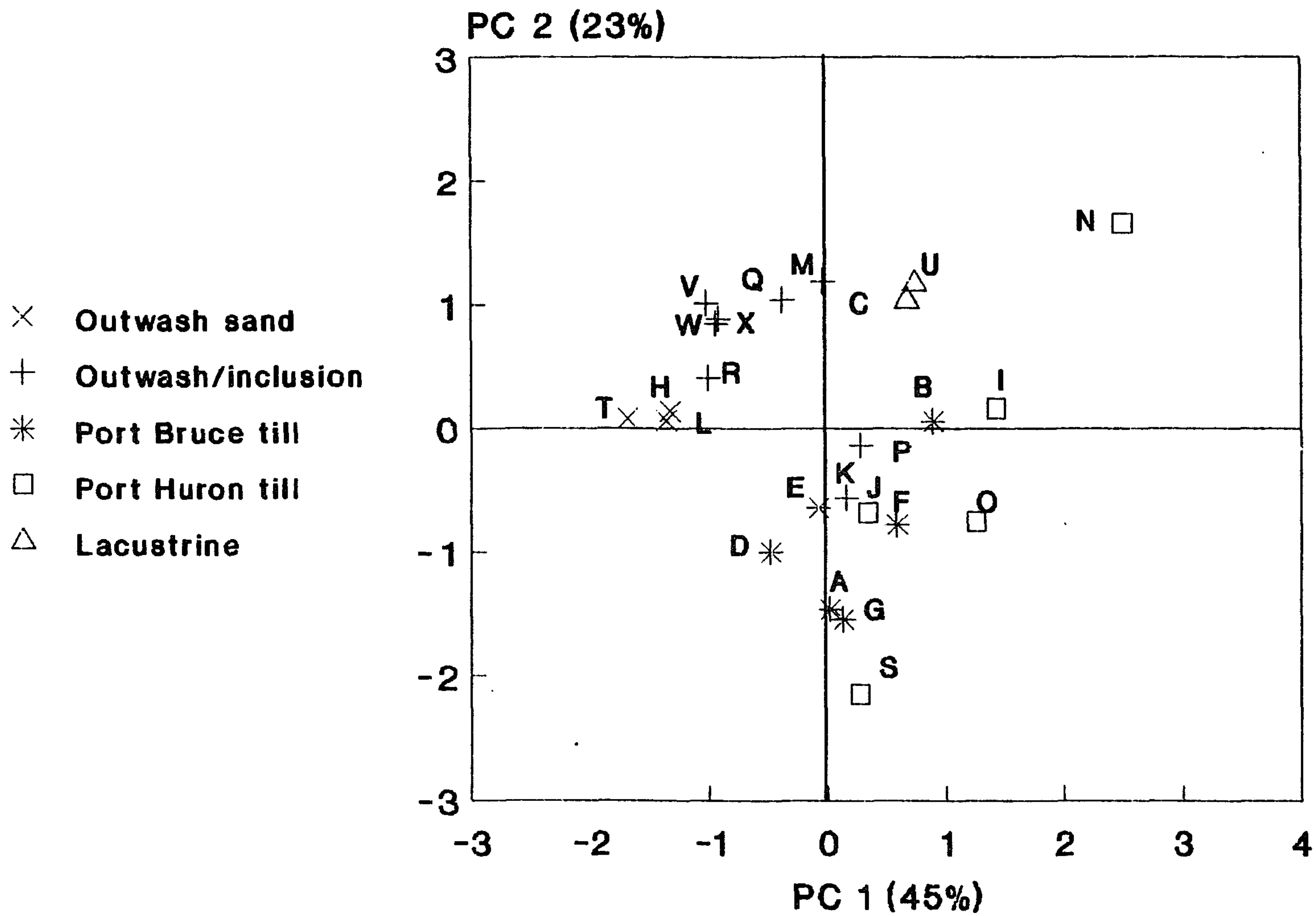
A plot of site ordinations in relation to PC's 1 and 2 is presented in Figure 2.4. Sites formed in outwash, T, H, and L, are located very near each other in this plot, which represents 68% of the variability in the data set. The location of these sites at the most negative end of PC 1 indicates that they contained the lowest overall level of nutrients, and an intermediate level of Oe nutrients.

Soils formed in outwash with ice-rafted inclusions are more dispersed in relation to each other than are the outwash sand sites. Their location with respect to the PC's indicates that they contain intermediate levels of nutrients overall, and slightly higher levels of Oe nutrients than other groups of sites. Some of these sites have nutrient levels similar to those of till soils.

Till soils dating from Port Bruce and Port Huron deposition are not cleanly separated from each other by the ordination along PC's 1 and 2. Generally speaking, the Port Bruce till sites are located nearer the origin of PC 1, and more to the negative extreme of PC 2. Port Huron till sites are located more toward the positive end of PC 1, with wide dispersion along PC 2. Thus, the Port Huron sites contain greater nutrient levels overall, and exhibit more variation in Oe nutrients than the Port Bruce sites.

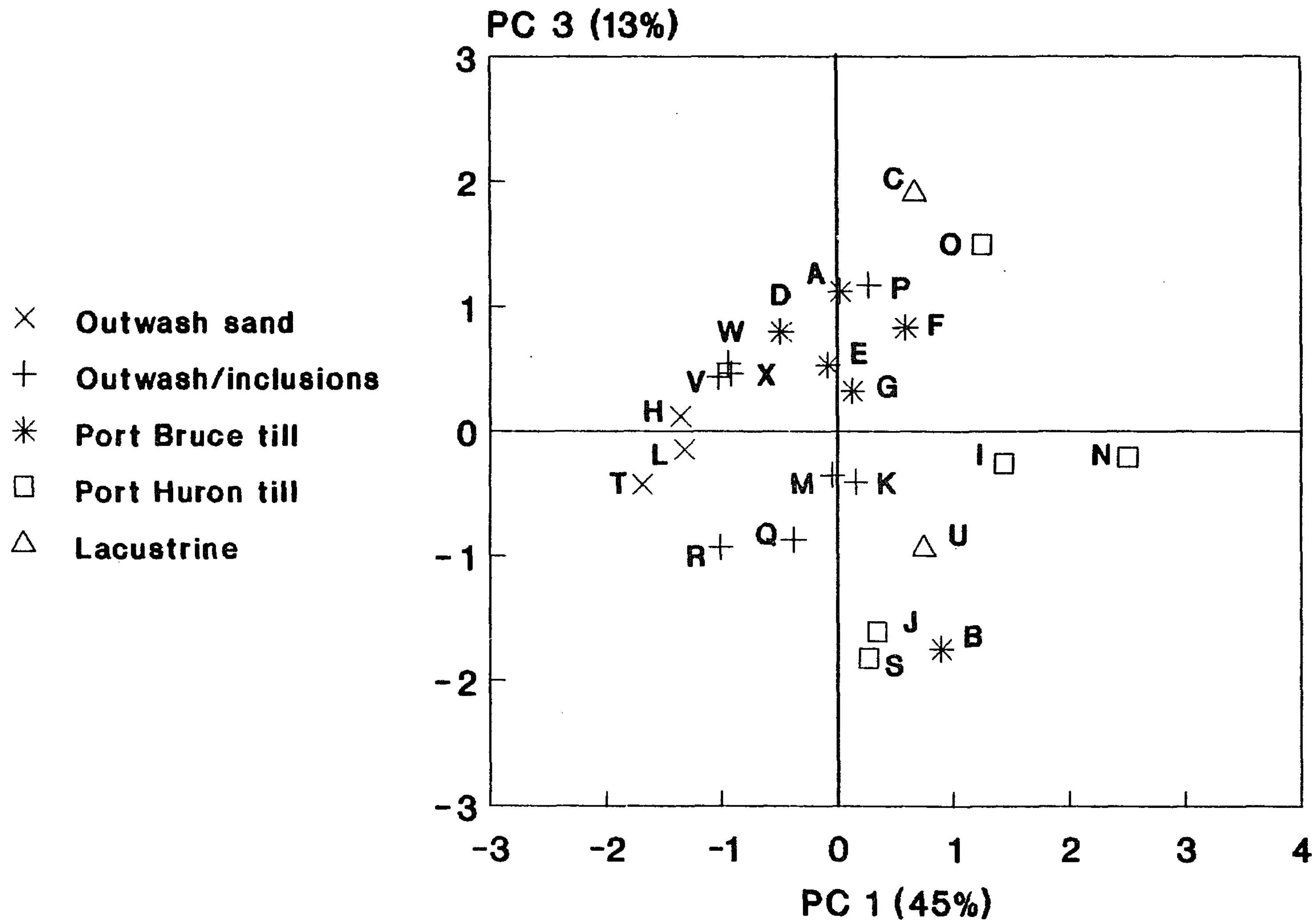
Figure 2.5 displays site locations with respect to PC 1 and PC 3 of laboratory data summed by horizons. PC 3 summarizes 13% of the variability of the data set, and is

Figure 2.4. Location of sites with respect to PC 1 and PC 2 of laboratory determined soil variables summed by horizon and averaged within a site.



PC 2 (23%)
PC 1 (45%)
Outwash sand
Outwash/inclusion
Port Bruce till
Port Huron till
Lacustrine
3
2
1
0
-1
-2
-3
-3
-2
-1
0
1
2
3
4
N
U
M
Q
V
C
W
X
R
H
T
L
B
I
P
K
E
J
F
O
D
A
G
S

Figure 2.5. Location of sites with respect to PC 1 and PC 3 of laboratory determined soil variables summed by horizon and averaged within a site.



PC 3 (13%)
PC 1 (45%)
Outwash sand
Outwash/inclusions
Port Bruce till
Port Huron till
Lacustrine
3
2
1
0
-1
-2
-3
-3
-2
-1
0
1
2
3
4
C
O
A
P
D
W
F
E
V
X
G
H
I
N
L
T
M
K
Q
U
R
J
B
S

primarily associated with characteristics of the C horizon. As in the previous figure of PC's 1 and 2, the outwash sand sites are closely grouped with respect to both axes. Sites formed in outwash with inclusions are dispersed along PC 3, and the two lacustrine sites are widely separated, indicating differences in nutrient content of the C horizon. The two till site groups are more separated by PC 3 than by PC 2, with the exceptions of sites B and O. C horizon nutrient content of the tills differs, due largely to the greater thickness of B horizons on Port Bruce sites, and the consequently lower calculated nutrient content of the C horizon.

PCA of laboratory data summed by horizons and including forest floor layers displayed an overall size trend in nutrient content, and especially emphasized forest floor nutrients. The first four PC's were identified with particular horizons rather than individual soil nutrients. Sites belonging to different depositional environments were generally separated along PC axes 1, 2, and 3, with sites formed in outwash sand exhibiting the closest groupings. Port Huron and Port Bruce till sites were not well separated, but an overall trend is evident for the groups. Sites formed in outwash sand with ice-rafted inclusions were placed between the outwash and till sites.

PCA of mineral soil laboratory data summed by horizons

The PCA performed on laboratory data including organic horizons was strongly influenced by the nutrient content of these layers. A PCA of the relationships among sites using only data derived from mineral soil analyses was also performed. Laboratory-determined variables summed by master horizon groups A, B, and C above a depth of 150 cm were used. All 21 variables available for this analysis were used in the PCA. Regression coefficients of the variables and the first four PC's appear in Table 2.9, and the correlation matrix for the PCA appears in Table 2.10. Correlations presented in Table 2.10 which are greater than or equal to an absolute value of 0.404 are significant at alpha=0.05 for n=24. Here, with Oi and Oe layers eliminated from the analysis, A and B horizon nutrients received the largest coefficients in the first PC, which accounted for 48% of the total variability. The first PC contained both positive and negative coefficients, with negative coefficients placed on hydrogen (H) ion concentrations. Acidity counterbalances desirable soil nutrients in the PC, and it is reasonable to conclude that soils with high acidity levels would be those with low amounts of other extractable nutrients. The high negative coefficient placed on Bray's P in the C horizon is also interpretable. Till soils of the region are calcareous, so that a Bray's weak acid solution fails to extract much P from them, and higher levels of Bray's extractable P are present in C horizons of sandy infertile soils. The second PC, accounting for 22% of total variability, emphasizes C horizon nutrients with

Table 2.9. Correlations between laboratory determined mineral soil variables and the first four principal components, with ranks of the eight highest correlations for each PC. Data are summed by horizon groups.

Variable	PC 1(Rank)	PC 2(Rank)	PC 3(Rank)	PC 4(Rank)
Eigenvalue	10.13	4.69	2.39	0.93
Percent	48.2	22.3	11.4	4.4
ATKN	0.8176(8)	-0.3863(8)	-0.3166(8)	-0.0469
ATKP	0.7196	-0.4502(7)	-0.0419	-0.29767(4)
AMG	0.7615	-0.0364	-0.5021(3)	0.3675(2)
ACA	0.8120	-0.3547	-0.4084(6)	0.0660
AK	0.6197	-0.1117	-0.4172(5)	0.6264(1)
ABRAYP	0.4925	-0.5168(6)	-0.3222(7)	-0.3313(3)
AHBUF	-0.8909(2)	0.0763	-0.0890	-0.0174
BTKN	0.8944(1)	-0.1218	0.2734	-0.0745
BTKP	0.7543	-0.2002	0.5984(2)	0.0452
BMG	0.8705(5)	0.1932	0.2875	0.1543(7)
BCA	0.8706(4)	-0.2118	0.2348	-0.0697
BK	0.8399(7)	0.1441	0.4313(4)	0.0954
BBRAYP	0.0925	-0.1831	0.8300(1)	0.2476(5)
BHBUF	-0.6461	0.0497	0.2253	0.1878(6)
CTKN	0.3017	0.8689(4)	-0.2269	-0.0064
CTKP	0.3740	0.8953(2)	-0.1252	-0.0620
CMG	0.3814	0.8789(3)	-0.0057	-0.1035
CCA	0.5029	0.7684(5)	-0.0936	-0.1027
CK	0.3553	0.8965(1)	0.1151	-0.0215
CBRAYP	-0.8802(3)	0.0597	-0.0360	0.1354(8)
CHBUF	-0.8577(6)	0.0386	0.0130	0.1182

Table 2.10. Simple linear correlations among variables used in principal component analysis of laboratory determined mineral soil variables summed by horizons.

	ATKN	ATKP	AMG	ACA	AK	ABRAYP	AHBUF	BTKN	BTKP	BMG	BCA	BK	BBRAYP	BHBUF	CTKN	CTKP	CMG	CCA	CK	CBRAYP	CHBUF
ATKN	1.000	0.836	0.781	0.908	0.644	0.700	-0.682	0.685	0.495	0.559	0.768	0.506	-0.148	-0.540	-0.001	-0.008	-0.035	0.175	-0.082	-0.709	-0.712
ATKP	0.836	1.000	0.492	0.712	0.343	0.643	-0.572	0.673	0.592	0.540	0.825	0.519	-0.006	-0.464	-0.167	-0.114	-0.078	0.096	-0.147	-0.625	-0.580
AMG	0.781	0.492	1.000	0.874	0.893	0.406	-0.620	0.521	0.310	0.563	0.546	0.431	-0.245	-0.537	0.299	0.294	0.223	0.370	0.183	-0.592	-0.623
ACA	0.908	0.712	0.874	1.000	0.738	0.722	-0.726	0.668	0.464	0.501	0.667	0.439	-0.151	-0.616	0.042	0.048	0.004	0.156	-0.076	-0.707	-0.711
AK	0.644	0.343	0.893	0.738	1.000	0.342	-0.519	0.386	0.263	0.505	0.408	0.402	-0.095	-0.394	0.177	0.140	0.088	0.213	0.066	-0.458	-0.439
ABRAYP	0.700	0.643	0.406	0.722	0.342	1.000	-0.413	0.400	0.292	0.182	0.427	0.202	-0.086	-0.481	-0.199	-0.203	-0.190	-0.087	-0.260	-0.454	-0.406
AHBUF	-0.682	-0.572	-0.620	-0.726	-0.519	-0.413	1.000	-0.857	-0.722	-0.717	-0.715	-0.748	-0.202	0.636	-0.212	-0.269	-0.270	-0.297	-0.230	0.838	0.844
BTKN	0.685	0.673	0.521	0.668	0.386	0.400	-0.857	1.000	0.868	0.810	0.859	0.825	0.255	-0.483	0.131	0.191	0.210	0.320	0.230	-0.829	-0.794
BTKP	0.495	0.592	0.310	0.464	0.263	0.292	-0.722	0.868	1.000	0.788	0.834	0.851	0.640	-0.391	-0.071	0.041	0.101	0.162	0.166	-0.655	-0.615
BMG	0.559	0.540	0.563	0.501	0.505	0.182	-0.717	0.810	0.788	1.000	0.847	0.959	0.228	-0.411	0.319	0.435	0.487	0.585	0.508	-0.690	-0.638
BCA	0.768	0.825	0.546	0.667	0.408	0.427	-0.715	0.859	0.834	0.847	1.000	0.831	0.194	-0.410	-0.004	0.098	0.134	0.333	0.137	-0.761	-0.676
BK	0.506	0.519	0.431	0.439	0.402	0.202	-0.748	0.825	0.851	0.959	0.831	1.000	0.376	-0.394	0.265	0.372	0.456	0.483	0.468	-0.690	-0.633
BBRAYP	-0.148	-0.006	-0.245	-0.151	-0.095	-0.086	-0.202	0.255	0.640	0.228	0.194	0.376	1.000	0.016	-0.266	-0.204	-0.131	-0.245	-0.010	-0.088	-0.084
BHBUF	-0.540	-0.464	-0.537	-0.616	-0.394	-0.481	0.636	-0.483	-0.391	-0.411	-0.410	-0.394	0.016	1.000	-0.208	-0.305	-0.241	-0.202	-0.148	0.537	0.581
CTKN	-0.001	-0.167	0.299	0.042	0.177	-0.199	-0.212	0.131	-0.071	0.319	-0.004	0.265	-0.266	-0.208	1.000	0.957	0.863	0.775	0.846	-0.187	-0.234
CTKP	-0.008	-0.114	0.294	0.048	0.140	-0.203	-0.269	0.191	0.041	0.435	0.098	0.372	-0.204	-0.305	0.957	1.000	0.932	0.856	0.909	-0.252	-0.276
CMG	-0.035	-0.078	0.223	0.004	0.088	-0.190	-0.270	0.210	0.101	0.487	0.134	0.456	-0.131	-0.241	0.863	0.932	1.000	0.853	0.920	-0.283	-0.290
CCA	0.175	0.096	0.370	0.156	0.213	-0.087	-0.297	0.320	0.162	0.585	0.333	0.483	-0.245	-0.202	0.775	0.856	0.853	1.000	0.880	-0.420	-0.388
CK	-0.082	-0.147	0.183	-0.076	0.066	-0.260	-0.230	0.230	0.166	0.508	0.137	0.468	-0.010	-0.148	0.846	0.909	0.920	0.880	1.000	-0.260	-0.259
CBRAYP	-0.709	-0.625	-0.592	-0.707	-0.458	-0.454	0.838	-0.829	-0.655	-0.690	-0.761	-0.690	-0.088	0.537	-0.187	-0.252	-0.283	-0.420	-0.260	1.000	0.852
CHBUF	-0.712	-0.580	-0.623	-0.711	-0.439	-0.406	0.844	-0.794	-0.615	-0.638	-0.676	-0.633	-0.084	0.581	-0.234	-0.276	-0.290	-0.388	-0.259	0.852	1.000

positive coefficients, and places negative coefficients on A and B horizon nutrients. The third PC, with 11% of the variability, places high positive coefficients on B horizon nutrients, and negative coefficients on A horizon variables. The fourth PC does not exhibit a meaningful pattern of horizon weightings, and accounts for only 4% of the variability in the data set. The PCA of laboratory-determined mineral soil data again identified important horizon groups rather than individual nutrients, and showed that B and C horizons contain more overall variability than A horizons. This result is likely due to soil variability resulting from glacial activity, so that there is a range in nutrient values related to textures.

Figure 2.6 shows the locations of sites with respect to PC 1 and PC 2 of laboratory-determined mineral soil variables. Locations and groupings of sites are similar to those derived from PCA of data which included organic horizons, shown in Figure 2.4, but PCA of mineral soil data provided a better separation of the site groups. Sites formed in outwash with ice-rafted inclusions are more distinctly grouped than in the previous analysis. Sites are arrayed along PC 1 to range from outwash sand soils, through the outwash with ice-rafted inclusions group, to till soils. The second PC separates Port Bruce till from Port Huron till, with the exception of Port Bruce site B, which was also grouped together with Port Huron sites in the previous PCA of soils data including organic horizons (Figure 2.5).

Figure 2.6. Location of sites with respect to PC 1 and PC 2 of laboratory determined mineral soil variables summed by horizon and averaged within a site.

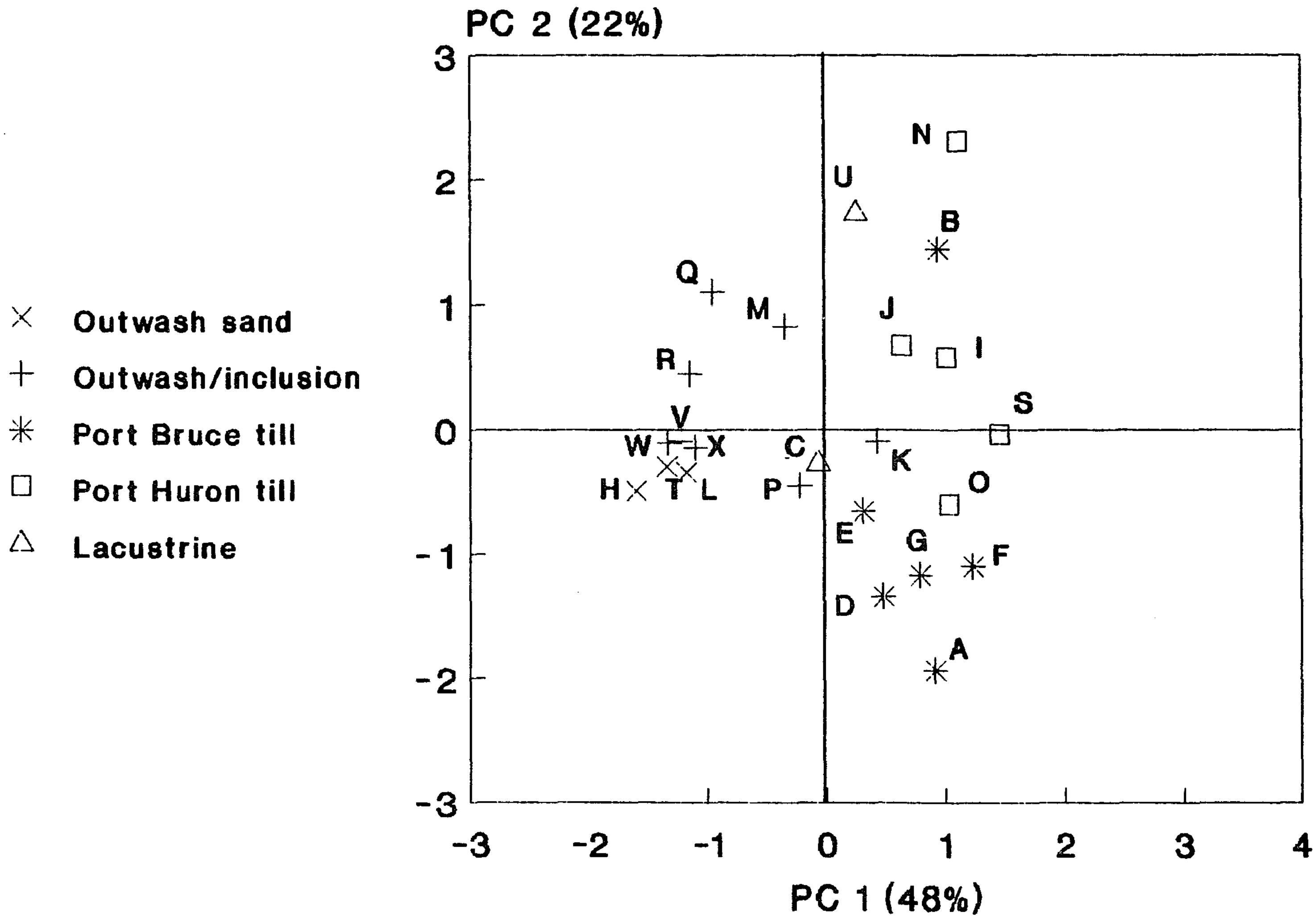
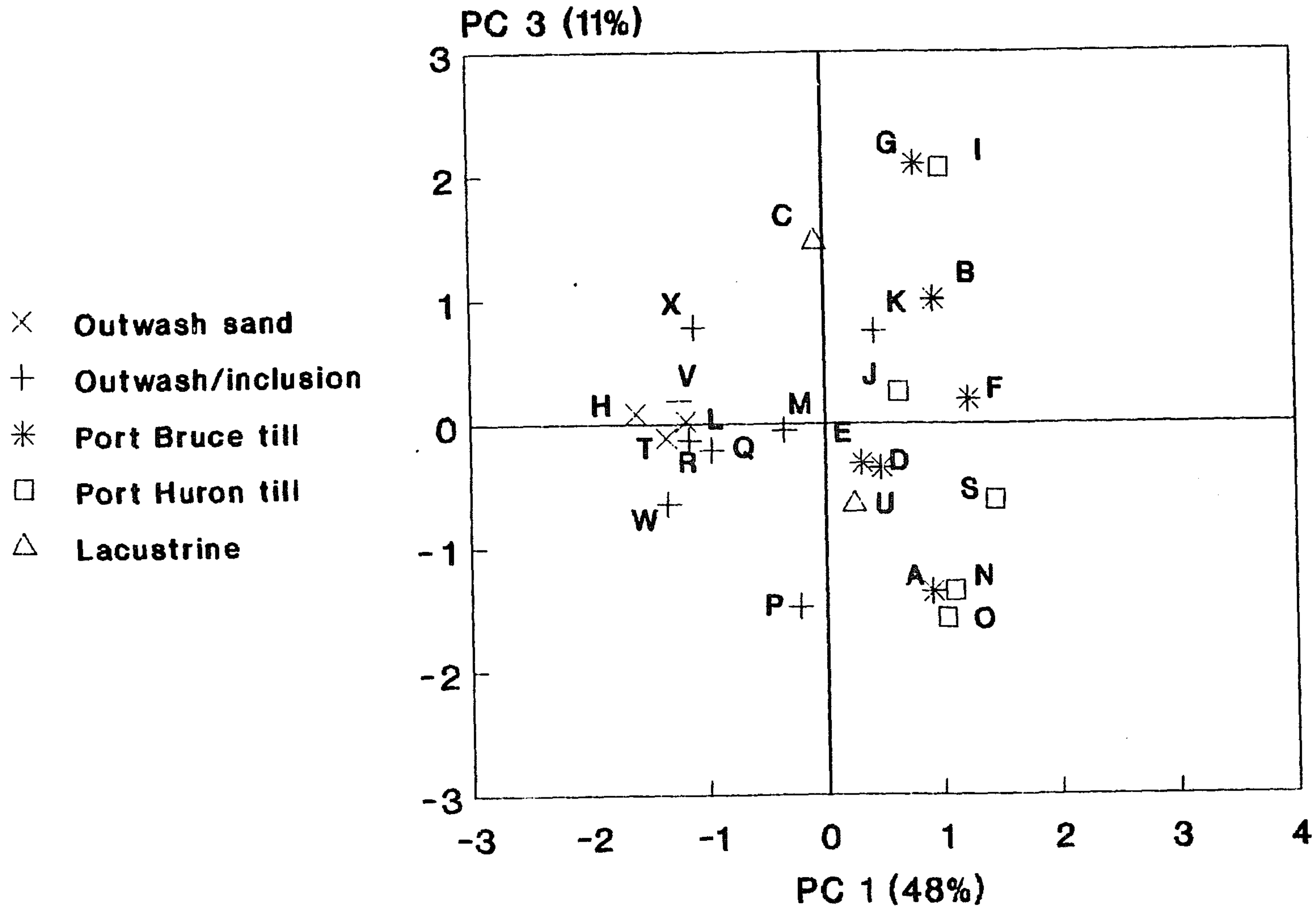

PC 2 (22%)
PC 1 (48%)
3
2
1
0
-1
-2
-3
-3
-2
-1
0
1
2
3
4
Outwash sand
Outwash/inclusion
Port Bruce till
Port Huron till
Lacustrine
N
U
B
Q
M
J
I
R
S
V
W
X
C
K
H
T
L
P
O
E
G
F
D
A

Figure 2.7 displays site locations with respect to PC axes 1 and 3 of mineral soil laboratory data. PC 3 includes 11.4% of the variability in the data set, with B horizon variables receiving high positive coefficients, and A horizon variables receiving negative coefficients. Outwash sand sites H, L, and T are closely grouped, but other sites are not arrayed along PC 3 in a manner which agrees with groupings by depositional environment. Sites formed in outwash with ice-rafted inclusions, lacustrine material, and tills, are not separated along PC 3.

PCA of mineral soil laboratory data produced a site ordination similar to that produced by PCA of laboratory data which included organic horizons. The simple correlation of site scores on the first axes of the two separate PCA's was r=0.817, significant at alpha=0.05, and Spearman's coefficient of rank correlation was r_s=0.810, also significant at alpha=0.05. The correlations of the two ordinations indicate that although organic horizon nutrients express greater variability, similar information regarding site relationships may be obtained from mineral soil horizon nutrients. The B horizon was the most important source of variability in mineral soil layers for these sites, which corresponds with the recognized importance of B horizons in classic soil-site studies (Coile 1952, Ralston 1964). It also corresponds with the principle of diagnostic spodic and argillic horizons as defined in Soil Taxonomy (Soil Survey Staff 1975).

Figure 2.7. Location of sites with respect to PC 1 and PC 3 of laboratory determined mineral soil variables summed by horizon and averaged within a site.



PC 3 (11%)
PC 1 (48%)
3
2
1
0
-1
-2
-3
-3
-2
-1
0
1
2
3
4
G
I
C
B
K
X
J
F
V
H
L
M
E
T
Q
R
D
S
U
W
A
N
P
O
Outwash sand
Outwash/inclusion
Port Bruce till
Port Huron till
Lacustrine

PCA of mineral soil laboratory data summed by depths

Studies reported in the literature have sometimes used soil data which were summed by horizons, while others have used depth sums. PCA was here applied to depth sums to determine whether they produced more interpretable results than PCA's of horizon sums, and to determine whether PCA site ordinations corresponded with those of horizon sums.

Table 2.11 presents regression coefficients of the variables and the first four PC's of mineral soil laboratory data summed by depths of 0-10 cm, 10-30 cm, 30-70 cm, and 70-150 cm. Table 2.12 presents the correlation matrix used for the PCA. Correlations in Table 2.12 which are greater than or equal to an absolute value of 0.404 are statistically significant at alpha=0.05 for n=24. Depths used for the sums were intended to correspond roughly with natural horizon development in the study area. The 0-10 cm depth normally included A horizons, the 10-30 cm depth corresponded approximately with upper B horizon development, the 30-70 cm depth took in most lower B horizon development, and the 70-150 cm depth usually included C horizons. A 0-150 cm depth sum was also included to represent the total nutrient content of the soil profile to the depth usually described by traditional survey methods.

The first PC of data summarized by depths accounted for 73% of variability in the data set, and placed the highest coefficients on the 0-150 cm sums. All the coefficients in

Table 2.11. Correlations between laboratory determined mineral soil variables and the first four principal components, with ranks of the eight highest correlations for each PC. Data are summed by the depths 0-10 cm, 10-30 cm, 30-70 cm, and 70-150 cm.

Variable	PC 1(Rank)	PC 2(Rank)	PC 3(Rank)	PC 4(Rank)
Eigenvalue	14.55	2.04	1.29	0.90
Percent	72.7	10.2	6.5	4.5
TKN10	0.6511	0.6006(2)	-0.0303	0.4050(2)
TKN70	0.9268(6)	0.1378	-0.0608	-0.0468
TKN150	0.9139	-0.0682	-0.2107(6)	0.0883
TKP30	0.5103	0.1802	0.8169(1)	0.0744
TKP70	0.8463	-0.0735	0.4620(2)	-0.0492
TKP150	0.9441(1)	-0.2025	-0.0108	0.1104
CA10	0.6597	0.6984(1)	-0.0386	0.1772
CA70	0.9090	0.0495	-0.2407(4)	-0.0053
CA150	0.8411	-0.3258(6)	-0.2144(5)	0.2814(4)
MG10	0.7624	0.5239(3)	-0.2068(7)	-0.2181(7)
MG30	0.8887	0.0108	-0.1702	-0.3060(3)
MG150	0.8943	-0.3816(5)	-0.0409	-0.0646
K10	0.6810	0.4768(4)	0.0594	-0.4735(1)
K70	0.9167(7)	-0.1584	0.0098	-0.2572(5)
K150	0.8893	-0.3570(7)	0.1379	0.1193
TKNSUM	0.9337(5)	0.2084	-0.0943	0.1784
TKPSUM	0.9342(4)	-0.0695	0.3121(3)	0.0948
CASUM	0.9113(8)	-0.1590	-0.1870(8)	0.2380(6)
MGSUM	0.9360(3)	-0.2530(8)	-0.0807	-0.1905(8)
KSUM	0.9365(2)	-0.2185	0.1189	-0.1023

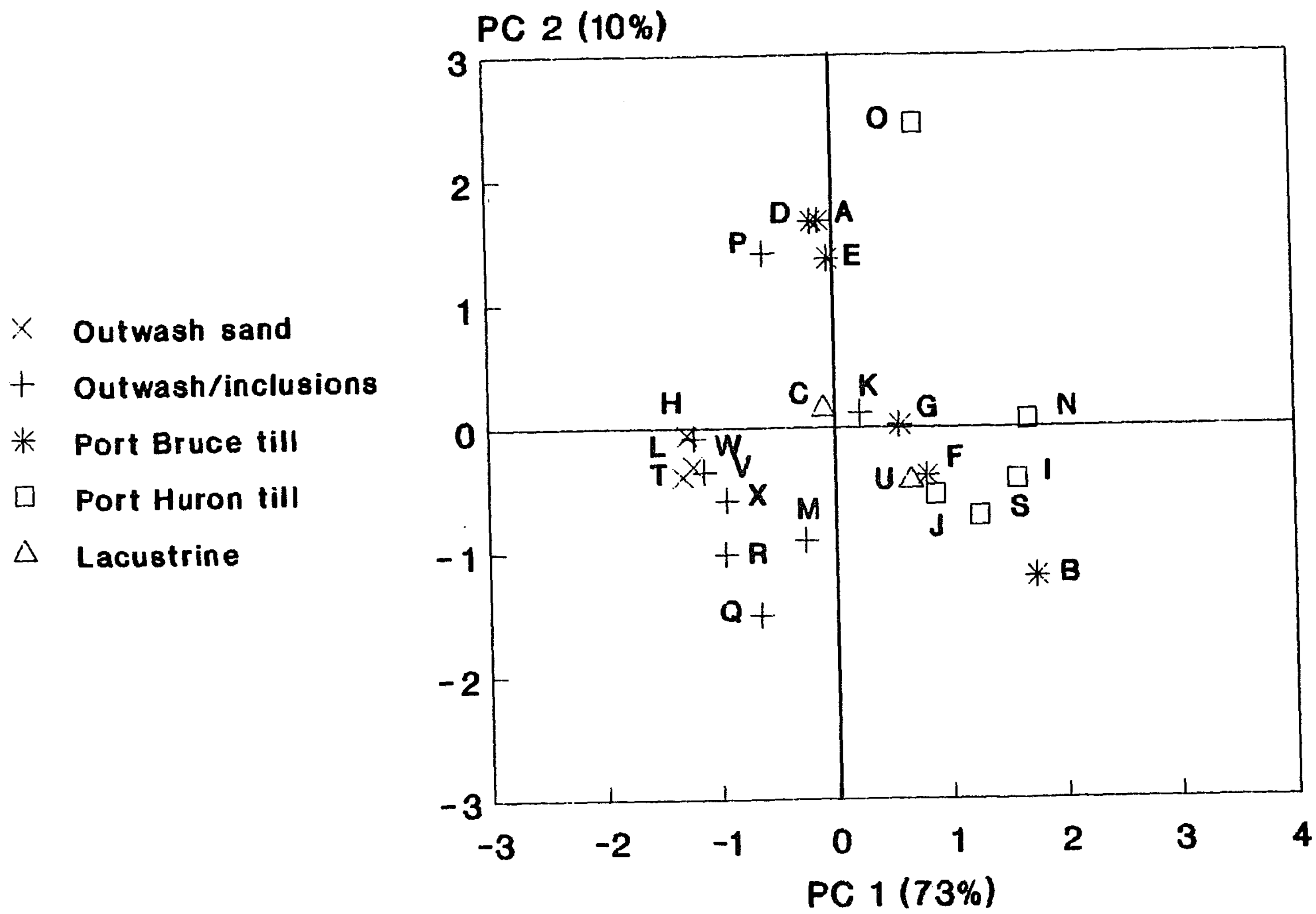
Table 2.12. Simple linear correlations among variables used in principal component analysis of laboratory determined mineral soil variables summed by depths.

	TKN10	TKN70	TKN150	TKP30	TKP70	TKP150	CA10	CA70	CA150	MG10	MG30	MG150	K10	K70	K150	TKNSUM	TKPSUM	CASUM	MGSUM	KSUM
TKN10	1.000	0.664	0.575	0.439	0.459	0.510	0.903	0.639	0.457	0.708	0.446	0.334	0.538	0.438	0.416	0.815	0.581	0.594	0.400	0.463
TKN70	0.664	1.000	0.880	0.421	0.787	0.832	0.695	0.852	0.687	0.759	0.869	0.786	0.670	0.837	0.743	0.936	0.829	0.778	0.837	0.816
TKN150	0.575	0.880	1.000	0.284	0.661	0.933	0.559	0.798	0.820	0.695	0.830	0.840	0.527	0.798	0.827	0.926	0.819	0.853	0.856	0.823
TKP30	0.439	0.421	0.284	1.000	0.769	0.445	0.437	0.289	0.236	0.310	0.317	0.350	0.446	0.425	0.503	0.445	0.721	0.314	0.350	0.514
TKP70	0.459	0.787	0.661	0.769	1.000	0.794	0.497	0.674	0.623	0.511	0.699	0.774	0.569	0.794	0.812	0.713	0.939	0.687	0.777	0.843
TKP150	0.510	0.832	0.933	0.445	0.794	1.000	0.508	0.805	0.883	0.618	0.831	0.910	0.486	0.837	0.927	0.866	0.927	0.901	0.902	0.897
CA10	0.903	0.695	0.559	0.437	0.497	0.508	1.000	0.643	0.388	0.846	0.555	0.334	0.675	0.446	0.346	0.773	0.578	0.544	0.415	0.431
CA70	0.639	0.852	0.798	0.289	0.674	0.805	0.643	1.000	0.824	0.744	0.845	0.790	0.631	0.855	0.738	0.847	0.754	0.906	0.861	0.816
CA150	0.457	0.687	0.820	0.236	0.623	0.883	0.388	0.824	1.000	0.476	0.688	0.858	0.313	0.728	0.868	0.753	0.764	0.977	0.830	0.799
MG10	0.708	0.759	0.695	0.310	0.511	0.618	0.846	0.744	0.476	1.000	0.781	0.518	0.873	0.640	0.461	0.781	0.594	0.604	0.634	0.583
MG30	0.446	0.869	0.830	0.317	0.699	0.831	0.555	0.845	0.688	0.781	1.000	0.818	0.688	0.881	0.680	0.802	0.759	0.756	0.892	0.795
MG150	0.334	0.786	0.840	0.350	0.774	0.910	0.334	0.790	0.858	0.518	0.818	1.000	0.433	0.893	0.921	0.739	0.833	0.852	0.964	0.906
K10	0.538	0.670	0.527	0.446	0.569	0.486	0.675	0.631	0.313	0.873	0.688	0.433	1.000	0.651	0.418	0.633	0.576	0.458	0.603	0.622
K70	0.438	0.837	0.798	0.425	0.794	0.837	0.446	0.855	0.728	0.640	0.881	0.893	0.651	1.000	0.838	0.778	0.832	0.794	0.954	0.948
K150	0.416	0.743	0.827	0.503	0.812	0.927	0.346	0.738	0.868	0.461	0.680	0.921	0.418	0.838	1.000	0.761	0.903	0.864	0.888	0.940
TKNSUM	0.815	0.936	0.926	0.445	0.713	0.866	0.773	0.847	0.753	0.781	0.802	0.739	0.633	0.778	0.761	1.000	0.848	0.845	0.791	0.804
TKPSUM	0.581	0.829	0.819	0.721	0.939	0.927	0.578	0.754	0.764	0.594	0.759	0.833	0.576	0.832	0.903	0.848	1.000	0.823	0.844	0.912
CASUM	0.594	0.778	0.853	0.314	0.687	0.901	0.544	0.906	0.977	0.604	0.756	0.852	0.458	0.794	0.864	0.845	0.823	1.000	0.865	0.849
MGSUM	0.400	0.837	0.856	0.350	0.777	0.902	0.415	0.861	0.830	0.634	0.892	0.964	0.603	0.954	0.888	0.791	0.844	0.865	1.000	0.952
KSUM	0.463	0.816	0.823	0.514	0.843	0.897	0.431	0.816	0.799	0.583	0.795	0.906	0.622	0.948	0.940	0.804	0.912	0.849	0.952	1.000

this analysis were positive, and there was not a large range in values of the coefficients, indicating that this PC reflected an overall size influence and ordinated sites according to a weighted mean nutrient content. The large proportion of variability in the data set expressed by the first PC indicated that size is the only major interpretation which can be obtained from this data set. The second PC, with 10% of the variability, emphasized 0-10 cm depths. The third PC emphasized Ca and especially P at several depths, but contained only 6% of variation in the data. The fourth PC, with only an additional 4% of variability, does not have an obvious interpretation. Generally, the depth sums of soil nutrients expressed less variability than horizon sums.

A plot of site locations with respect to PC 1 and PC2 of laboratory data summed by depths appears in Figure 2.8. Even though size is the only major interpretation of this PCA, the plot displays relative nutrient levels among the study sites. Outwash sand sites are closely grouped at the left end of the first PC indicating their overall low nutrient content. Sites formed in outwash sand with ice-rafted inclusions are dispersed over a wide range in the center of the first axis, indicating the variability of such sites. Port Bruce sites are nearer the origin, while Port Huron sites are further to the right; however, group members are not placed closely together by this ordination. Differences in nutrient content between the tills may be

Figure 2.8. Location of sites with respect to PC 1 and PC 2 of laboratory determined soil variables summed by depths 0-10 cm, 10-30 cm, 30-70 cm, 70-150 cm, and 0-150 cm, and averaged within a site.



PC 2 (10%)
PC 1 (73%)
3
2
1
0
-1
-2
-3
-3
-2
-1
0
1
2
3
4
Outwash sand
Outwash/inclusions
Port Bruce till
Port Huron till
Lacustrine
O
D
A
P
E
C
K
G
N
H
L
W
V
T
X
M
R
Q
U
F
I
J
S
B

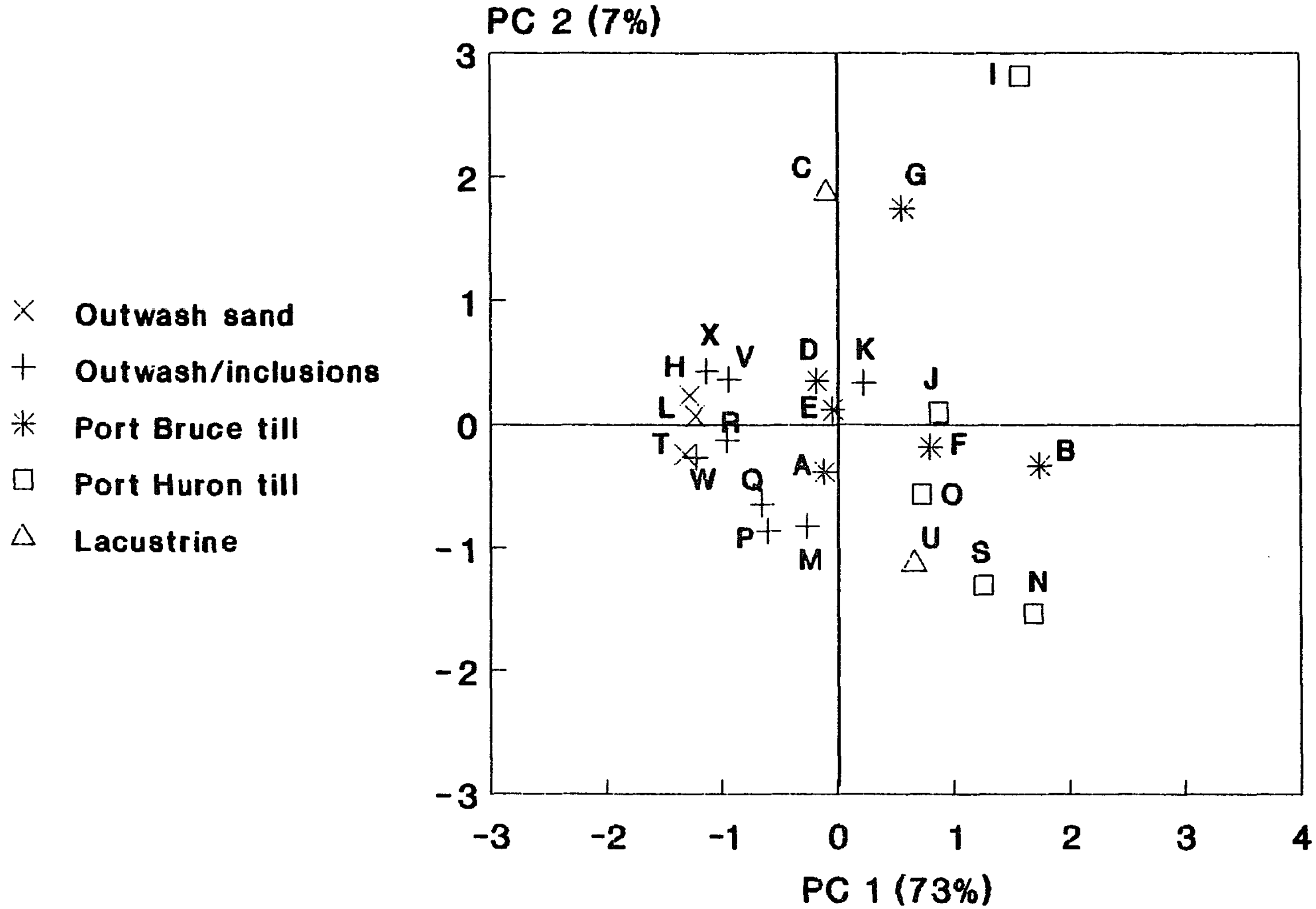
related to the greater overall volume of coarse fragments in Port Bruce tills, since nutrient content calculations were corrected for coarse fragment volume. The second axis of this plot accounts for only 10% of variation in the data set, emphasizing the 0-10 cm depth. Outwash sand sites H, L, and T are again closely grouped, but other sites are not arrayed in a meaningful manner with respect to PC 2.

A plot of PC's 1 and 3 of depth summed data appears in Figure 2.9. The third PC summarized only about 7% of variability in the data set, and was associated with P and Ca content of the soils. Most sites were closely grouped along this axis, with only three sites of relatively high P and low Ca content separated out at the positive end of the axis.

Depth sums of soils data did not produce more meaningful site ordinations than horizon sums. The 0-150 cm depth sums expressed a size trend in overall nutrient content which overwhelmed other nutrient summaries in PCA. Generally, horizon sums were more effective in grouping sites of similar depositional environment.

Scores of the 24 sites in PCA's of horizon summed data were compared to site scores from PCA of depth summed data using simple linear correlations. The correlation between scores from depth summed data and scores in the first PC of horizon sums including organic layers was $r=0.892$ (significant at $\alpha=0.05$ for $n=24$). A similar correlation

Figure 2.9. Location of sites with respect to PC 1 and PC 3 of laboratory determined soil variables summed by depths 0-10 cm, 10-30 cm, 30-70 cm, 70-150 cm, and 0-150 cm, and averaged within a site.


PC 2 (7%)
PC 1 (73%)
3
2
1
0
-1
-2
-3
-3
-2
-1
0
1
2
3
4
I
C
G
X
H
V
D
K
J
L
E
R
T
F
B
A
W
Q
O
P
M
U
S
N
Outwash sand
Outwash/inclusions
Port Bruce till
Port Huron till
Lacustrine

was produced from PC scores on the first axis of horizon summed mineral soil laboratory data. This correlation was r=0.913, also significant at alpha=0.05. Spearman's coefficient of rank correlation was also calculated for sites on the first axes of these PCA's. The correlation of site ranks in PCA of data summed by horizon including organic layers with depth summed data was r_s=0.909, significant at alpha=0.05. The correlation between site ranks in PCA of mineral soil laboratory data and depth summed data was r_s=0.924, also significant at alpha=0.05. The correlations indicate that site scores with respect to the first PC axis of all three sets of laboratory data are not significantly different, so that similar first-dimensional ordinations may be derived from data summed by horizons or by depths, with or without inclusion of organic layers.

PCA of field data

Field data were analyzed to identify which of the many morphological variables best expressed variability among sites. The analysis also examined ordinations of sites in comparison to depositional environment designations, and to ordinations derived from laboratory data.

Regression coefficients of variables and the first four PC's appear in Table 2.13, and the associated correlation matrix used in the PCA appears in Table 2.14. Correlations in Table 2.14 which are greater than or equal to an absolute

Table 2.13. Correlations between field observed variables and the first four principal components, with ranks of the eight highest correlations for each PC.

Variable	PC 1(Rank)	PC2(Rank)	PC 3(Rank)	PC 4(Rank)
Eigenvalue	11.07	3.78	2.03	1.57
Percent	48.1	16.4	8.8	6.9
ATHICK	-0.2226	0.2996	0.0376	0.1337
ETHICK	-0.0309	-0.6830(3)	0.0583	0.3581(5)
BTHICK	-0.6647	0.4501	0.4786(2)	0.1010
BSTHICK	0.7222	-0.0015	0.2666	0.4540(1)
CTHICK	0.6924	-0.4757(8)	-0.4393(5)	-0.1424
MOTTDEP	0.6525	0.1925	-0.5396(1)	-0.2131
DRCLASS	-0.6788	0.1171	0.4036(6)	-0.2245
ACLAY	-0.7539	0.3435	-0.2162	-0.2481
BSAND	0.8704(4)	0.0443	0.1573	0.4187(2)
CSILT	-0.6580	-0.3368	0.2437	-0.2557
SAND30	0.8058(7)	0.0307	-0.0049	0.3941(3)
SLT150	0.7977(8)	0.1819	0.3354	0.2648(8)
SGT150	0.6614	0.5363(6)	0.2350	-0.2512
SAND450	0.6615	0.5380(5)	0.3505(8)	-0.2208
HEAVC	-0.8696(5)	-0.1406	0.0734	0.3602(4)
DEPSL	0.9444(1)	-0.0747	-0.0575	-0.1935
DEPSCL	0.9237(3)	-0.0997	-0.0260	-0.0943
BIC	-0.9396(2)	0.0722	0.1565	0.0896
DEPTEX	0.8592(6)	-0.0305	0.1306	-0.3048(7)
TEXS	0.6339	0.5050(7)	0.4414(4)	-0.1562
ACSFR	-0.4381	0.6637(4)	-0.2552	0.0421
BCSFR	0.0505	0.7131(2)	-0.4527(3)	0.3455(6)
CCSFR	-0.2267	0.8096(1)	-0.3698(7)	0.1838

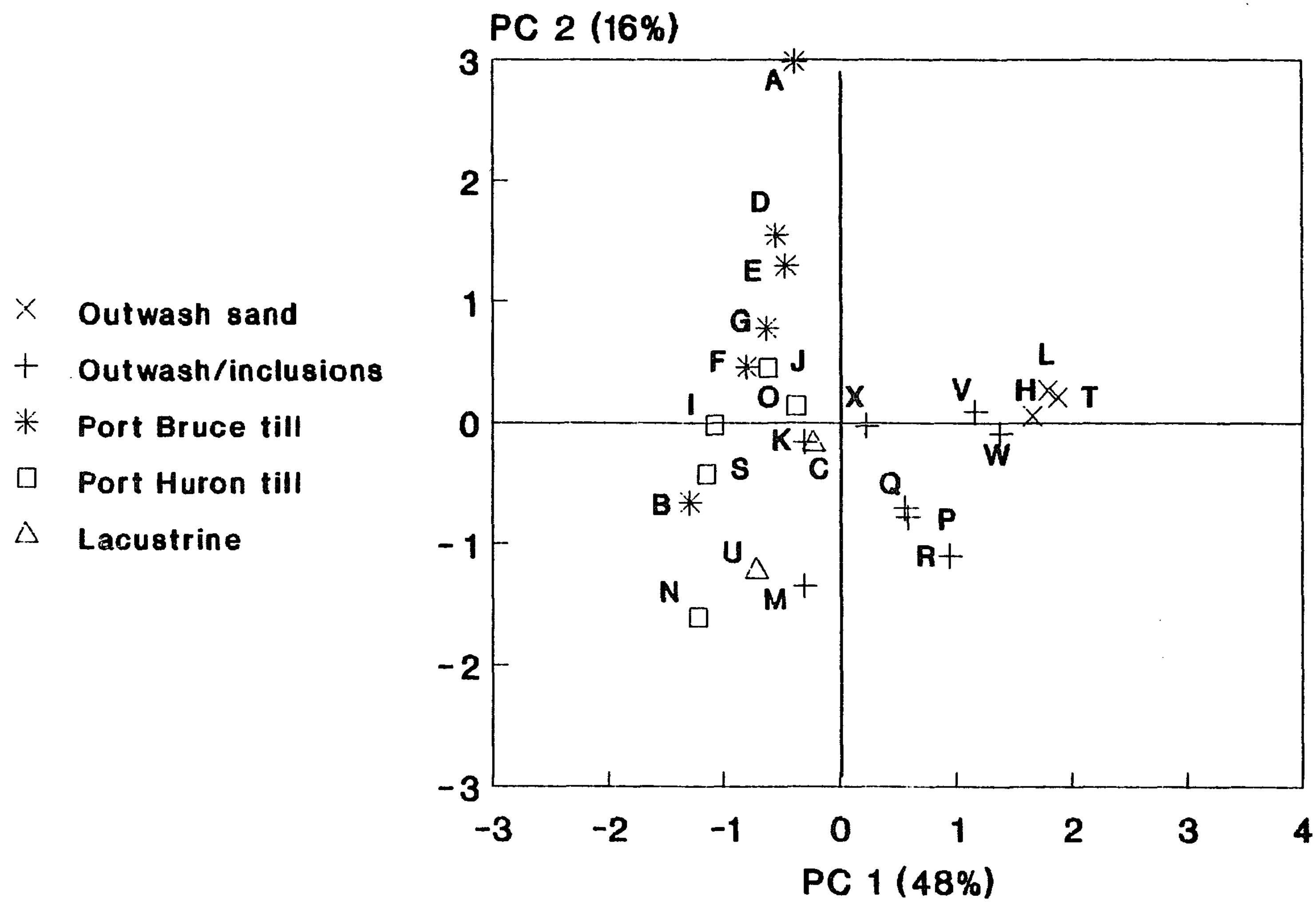
Table 2.14. Simple linear correlations among variables used in principal component analysis of field data.

	ATHICK	ETHICK	BTHICK	BSTHICK	CTHICK	MOTTDEP	DRCLASS	ACLAY	BSAND	CSILT	SAND30	SAND150	SGT150	SAND450	HEAVC	DEPSL	DEPSCL	BIC	DEPBAND	BANDS	ACSFR	BCSFR	CCSFR
ATHICK	1.000	-0.074	0.176	-0.314	-0.307	-0.061	0.094	0.093	-0.090	0.270	-0.060	0.041	-0.037	-0.113	0.232	-0.234	-0.230	0.213	-0.149	0.126	0.447	0.090	0.302
ETHICK	-0.074	1.000	-0.247	0.101	0.238	-0.228	-0.103	-0.297	0.059	0.043	-0.032	-0.082	-0.319	-0.321	0.243	-0.040	0.046	0.104	-0.112	-0.367	-0.368	-0.391	-0.482
BTHICK	0.176	-0.247	1.000	-0.236	-0.974	-0.625	0.623	0.623	-0.438	0.336	-0.486	-0.290	-0.163	-0.072	0.526	-0.700	-0.638	0.730	-0.504	-0.066	0.449	0.113	0.335
BSTHICK	-0.314	0.101	-0.236	1.000	0.278	0.164	-0.494	-0.582	0.830	-0.624	0.747	0.710	0.396	0.459	-0.485	0.613	0.634	-0.616	0.564	0.420	-0.312	0.066	-0.228
CTHICK	-0.307	0.238	-0.974	0.278	1.000	0.609	-0.607	-0.625	0.450	-0.392	0.474	0.282	0.197	0.103	-0.568	0.724	0.666	-0.762	0.531	0.079	-0.515	-0.136	-0.407
MOTTDEP	-0.061	-0.228	-0.625	0.164	0.609	1.000	-0.601	-0.326	0.425	-0.497	0.490	0.374	0.447	0.417	-0.667	0.652	0.601	-0.618	0.521	0.340	-0.031	0.265	0.188
DRCLASS	0.094	-0.103	0.623	-0.494	-0.607	-0.601	1.000	0.444	-0.607	0.554	-0.594	-0.436	-0.231	-0.199	0.503	-0.596	-0.593	0.676	-0.519	-0.204	0.253	-0.100	0.088
ACLAY	0.093	-0.297	0.623	-0.582	-0.625	-0.326	0.444	1.000	-0.787	0.314	-0.691	-0.749	-0.352	-0.352	0.421	-0.653	-0.646	0.670	-0.533	-0.410	0.626	0.226	0.426
BSAND	-0.090	0.059	-0.438	0.830	0.450	0.425	-0.607	-0.787	1.000	-0.592	0.909	0.874	0.492	0.539	-0.600	0.729	0.755	-0.759	0.648	0.594	-0.381	0.153	-0.142
CSILT	0.270	0.043	0.336	-0.624	-0.392	-0.497	0.554	0.314	-0.592	1.000	-0.544	-0.433	-0.651	-0.572	0.544	-0.525	-0.511	0.590	-0.395	-0.399	0.019	-0.485	-0.197
SAND30	-0.060	-0.032	-0.486	0.747	0.474	0.490	-0.594	-0.691	0.909	-0.544	1.000	0.736	0.374	0.420	-0.578	0.686	0.675	-0.737	0.595	0.447	-0.239	0.150	-0.135
SLT150	0.041	-0.082	-0.290	0.710	0.282	0.374	-0.436	-0.749	0.874	-0.433	0.736	1.000	0.578	0.641	-0.595	0.663	0.739	-0.642	0.639	0.713	-0.334	0.104	-0.035
SGT150	-0.037	-0.319	-0.163	0.396	0.197	0.447	-0.231	-0.352	0.492	-0.651	0.374	0.578	1.000	0.957	-0.674	0.578	0.514	-0.537	0.584	0.866	-0.005	0.214	0.138
SAND450	-0.113	-0.321	-0.072	0.459	0.103	0.417	-0.199	-0.352	0.539	-0.572	0.420	0.641	0.957	1.000	-0.669	0.586	0.521	-0.497	0.612	0.898	-0.033	0.178	0.118
HEAVC	0.232	0.243	0.526	-0.485	-0.568	-0.667	0.503	0.421	-0.600	0.544	-0.578	-0.595	-0.674	-0.669	1.000	-0.909	-0.906	0.877	-0.887	-0.582	0.257	-0.084	0.142
DEPSL	-0.234	-0.040	-0.700	0.613	0.724	0.652	-0.596	-0.653	0.729	-0.525	0.686	0.663	0.578	0.586	-0.909	1.000	0.923	-0.946	0.893	0.550	-0.419	-0.030	-0.284
DEPSCL	-0.230	0.046	-0.638	0.634	0.666	0.601	-0.593	-0.646	0.755	-0.511	0.675	0.739	0.514	0.521	-0.906	0.923	1.000	-0.887	0.875	0.489	-0.452	-0.002	-0.279
BIC	0.213	0.104	0.730	-0.616	-0.762	-0.618	0.676	0.670	-0.759	0.590	-0.737	-0.642	-0.537	-0.497	0.877	-0.946	-0.887	1.000	-0.844	-0.476	0.426	-0.068	0.244
DEPTEX	-0.149	-0.112	-0.504	0.564	0.531	0.521	-0.519	-0.533	0.648	-0.395	0.595	0.639	0.584	0.612	-0.887	0.893	0.875	-0.844	1.000	0.575	-0.380	-0.185	-0.306
TEXS	0.126	-0.367	-0.066	0.420	0.079	0.340	-0.204	-0.410	0.594	-0.399	0.447	0.713	0.866	0.898	-0.582	0.550	0.489	-0.476	0.575	1.000	-0.098	0.141	0.069
ACSFR	0.447	-0.368	0.449	-0.312	-0.515	-0.031	0.253	0.626	-0.381	0.019	-0.239	-0.334	-0.005	-0.033	0.257	-0.419	-0.452	0.426	-0.380	-0.098	1.000	0.457	0.651
BCSFR	0.090	-0.391	0.113	0.066	-0.136	0.265	-0.100	0.226	0.153	-0.485	0.150	0.104	0.214	0.178	-0.084	-0.030	-0.002	-0.068	-0.185	0.141	0.457	1.000	0.820
CCSFR	0.302	-0.482	0.335	-0.228	-0.407	0.188	0.088	0 426	-0.142	-0.197	-0.135	-0.035	0.138	0.118	0.142	-0.284	-0.279	0.244	-0.306	0.069	0.651	0.820	1.000

value of 0.404 are statistically significant at alpha=0.05 for n=24. The first PC accounted for 48% of the variability in the data set, and emphasized variables which described depths and textures of loamy soil layers. The score of an observation in the first PC became more negative as textural layers were nearer the surface and textures were loamier. In the second PC, which accounts for 16% of the variability, the highest positive coefficients were placed on the coarse fragment content of horizons and the average texture of the soil pedon, while the thickness of the E horizon received negative coefficients. Soils with high scores in the second PC were those with loamier textures, thinner E horizons, and many coarse fragments. The third PC, with 9% of the variation, emphasized drainage features and upper horizon thicknesses, and the fourth PC, which described 7% of the variability, highlighted B horizon characteristics and also some textural variables which received high coefficients in the first PC.

Figure 2.10 shows site locations with respect to PC's 1 and 2 of field data. Because the first PC emphasizes textural layers, the outwash sand sites are located at one end of the axis, while sites formed in outwash with ice-rafted inclusions are located near the center, and till sites are located at the opposite end. The second PC separates tills of different deposition, based predominantly on coarse fragment content, average texture, and associated E horizon thickness. Site B is located on Port Bruce till

Figure 2.10. Location of sites with respect to PC 1 and PC 2 of field observed soil variables averaged within a site.

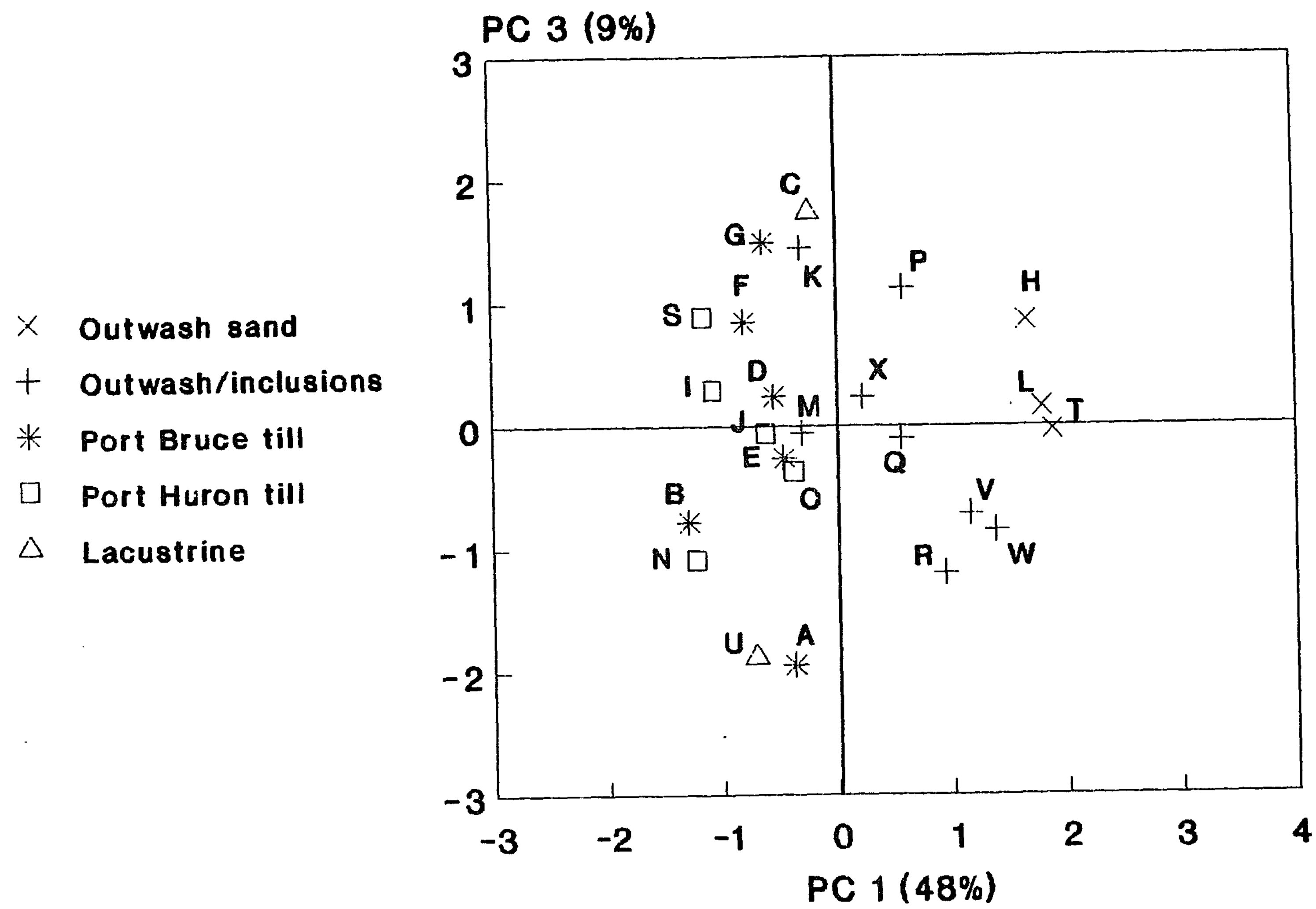

PC 2 (16%)
PC 1 (48%)
Outwash sand
Outwash/inclusions
Port Bruce till
Port Huron till
Lacustrine
A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
P
Q
R
S
T
U
V
W
X
3
2
1
0
-1
-2
-3
-3
-2
-1
0
1
2
3
4

but in this plot appears grouped with Port Huron sites. Lacustrine sites C and U were not placed together along PC's 1 and 2.

A plot of site locations with respect to PC's 1 and 3 of field data appears in Figure 2.11. PC 3 summarized about 9% of the variability in the data set, primarily emphasizing drainage features, thickness of the B horizon, and coarse fragment content. Site locations with respect to PC 3 show no relationship to depositional environment designations, with even outwash sand sites appearing more dispersed than in previous plots.

On the first PC axis, sites were arranged in a similar order as that which was obtained from PCA's of laboratory data. Simple linear correlations among site scores on the first axes of separate PCA's were used to compare the ordinations, and all were found to be significant at alpha=0.05. The correlation between first axis site scores from PCA of field data and PCA of horizon summed laboratory data including organic layers was r=-0.839; the correlation with PCA of mineral soil laboratory data summed by horizons was r=-0.919, and the correlation with PCA of depth summed data was r=-0.922. Spearman's coefficient of rank correlations for the same comparisons were likewise significant at alpha=0.05. The correlation between ranks of the 24 sites on the first axis of PCA of field data and PCA of horizon summed laboratory data including organic layers was r_s=-0.804; for field data compared with mineral soil

Figure 2.11. Location of sites with respect to PC 1 and PC 3 of field observed soil variables averaged within a site.


PC 3 (9%)
PC 1 (48%)
3
2
1
0
-1
-2
-3
-3
-2
-1
0
1
2
3
4
C
G
K
P
H
F
S
I
D
X
M
L
T
J
E
Q
O
B
V
W
N
R
U
A
Outwash sand
Outwash/inclusions
Port Bruce till
Port Huron till
Lacustrine

laboratory data the correlation was r_s=-0.905, and the correlation of field data with depth summed laboratory data was r_s=-0.953. Thus, the gradients expressed by the first axis of all the PCA's appear to coincide.

PCA of combined field and laboratory data summed by horizons and depths

Principal component analyses were applied to a combined data set containing selected variables from field data, laboratory data summed by horizon groups, and laboratory data summed by depths. This PCA was performed to identify the most important soil variables from the data sets used previously. PCA was also used to produce a plot derived from this combination of different data sets, to determine whether site locations corresponded with those derived from separate data sets, and with depositional environment designations.

Variables used in this PCA were those which had received the six highest coefficients in the first PC of field data, and the three highest coefficients in the second and third PC's. Additionally, the five 0-150 cm depth sums of laboratory data were used, and the variables which received the three highest coefficients in each of the first two PC's of laboratory data summed by horizons, both with and without organic layers.

Table 2.15 presents regression coefficients of the variables with the first four PC's of the data set which

Table 2.15. Correlations of laboratory determined soil variables summed by horizons and by depths, and field observed variables, with the first four principal components. Ranks of the eight highest correlations for each PC are shown.

Variable	PC 1(Rank)	PC 2(Rank)	PC 3(Rank)	PC 4(Rank)
Eigenvalue	12.03	3.49	2.01	1.32
Percent	52.3	15.2	8.8	5.8
ETHICK	0.1220	0.7067(4)	0.1449	-0.2793(7)
BTHICK	0.6097	-0.4530(7)	0.0074	-0.2392(8)
MOTTDEP	-0.6499	-0.0423	0.2536	0.5220(1)
BSAND	-0.8819(6)	0.0219	0.1387	-0.2320
HEAVC	0.8789(8)	0.0058	0.1747	-0.2925(5)
DEPSL	-0.9254(3)	0.2047	-0.1083	0.2052
DEPSCL	-0.8972(4)	0.1992	-0.1075	0.1836
BIC	0.9467(1)	-0.1239	0.1160	-0.0803
DEPTEX	-0.8261	0.1255	-0.2968(8)	0.2858(6)
TEXS	-0.6241	-0.3607(8)	-0.0776	0.1555
BCSFR	-0.1776	-0.6459(5)	0.6052(1)	-0.0836
CCSFR	0.1434	-0.7173(2)	0.5982(2)	0.2186
TKNSUM	0.9343(2)	-0.0953	-0.0280	0.0907
TKPSUM	0.8883(5)	-0.0275	-0.2376	0.1360
CASUM	0.8446	-0.1085	-0.3479(6)	-0.0350
MGSUM	0.8471	0.1564	-0.3626(5)	0.1505
KSUM	0.8798(7)	0.0858	-0.3414(7)	0.0990
OITKP	0.7317	0.2240	0.2091	0.4591
OIMG	0.7795	0.2021	0.2742	0.3072(4)
OIK	0.7285	0.3402	0.1430	0.3763(2)
OETKN	0.0890	0.7610(1)	0.4744(4)	-0.0895(3)
OEK	0.2719	0.7166(3)	0.4812(3)	-0.0514
ATKN	0.6075	-0.5035(6)	0.0453	0.11720

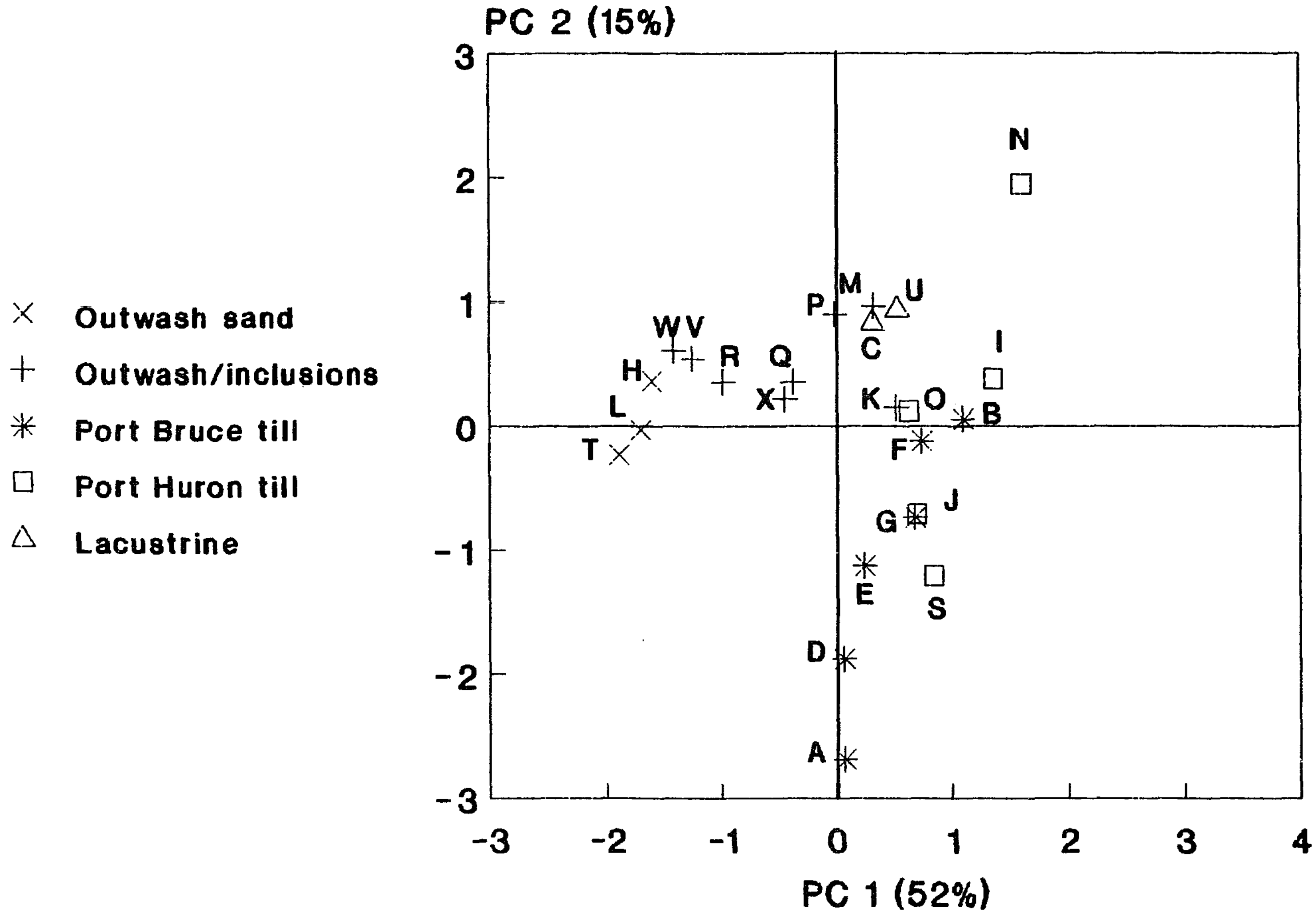
combined field and laboratory variables. The correlation matrix used in the PCA appears in Table 2.16. Correlations in Table 2.16 which are greater than or equal to an absolute value of 0.404 are statistically significant at alpha=0.05 for n=24. The first PC, which accounted for 52% of the variability of the data set, emphasized textural layers, including banding intensity, depth to a textural accumulation, and texture of the most loamy layer. Sums of N, P, and K in the 0-150 cm depth also received high coefficients, so that the textural gradient coincided with a nutrient gradient. The presence of loamy textured layers near the surface and a high overall nutrient content gave sites a high score in this PC. The second PC, with an additional 15% of the variability, emphasized Oe nutrients, coarse fragment content, and horizon thickness of the E and B. The third PC, which accounted for 9% of variability, emphasized nutrient sums of the 0-150 cm depth. The fourth PC represented 6% of the variability, and placed high coefficients on a combination of nutrient and morphological variables.

A plot of site locations with respect to PC 1 and PC 2 of the combination of field and laboratory data is presented in Figure 2.12. Site arrangement along the first axis was based on depths to loamy textural layers and overall nutrient content, so that outwash sands are grouped at the left, soils formed in outwash with loamy inclusions are located near the center, and till soils appear at the right.

Table 2.16. Simple linear correlations among variables used in principal component analysis of laboratory determined variables summed by horizons and by depths, and field observed variables.

	ETHICK	BTHICK	MOTTDEP	BSAND	HEAVC	DEPSL	DEPSCL	BIC	DEPTEX	TEXS	BCSFR	CCSFR	TKNSUM	TKPSUM	CASUM	MGSUM	KSUM	OITKP	OIMG	OIK	OETKN	OEK	ATKN
ETHICK	1.000	-0.247	-0.228	0.059	0.243	-0.040	0.046	0.104	-0.112	-0.367	-0.391	-0.482	0.086	-0.085	-0.018	0.065	-0.008	0.127	0.345	0.339	0.480	0.437	-0.064
BTHICK	-0.247	1.000	-0.625	-0.438	0.526	-0.700	-0.638	0.730	-0.504	-0.066	0.113	0.335	0.569	0.639	0.456	0.274	0.480	0.385	0.275	0.235	-0.151	-0.072	0.549
MOTTDEP	-0.228	-0.625	1.000	0.425	-0.667	0.652	0.601	-0.618	0.521	0.340	0.265	0.188	-0.525	-0.595	-0.549	-0.503	-0.616	-0.305	-0.324	-0.378	-0.012	-0.097	-0.295
BSAND	0.059	-0.438	0.425	1.000	-0.600	0.729	0.755	-0.759	0.648	0.594	0.153	-0.142	-0.917	-0.887	-0.833	-0.896	-0.889	-0.633	-0.626	-0.584	-0.050	-0.228	-0.507
HEAVC	0.243	0.526	-0.667	-0.600	1.000	-0.909	-0.906	0.877	-0.887	-0.582	-0.084	0.142	0.740	0.631	0.689	0.632	0.647	0.560	0.714	0.628	0.117	0.268	0.529
DEPSL	-0.040	-0.700	0.652	0.729	-0.909	1.000	0.923	-0.946	0.893	0.550	-0.030	-0.284	-0.837	-0.745	-0.756	-0.689	-0.728	-0.581	-0.662	-0.559	0.035	-0.143	-0.631
DEPSCL	0.046	-0.638	0.601	0.755	-0.906	0.923	1.000	-0.887	0.875	0.489	-0.002	-0.279	-0.823	-0.715	-0.743	-0.674	-0.710	-0.538	-0.635	-0.506	-0.018	-0.177	-0.602
BIC	0.104	0.730	-0.618	-0.759	0.877	-0.946	-0.887	1.000	-0.844	-0.476	-0.068	0.244	0.880	0.805	0.745	0.687	0.750	0.694	0.727	0.661	0.050	0.214	0.662
DEPTEX	-0.112	-0.504	0.521	0.648	-0.887	0.893	0.875	-0.844	1.000	0.575	-0.185	-0.306	-0.705	-0.595	-0.646	-0.599	-0.616	-0.493	-0.552	-0.497	-0.091	-0.296	-0.493
TEXS	-0.367	-0.066	0.340	0.594	-0.582	0.550	0.489	-0.476	0.575	1.000	0.141	0.069	-0.598	-0.536	-0.521	-0.653	-0.563	-0.338	-0.532	-0.398	-0.323	-0.428	-0.058
BCSFR	-0.391	0.113	0.265	0.153	-0.084	-0.030	-0.002	-0.068	-0.185	0.141	1.000	0.820	-0.119	-0.256	-0.253	-0.381	-0.338	-0.251	-0.193	-0.331	-0.219	-0.185	0.121
CCSFR	-0.482	0.335	0.188	-0.142	0.142	-0.284	-0.279	0.244	-0.306	0.069	0.820	1.000	0.223	0.069	0.008	-0.149	-0.103	0.139	0.176	0.001	-0.264	-0.179	0.451
TKNSUM	0.086	0.569	-0.525	-0.917	0.740	-0.837	-0.823	0.880	-0.705	-0.598	-0.119	0.223	1.000	0.848	0.845	0.791	0.804	0.614	0.759	0.597	0.022	0.167	0.704
TKPSUM	-0.085	0.639	-0.595	-0.887	0.631	-0.745	-0.715	0.805	-0.595	-0.536	-0.256	0.069	0.848	1.000	0.823	0.844	0.912	0.685	0.575	0.610	0.017	0.179	0.450
CASUM	-0.017	0.456	-0.549	-0.833	0.689	-0.756	-0.743	0.745	-0.646	-0.521	-0.253	0.008	0.845	0.823	1.000	0.865	0.849	0.409	0.493	0.424	-0.129	0.049	0.611
MGSUM	0.065	0.275	-0.503	-0.896	0.632	-0.689	-0.674	0.687	-0.599	-0.653	-0.381	-0.149	0.791	0.844	0.865	1.000	0.952	0.584	0.584	0.628	-0.002	0.185	0.344
KSUM	-0.008	0.480	-0.616	-0.889	0.647	-0.728	-0.710	0.750	-0.616	-0.563	-0.338	-0.103	0.804	0.912	0.849	0.952	1.000	0.625	0.564	0.647	0.008	0.201	0.373
OITKP	0.127	0.385	-0.305	-0.633	0.560	-0.581	-0.538	0.694	-0.493	-0.338	-0.251	0.139	0.614	0.685	0.409	0.584	0.625	1.000	0.809	0.902	0.275	0.423	0.351
OIMG	0.345	0.275	-0.324	-0.626	0.714	-0.662	-0.635	0.727	-0.552	-0.532	-0.193	0.176	0.759	0.575	0.493	0.584	0.564	0.809	1.000	0.849	0.236	0.331	0.548
OIK	0.339	0.235	-0.378	-0.584	0.628	-0.559	-0.506	0.661	-0.497	-0.398	-0.331	0.001	0.597	0.610	0.424	0.628	0.647	0.902	0.849	1.000	0.250	0.401	0.351
OETKN	0.480	-0.151	-0.012	-0.050	0.117	0.035	-0.018	0.050	-0.091	-0.323	-0.219	-0.264	0.022	0.017	-0.129	-0.002	0.008	0.275	0.236	0.250	1.000	0.946	-0.336
OEK	0.437	-0.072	-0.097	-0.228	0.268	-0.143	-0.177	0.214	-0.296	-0.428	-0.185	-0.179	0.167	0.179	0.049	0.185	0.201	0.423	0.331	0.401	0.946	1.000	-0.255
ATKN	-0.064	0.549	-0.295	-0.507	0.529	-0.631	-0.602	0.662	-0.493	-0.058	0.121	0.451	0.704	0.450	0.611	0.344	0.373	0.351	0.548	0.351	-0.336	-0.255	1.000

Figure 2.12. Location of sites with respect to PC 1 and PC 2 of laboratory determined soil variables summed by horizon and by depths, and field determined variables, averaged within a site.


PC 2 (15%)
PC 1 (52%)
3
2
1
0
-1
-2
-3
-3
-2
-1
0
1
2
3
4
Outwash sand
Outwash/inclusions
Port Bruce till
Port Huron till
Lacustrine
N
M
U
P
C
I
W
V
R
Q
H
X
K
O
B
L
T
F
J
G
E
S
D
A

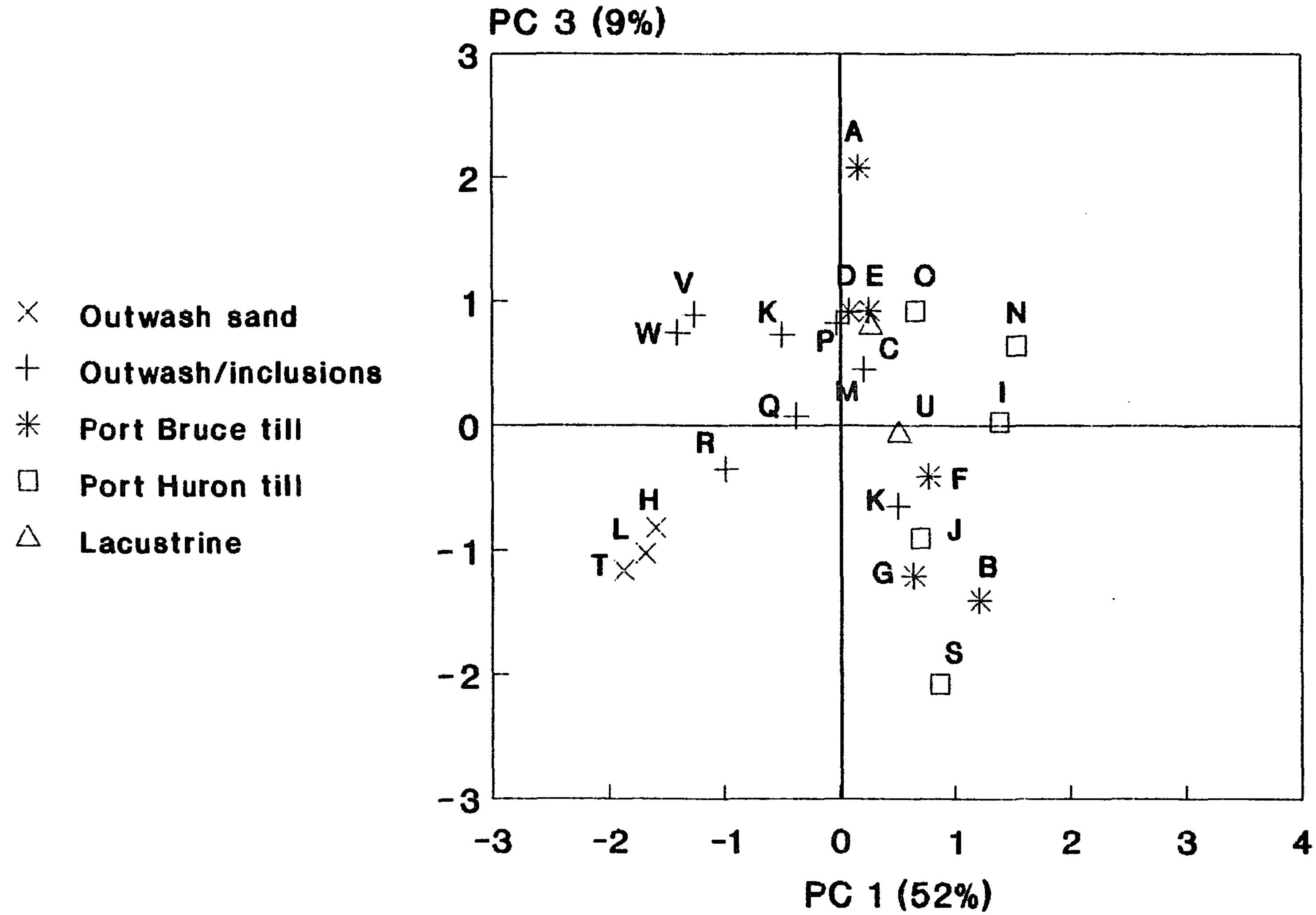
There was overlap among the Port Bruce and Port Huron till sites, but Port Huron sites were generally displaced to the right along the first axis, indicating that textural layers occurred nearer the surface. The second axis, which emphasized coarse fragments and Oe nutrients, indicated that Port Bruce sites generally have more coarse fragments, and lower levels of Oe nutrients. The two lacustrine sites are closely grouped in this plot.

A plot of site locations along PC axes 1 and 3 is presented in Figure 2.13. This PC is associated with coarse fragment content and Oe nutrients, so that site A, which contains large amounts of coarse fragments, is treated as an outlier and serves to compress the ordination of other sites along the axis.

Textural variables received larger coefficients than nutrient sums in the PCA of combined variables, so that although the gradients corresponded, the textural data in my study expressed greater variability than the nutrient sums.

Ordinations of sites on the first PC axis were compared with similar first axis ordinations from previous PCA's. The simple linear correlation of scores from PCA of combined field and laboratory data with scores from laboratory data including organic layers was $r=0.920$; with laboratory data excluding organic layers the correlation was $r=0.908$; with depth summed data the correlation was $r=0.938$, and with field data was $r=-0.971$. All the correlations were significant at $\alpha=0.05$ for $n=24$. Spearman's coefficient

Figure 2.13. Location of sites with respect to PC 1 and PC 3 of laboratory determined soil variables summed by horizon and by depths, and field determined variables, averaged within a site.


Outwash sand
Outwash/inclusions
Port Bruce till
Port Huron till
Lacustrine
PC 3 (9%)
PC 1 (52%)
3
2
1
0
-1
-2
-3
-3
-2
-1
0
1
2
3
4
A
D
E
O
V
K
N
W
P
C
M
I
Q
U
R
F
K
H
J
L
T
G
B
S

of rank correlation was also calculated for site ranks on the first axes of these PCA's. The correlation between site ranks in PCA of combined field and laboratory data with those in PCA of laboratory data including organic layers was r_s=0.917; with mineral soil laboratory data the correlation was r_s=0.920; with depth summed data the correlation was r_s=0.991, and with field data the correlation was r_s=-0.942. These correlations, all significant at alpha=0.05, show that site scores along the first PC axis were similar whether laboratory data, field data, or a combination of these data was used. Most classification studies rely on field data because of the expense of obtaining laboratory data; for sites in my study area field data would be sufficient for ordinating along a strong environmental gradient in which loamy textural material and nutrient supply increase coincidentally.

Plots of site locations along the first axis of all the PCA's indicate that there are differences among groups based on depositional environment. Assumptions of multivariate normality are not met by this data set; therefore, it is not feasible to develop mathematical functions to place observations accurately within one group or the other. Differences in variances among site groups would limit the applicability of discriminant analysis even with a larger data set. However, PCA does not disagree with groupings based on depositional environment as reflected by surficial deposit, particularly with respect to first and second axis ordinations.

Differences among groups based on depositional environment

PCA did not contradict site groupings based on depositional environment, so individual comparisons were made to determine if differences were significant, and if so, which variables differed significantly between what groups. A Kruskal-Wallis test was used to determine that the groups had different distributions. Individual t-tests with reduced degrees of freedom for comparisons of groups with significantly different variances were used to determine which groups and variables differed. The t-tests, and tests of variances, are presented in Appendix Table A.1, which is too lengthy for inclusion in the text. Many variables had significantly different variances between groups, and so reduced degrees of freedom were used to test for mean differences in these cases. Group 1 refers to sites formed in outwash sand; Group 2 includes sites formed in outwash sand with ice-rafted loamy inclusions; Group 3 consists of sites formed in Port Bruce till; Group 4 includes sites formed in Port Huron till, and Group 5 refers to sites formed in lacustrine material (Table 2.4). Variable descriptions and units appear in Tables 2.2 and 2.3.

Group 1, formed in outwash sand, differs significantly from other groups in content of most nutrients investigated, and with regard to most textural variables. Fewer significant differences were found between Groups 1 and 2 than between Group 1 and other groups; however, differences occur often enough to provide justification for keeping the groups separate.

Group 2, formed in outwash sand with inclusions of ice-rafted material and flow till, also differed significantly from other groups in most comparisons. Soil nutrient content, horizon thickness, and textural variables were often significantly different between Group 2 and Groups 3, 4, and 5.

Differences between soils formed in the two different tills, of Port Bruce and Port Huron age, and between till soils and lacustrine soils, were less often significant. Comparisons of Groups 3 and 4, the two tills, were significant only with respect to the variables BTKN, CMG, MGSUM, OIK, OITKP, BTHICK, BSTHICK, BTTHICK, CTHICK, ASILT, ACLAY, CSILT, and CCLAY. These differences may not provide sufficient justification for separating the two tills based solely on soil properties. As discussed in Chapter 3, vegetation differs between sites found on these till groups, and the classification system ultimately derived from ecosystem components may require keeping the tills separate based on vegetation. Soils, however, are not dramatically different.

Lacustrine soils in Group 5 are found only on two sites, and should be investigated more closely before conclusions are made regarding their differences or similarities to other groups. Significant differences occurred with most comparisons of Group 5 to Groups 1 and 2; significant differences were found less often with comparisons to Groups 3 and 4. These soils are not greatly different from till soils with respect to textural variables; nutrient variables are more often significantly different, but there is not clear justification for keeping the groups separate based on soils data.

CONCLUSIONS

Principal component analyses identified variables obtained from field and laboratory investigations which expressed the most variability among sites in northeastern lower Michigan. Analysis of laboratory data revealed that no individual nutrient displayed a greater amount of variability than any other. Total phosphorous content, when summed by various depths, often had a slightly higher correlation with the PC's than other nutrient sums. Generally, the PC's identified particular horizon groups or depth ranges which contained most of the variability in the data set. For horizon sums, nutrient content of the Oi had the greatest variability, followed by the Oe, the C above 150 cm, and finally the A and B layers. When O layers were excluded from the analysis, the B horizon was emphasized in the first PC as expressing the greatest variability, followed by the C above 150 cm, and then the A horizon.

Depth sums of soil nutrients were not preferable to horizon sums for expressing variability among sites. Nutrient sums of the entire upper 150 cm soil depth received the highest weightings in the first PC, where they represented a size feature in overall nutrient content of sites which obscured all other interpretations of the PCA. Horizon sums gave better results in PCA than depth sums, producing plots which had interpretable variation along several axes.

Field determined variables which expressed the most variability between sites in the first PC were those related to texture, particularly depths to accumulations of loamy till soil layers, and the texture of those layers. In the second PC, coarse fragment content, E horizon thickness, and overall average textures were important. These variables in the second PC distinguished between sites located on the two different tills identified by Burgis (1981). Soils formed in the older Port Bruce till, of which the West Branch moraine is formed, had a greater coarse fragment content, thinner E horizons, and slightly lighter textures than soils formed in Port Huron till. The coarse fragment content differences may be attributable to a 500-1000 year longer time of weathering, with processes including erosion and frost heaving, on the West Branch moraine. The thinner E horizons may be related to vegetation, as northern hardwood species dominate sites on the West Branch moraine, and the less acidic litter of these species is less conducive to eluviation.

There is a good agreement among plots of site locations with respect to the first two PC's of the various data sets. The first PC generally placed sandy outwash sites and till sites at opposite ends of the axis, while sites formed in outwash with ice-rafted or flow till inclusions were placed near the center. The second PC generally separated Port Bruce till sites from Port Huron till sites, although the separation was not always distinct.

Lacustrine sites were seldom placed near each other by plots of PC axes.

There were significant correlations among site scores along the first PC axis obtained from analysis of different data sets, indicating that the nutrient status of a site may be inferred from more easily obtained field data. Gradients of soil nutrients in this area correspond with gradients of soil texture expressed by site ordinations along the first PC axis of separate and combined data sets. This is likely attributable to the diversity of glacial deposits in the area, which range from loamy till deposits near the surface, through progressively sandier material, to outwash sands. The loamy material provides a higher soil nutrient status related to greater exchange capacity and weatherable mineral supply, creating a strong environmental gradient which can be discerned from either field or laboratory data. In other regions, where sites may have less diversity in soil texture and topography, PCA ordinations of field data may not correspond with that of laboratory data.

Comparisons among groups based on localized depositional environments, with relatively uniform surficial deposits, demonstrated that there were many significant differences between soils formed in outwash and those formed in loamy till or in outwash with loamy inclusions. Sites formed in loamy till were also significantly different from those formed in outwash with loamy inclusions with respect to most variables investigated. Fewer significant soil differences were found between tills of different depositions, dating from Port Bruce and Port Huron age, so that there was not as great a basis for separating these groups. Lacustrine sites require further investigation, but did not differ significantly from till soils with regard to most variables studied.

For purposes of developing an ecological classification system, the analysis of soils data provided a sound basis for identifying at least three groups which differ significantly in many respects. The three groups are: outwash sands on hilly localized ice-disintegration features, outwash sand with inclusions of ice-rafted till or flow till on moraines, and loamy till on moraines. These three groups may be subdivided based on vegetation (Chapter 3), and there are some soil differences between tills of two different depositions which may be great enough to warrant separating them. Also, outwash plains were not investigated as part of my study, and likely comprise yet another group. On glacial landforms found in northwestern lower Michigan, landform accounted for a significant portion of variability in overstory biomass (Host et al. 1988). Landform was determined to be an appropriate division at the mesoscale level, although finer, microscale divisions were needed for ecological land units . Although biomass differences were not analyzed as part of my study, it would appear that glacial landforms in northeastern lower Michigan are internally heterogeneous to an even greater degree than those in northwestern lower Michigan. My study showed no justification for considering glacial landforms identified and mapped by Burgis (1977, 1981) as homogenous areas of similar surficial deposit which could delineate divisions at the spatial scale required for ecological map units. Localized deposition of widely differing surficial material was evident within these landform boundaries, so that sites formed in outwash sand could not be distinguished from loamy till sites based on the mapped landforms. The landforms as mapped must be regarded as topographic masses; categories useful for land classification at the ecosystem level require subdivision of these topographic masses to recognize localized surface deposits.

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CHAPTER III

ASSOCIATIONS OF SITE PROPERTIES WITH AN ORDINATION OF GROUND FLORA SPECIES FOR UPLAND FORESTS OF NORTHEASTERN LOWER MICHIGAN

INTRODUCTION

Vegetation has been described as a phytometer of the environment, integrating the effects of climate, topography, and soils within discrete localities (Cajander 1926, Rowe 1956, Pfister and Arno 1980). Landform and soil are said to quantify most of the environment within a macroclimatic area (Grigal 1984), but mapping may be facilitated by the use of vegetation, which is more easily observed than soil and has predictable relationships with physiography and soils (Barnes et al 1982, Rowe 1984). Many land classification systems rely on vegetative indicator species or groups of species. Habitat type classification systems use vegetation exclusively (Kotar and Coffman 1984), while multifactor or ecological classifications use vegetation in combination with other ecosystem components (Barnes 1984, Jones 1984, Moon 1984, Rowe 1984).

Vegetation data is summarized and interpreted through the construction of synthesis tables, and by one or more numerical analyses of the correspondence between species and sites. Sites are grouped together based on their similarity as determined by the vegetative ordination. Classification systems use the patterned occurrence of vegetation within site groups to predict or infer patterns, characteristics, and responses of ecosystems along landscape gradients.

Vegetation as an indicator of site conditions is more effective in some locations than others. Barnes (1984) has stated that "the Germans have long recognized that areas with similar vegetations are not necessarily the same ecosystem type". Grigal and Arneman (1970), reporting several studies from the literature, noted that there were conflicting reports regarding the relationship between soil and vegetation, ranging from no correlation to a very close correlation. There is some geographic specificity to vegetative indicators, with shifts in the distribution of species within a statewide area (Pregitzer and Ramm 1984).

Vegetation is used extensively in classification, and its value as an indicator and its relationship to other ecosystem components varies regionally. This portion of my study examines associations of vegetation, soil, and landscape features on a study site in northeastern lower Michigan.

Relationships of vegetation to other ecosystem components

Vegetation and soil

Studies in various parts of the world have shown that there are associations between vegetation and soil. Grigal and Arneman (1970) reported that a classification system developed in Minnesota, based on frequency of vascular plant species, was closely related to other classifications based on soil, on environmental gradients of heat, moisture, and nutrients, and on overstory vegetation. In the coastal redwood region of California, measured gradients of moisture, light, temperature, and soil nutrients were also related to a gradient of vegetation (Waring and Major 1964).

In West Germany, ground flora species groups corresponded with soil properties which were related to local landforms, including texture, depth, acidity, and moisture-holding capacity (Barnes 1984). In British Columbia, depth to bedrock, depth to dense till, drainage, humus type, color of the B horizon, and slope all covaried with vegetation classes (Moon 1984). Additionally, laboratory-determined soil properties organic carbon, nitrogen (N), and cation-exchange capacity were more precisely defined by strata which included vegetative classes than strata based on soil properties alone. Another study in British Columbia found significant correlations among forest strata and some environmental variables (Gagnon and Bradfield 1986). The sapling layer was associated with elevation, slope, and soil depth, while the seedling layer was associated with fire and wind disturbance, and the herb layer with carbon and nitrogen concentrations in the soil. Studies conducted to develop forest site classification in Ontario found that soils data correctly predicted vegetation type for 70% of the plots using subsurface texture, thickness of humus layers, moisture regime and drainage, depth to carbonates, and rooting zone thickness (Jones

1984). McCune and Antos (1981) found poor correlations among forest layers in a small study area in Montana, but noted that the "cover of most species was roughly predictable from environmental parameters and the cover values of species in another layer". A study of wetland forests in Wisconsin found that the composition of each of three forest layers was related to different soil properties (Dunn and Stearns 1987). Tree species composition was associated with pH, organic matter and Mg concentrations in the soil. Composition of the herbaceous layer was also associated with organic matter and Mg in the soil, and the density of the woody understory was associated with the occurrence of the site on a floodplain versus a basin.

A study on the Sylvania Recreation Area in upper Michigan demonstrated that coverage of the Clintonia species group increased along a canonical axis concomitantly with increasing amounts of fine sand and thickness of the O2, or F, horizon (Spies and Barnes 1985). The second canonical axis expressed a gradient of increasing total sand and medium sand content, and decreasing silt content, pH, and coverage of the Osmorhiza and Caulophyllum species groups. In the McCormick tract, also in upper Michigan, ecological species groups were associated with soil characteristics including texture, moisture regime, acidity, and total nitrogen (Pregitzer and Barnes 1982, 1984). Potential N mineralization in northwestern lower Michigan was associated with upland forest ecosystem groups characterized by overstory and ground flora (Zak et al. 1986). The abundance of spring ephemerals in the same region was associated with mor versus mull soil types, and associated differences in surface soil acidity (Overlease and Overlease 1976). In northeastern Wisconsin, the development of organic accumulations in spodic horizons was related to the presence of hemlock in the overstory (Hole 1975). Ordination of sites in New York using correspondence analysis of overstory and ground flora indicated that the first axis was related to moisture, and the second axis to abundance of hemlock (Gauch and Stone 1979).

Vegetation and landform

Bailey (1984, 1987) has described three spatial scales of interest in land classification. The macroscale is controlled primarily by climate and can be mapped at a regional scale of 1:3,000,000. The mesoscale is characterized by landform control of climate due to geologic substrate, surface shape, and relief, and can be delineated at map scales between 1:250,000 and 1:1,000,000. The microscale is associated with local differences in slope and aspect, and map scales may be between 1:10,000 and 1:80,000.

Landforms, here defined as topographic masses of a mesoscale areal extent, are characterized by differences in slope, aspect, and elevation. These differences result in local modification of regional climatic conditions. Composition of vegetative communities in many areas is strongly associated with landform features. Brubaker (1975) has shown that forest composition in Michigan has been related to patterns of glacial till and outwash during the entire time since glaciation. Whitney (1986, 1987) has further shown that these patterns of presettlement forest composition are the result of landform mediated fire frequency.

Overstory vegetation has been associated with specific landforms in northwestern lower Michigan, with black and pin oaks dominating outwash plains, white oak increasing with finer sand textures, red oak occurring on ice-disintegration topography, and sugar maple occurring only on moraines (Pregitzer and Ramm 1984). Succession of species in this area may be related to landforms, as they control microclimatic conditions which affect the competitive ability of species (Host et al. 1987).

Habitat-type classification in upper Michigan and northern Wisconsin has also related overstory types to glacial landforms, with sugar maple and hemlock occurring on till plains, and pine and oak on outwash plains (Kotar and Coffman 1984). Certain species groups on the McCormick tract in upper Michigan were associated with topographic position along a north-facing hillslope (Pregitzer et al. 1983). The _Corydalis_ group occurred on rocky, shallow soils, while the _Viola_ group indicated fertile sites in colluvial slope positions, and the _Athyrium_ group was found in moist areas.

Characteristics of the forest floor and annual litterfall

The forest floor is an ecosystem component which has not been extensively studied, especially in the Great Lakes Region. The forest floor is an important component of ecosystems, since most organic decomposition and nutrient cycling occurs within it. It also serves as a storage compartment for nutrients accumulated over time on a forested site. The forest floor layer is difficult to study due to its temporal and spatial variability, and ambiguity regarding the location of its lower boundary. Most studies of the forest floor have been conducted in the eastern U.S., on or near the Hubbard Brook Forest in New Hampshire.

The weight of forest floor material on the Hubbard Brook Forest, determined as loss on ignition of litter (L), fermentation (F), and humus (H) layers, averaged over three elevation zones was 46,800 kg ha^{-1} (Gosz et al. 1976). During an August sampling, the L layer weighed 4,300 kg ha^{-1}, the F layer weighed 19,300 kg ha^{-1}, and the H weighed 27,500 kg ha^{-1}. Covington (1981), and Federer (1984), working in the same general area found that the mature forest floor weighed about 80 Mg ha^{-1}, but did not break the figure down into component layers L, F, and H. Federer (1984) noted that another study in New Hampshire found the forest floor to weigh 63 Mg ha^{-1}, and that areas further south and west had lesser amounts of forest floor material.

Forest floor weight was thought to vary widely depending on geography, drainage, and species composition.

Annual litterfall has been measured in a number of studies. Vitousek (1982) summarized studies in evergreen tropical forests, finding that the range of litter production was between 5,510 and 15,300 kg ha^{-1} yr^{-1}. Northern deciduous forests produce less litter. A one-year sampling on the Hubbard Brook Forest showed that an average of 3,419 kg ha^{-1} of deciduous tissue were produced over three elevation zones (Gosz et al. 1972). Boerner (1984) working in mature forests in Ohio, found litter production to be 3,858 kg ha^{-1} averaged over 2 years and four sites of different species composition. MacLean and Wein (1977) found that there was a decreasing trend in forest floor litter (L) layer weight with age for a hardwood forest in New Brunswick. The oldest site studied, aged 37 years, had 9,510 kg ha^{-1} of undecomposed litter on the forest floor during August samplings. Crow (1978) in Wisconsin found that annual leaf and current twig production on an aspen site was 2,413 kg ha^{-1}, while on an aspen-maple-birch site production was 2,773 kg ha^{-1}, and on a maple-birch-aspen site was 3,726 kg ha^{-1}. Another study in Wisconsin (Pastor et al. 1984) also demonstrated differences in annual litter production among ecosystems. Conifer dominated forests produced the least amount of litter, while forests with sugar maple and basswood had the highest amount, and oak-dominated forests produced an intermediate level. In northwestern lower Michigan, Zak et al. (1986) also found differences in litter production with different overstory composition. A black oak-white oak site produced 1,749 kg ha^{-1} of litter during an autumn sampling, while a sugar maple-red oak site produced 3,179 kg ha^{-1} and a sugar maple-basswood site produced 2,624 kg ha^{-1}. Litter production, like forest floor accumulation, appears to vary geographically and with species composition.

Nutrient concentrations in litterfall sampled over one year were measured at the Hubbard Brook Forest by Gosz et al. (1972). Concentrations of some nutrients in deciduous tissue were: N - 1.196%, P - 0.079%, Ca - 0.787%, Mg - 0.129%, and K - 0.456%. Boerner (1984) in Ohio found similar nutrient levels in autumn litterfall sampled during October. Concentrations were: N - 0.815%, P - 0.083%, Ca - 0.958%, Mg - 0.169%, and K - 0.479%. Pastor et al. (1984) analyzed N and P concentrations in annual litterfall by species. Sugar maple litter contained 0.96% N and 0.11% P, red oak contained 0.87% N and 0.11% P, white oak contained 0.89% N and 0.14% P, and basswood contained 1.60% N and 0.18% P. Nitrogen concentrations in autumn litterfall in northwestern lower Michigan were: 0.749% on a black oak-white oak site, 0.959% on a sugar maple-red oak site, and 1.239% on a sugar maple-basswood site, indicating species differences in litter quality (Zak et al. 1986). Nutrient concentrations seemed unrelated to geographic differences and also seemed not to vary greatly depending on whether litter was sampled on an annual basis or only during autumn; rather, species composition of the overstory seemed to be the major variable related to differences in nutrient concentration of litter.

Nitrogen mineralization in forested ecosystems

The rate at which N is mineralized has been related to total aboveground net primary production for sites in Massachusetts, Wisconsin, and Alaska, so that the N mineralization rate is thought to be the best measure of forest stand production (Aber and Mellilo 1984, Pastor et al. 1984). Powers (1980) found that N mineralization rates correlated with site index, yield potential, and foliar N in ponderosa pine (Pinus ponderosa). Similarly, Keeney (1980) in his review of N mineralization studies, reported that the amount of N released during anaerobic incubations was correlated with diameter growth increase in N fertilized Douglas fir. N mineralization rates have been correlated with litter production and N return in litterfall (Pastor et al. 1984, Zak et al. 1986).

Nitrogen mineralization rates vary among ecosystems. Zak et al. (1986) demonstrated that the N mineralization rate was twice as great in sugar maple ecosystems as in oak, and Pastor et al. (1984) also found differences among ecosystems dominated by conifers, oaks, and sugar maples. However, in one study in the western U.S., within site variability was great enough so that habitat sites could not be distinguished by N mineralization rates (Keeney 1980).

Nitrogen mineralization rates have been found to be unrelated to soil N and pH (Aber and Mellilo 1984, Pastor et al. 1984), although soil properties may not have been adequately quantified in these studies. Ratios of C:N and C:P in litter were found to be negatively correlated with N mineralization on sites in Wisconsin, indicating that P supply may limit the rate (Pastor et al. 1984). Sahrawat et al. (1985), working on the same sites found that P additions did not alter N mineralization rates, but addition of lime did, so that acidity and not P supply was believed to be limiting to N mineralization rates.

Methods of determining N mineralization rates vary, and the benefits of each have been debated. In situ incubations are thought to be the best for determining actual rates, but are time consuming and labor intensive (Pastor et al. 1984). The anaerobic laboratory incubation method was compared to in situ incubations on sites in the western U.S., showing that for mesic zone sites twice as much N was mineralized in the field as in the laboratory (Keeney 1980). For xeric sites, more N was mineralized in laboratory incubations. Laboratory incubations, both aerobic and anaerobic, give an index of relative rates among sites examined rather than an actual value which can be translated into amounts of N available for forest growth on an annual basis. An aerobic incubation of forest soils has been shown to mineralize higher levels of N than the anaerobic incubation, likely due to the relatively low levels of anaerobic bacteria present in forest soils (Smith et al. 1981). Unfortunately, the authors do not state whether the forest was coniferous or deciduous, and it is likely that there would be a difference related to overstory composition. The correlation between amounts of N released from the anaerobic and aerobic laboratory methods was r=0.93 . Powers (1980) compared anaerobic incubations in the field with anaerobic laboratory incubations and found that a 2-week incubation at 30^{o}C was comparable to a 6-month field incubation, although the field incubation was affected by soil temperature. Drying and storage have also been shown to affect levels of N released during anaerobic incubation. McNabb et al. (1986) found that values varied irregularly with samples from six forest habitat types in Oregon, so that some samples produced more ammonium-N after drying and storage while others produced less.

Myrold (1987) has shown that there is a strong correlation between the amount of N mineralized during anaerobic incubation and microbial biomass as measured by chloroform fumigation. Myrold suggests that the N mineralized during the incubation may result from anaerobic decomposers acting on dead cells of aerobic microorganisms. Thus, the anaerobic incubation procedure measures populations of aerobic microbes responsible for the decomposition of most organic matter on a site, and is indicative of an overall site potential for organic decomposition and release of a suite of nutrients.

Although there is still considerable debate regarding methods for measuring N mineralization, its association with important site productivity measures makes it an important technique for identifying and distinguishing among ecosystems.

OBJECTIVES AND HYPOTHESES

The objective of this chapter is to investigate relationships among vegetative and non-vegetative ecosystem components. Ordinations based on vegetation are necessarily a part of ecological or multi-factor classification systems, and information on how vegetation is associated with other site components will help in identification and mapping of ecosystem units. Information regarding ecosystem relationships will be vital for developing interpretations for the map units which will be developed.

The questions which are addressed in this chapter are: 1) are site ordinations based on ground flora abundance equivalent to ordinations based on overstory composition or on soil characteristics, 2) are differences in overstory composition associated with soil nutrients or textures, or to nutrient turnover rates, 3) are characteristics of litterfall and the forest floor important to ecosystem structure and function (and therefore important for describing ecosystems), and 4) are some site properties associated with amount and nutrient quality of litterfall?

The associated hypotheses, again stated as alternative hypotheses rather than null hypotheses, are: 1) first-dimension site ordinations obtained from ground flora cover-abundance, overstory basal area, and soil properties are not equivalent, 2) there are differences in soil nutrients between sites with different vegetation, 3) varying levels of individual soil physical and chemical features are associated with first-dimensional ordinations obtained from vegetative species composition, 4) nitrogen mineralization rates are associated with low-level ordinations obtained from vegetative species composition, 5) amount of litterfall is not equal on all sites, 6) amount of partially decomposed forest floor material is not equal on all sites, and 7) nutrient return in litterfall is associated with species composition and amount of litterfall produced.

Addressing the hypotheses will entail: 1) ordination of sites along an environmental gradient expressed by ground flora species abundance, 2) comparing gradients of soil and geologic features, litterfall, and overstory composition with the ordination of ground flora, and 3) comparing soil and litterfall characteristics among groups of sites with different overstory species composition.

METHODS AND MATERIALS

Methods used for selection of sample sites, and for field sampling and laboratory analyses of soils and forest floor samples are described in Chapter 2. Methods used in sampling vegetation, and in the determination of nitrogen mineralization rates, are described in this section.

Field sampling for vegetation and nitrogen mineralization

Overstory measurements used variable-radius plots with tally trees identified by use of a 10 basal area factor prism at each subplot. Measurements at each of the four subplots included basal area by species and average age of the overstory. Measurements were averaged for the site.

Ground flora were described within a 5 by 30 m plot located along a north-south transect through the center of each subplot, except where a strong physiographic gradient was present and the transect was placed parallel to the gradient. Species were identified, and cover-abundance classes were assigned to each based on visual observation. Values were averaged over the four subplots at each site. Frequency of occurrence was measured at each subplot by placing six 1 m^2 frames at 5 m intervals along the north-south transect, and noting presence/absence of various species within the frames. Average site-level frequencies for each species were determined by dividing the number of occurrences by 24, the total number of frames. Cover-abundance classes were converted to ranked values according to a modified Braun-Blanquet cover-abundance scale (Table 3.1). A scale such as this is commonly used in vegetation analysis because it allows easier visual estimation of species cover in the field than a scale comprised of equal intervals. Also, less abundant species may have a greater ecological significance than species of larger cover. Scales used in vegetation analysis are designed so that less abundant species receive a higher weight in analysis due to the greater number of categories among the lower coverages (Mueller-Dombois and Ellenberg 1974).

Table 3.1. Cover-abundance classes and corresponding ranks used in vegetation analysis.

Coverage class midpoint %	Rank
0.05	1
0.5	2
2	3
10	4
25	5
50	6
80	7

Core samples of the surface 0-10 cm of mineral soil were obtained for a study of nitrogen mineralization rates. These samples were collected at the same time as forest floor samples. A composite sample of six soil cores was obtained at each subplot within a site, with two cores taken adjacent to each forest floor sample (Figure 2.2).

Laboratory procedure for determination of nitrogen mineralization rates

The composite soil core samples were placed in plastic bags inside individual waxed cardboard containers, and refrigerated at 4°C for 10 weeks until analyzed. Field moist soil was sieved to remove coarse fragments and medium roots; fine roots were included with the sample. The incubation and analysis method was a modification of the anaerobic technique of Keeney and Bremner (1966) reported in Myrold (1987), except that a Technicon autoanalyzer system was used. Mineralizable N was calculated as the increase in ammonium-N concentration during a 7 day incubation at 40°C.

Numerical analyses

Sites were ordinated by reciprocal averaging (RA) using ranked ground flora cover-abundance values derived from a modified Braun-Blanquet cover-abundance scale. Species having zero frequency, and also species occurring on only one site, were not used in the analysis because rare species have been determined to be of little value in site ordination (Gauch 1982).

RA was performed using an option available in the DECORANA program of the Cornell Ecology Package (Hill 1979). RA and correspondence analysis (CA) are different methods of calculating the same site ordination scores, and the names are used interchangeably by some authors (Pielou 1984). Others (Greenacre 1984) feel that the names should be kept separate, so that CA would only be used in reference to the matrix solution and RA only to the iterative solution. Agreement of CA with RA using the option in DECORANA was verified using an example data matrix from Pielou (1984) on which CA had been performed using the matrix procedure. When the data matrix was analyzed with RA in DECORANA, output agreed with Pielou's result except that DECORANA had multiplied the observation scores by a constant to scale the axes. The comparison confirmed that the order of sites and samples as determined by RA in DECORANA were identical to those in Pielou's CA result.

Site groups based on overstory composition were compared using the same methods which were employed in Chapter 2 for comparing groups based on depositional environments. A Kruskal-Wallis test was followed by individual tests of group means with reduced degrees of freedom where variances were significantly different (Steel and Torrie 1980).

Simple linear correlations and Spearman's coefficient of rank correlation were used to test the strength of associations among site variables. These tests were also used to evaluate associations between first dimension ordinations from RA of overstory and ground flora data, and from PCA of soils data. The Statistical Analysis System (SAS) (SAS Institute Inc. 1985) was used for obtaining correlations and for comparing overstory groups.

RESULTS AND DISCUSSION

In this chapter, a site ordination using ground flora species ranked cover-abundance values is described, and discussed with reference to glacial depositional environments. Overstory species composition is discussed relative to ground flora, depositional environments, soil, and litterfall characteristics. Nitrogen mineralization rates are presented, and their associations with vegetation, soil and depositional environments are discussed.

Site ordination by ground flora abundance

Ranked cover-abundance ground flora data were used in RA of the 24 sites and 81 species. RA was performed using an option in the DECORANA program; only four eigenvalues and the associated sample and species scores in the eigenvector are given by the program. The eigenvalues of the first four vectors were, respectively, 0.658, 0.271, 0.164, and 0.146. Of the four vectors given, the first accounted for 53.1%, the second for 21.9%, the third for 13.2% and the fourth for 11.8%. Since total variability is not given by the program, the actual percentage of the total summarized by any vector is not known. It is apparent that the first vector contains much more variability than any of the others. The arrangement of species and sites with respect to the first vector was subjectively interpreted as being associated with the soil texture-nutrient gradient described in Chapter 2. The other three RA axes did not have an apparent interpretation, and were not used in this discussion.

Some of the important ground flora species used in ordination of sites by RA are diagrammed along the first ordination axis in Figure 3.1. Ranked cover-abundance values of these species, and selected other species, are also shown in Table 3.2. Figure 3.1 shows that high abundances of Vaccinium angustifolium and Pteridium aquilinium are present on sites T through M at the left of the ordination axis. Sites D through F on the right of the ordination are characterized by the presence of Viola canadensis, and a greater abundance of Osmorhiza chilensis and Galium triflorum than is present on sites N through O in the center of the ordination. Viburnum acerifolium is present on sites at the left and center of the ordination, but its abundance does not increase on sites at the center. Because of its similarity in abundance across most of the gradient, Viburnum acerifolium is not as useful an indicator species in northeastern lower Michigan as it is in the northwestern part of the state. There, it is an indicator of certain ecosystem groups (Host et al. 1987, 1988). A similar trend is apparent for Smilacina racemosa, which occurs at similar abundances through sites at the left and center of the ordination. Prenanthes alba, which increases in abundance on sites M through O, may be a useful indicator species for these sites.

Figure 3.1. Cover-abundance of selected ground flora species for sites ordinated by reciprocal averaging of ranked ground flora species cover-abundance values.

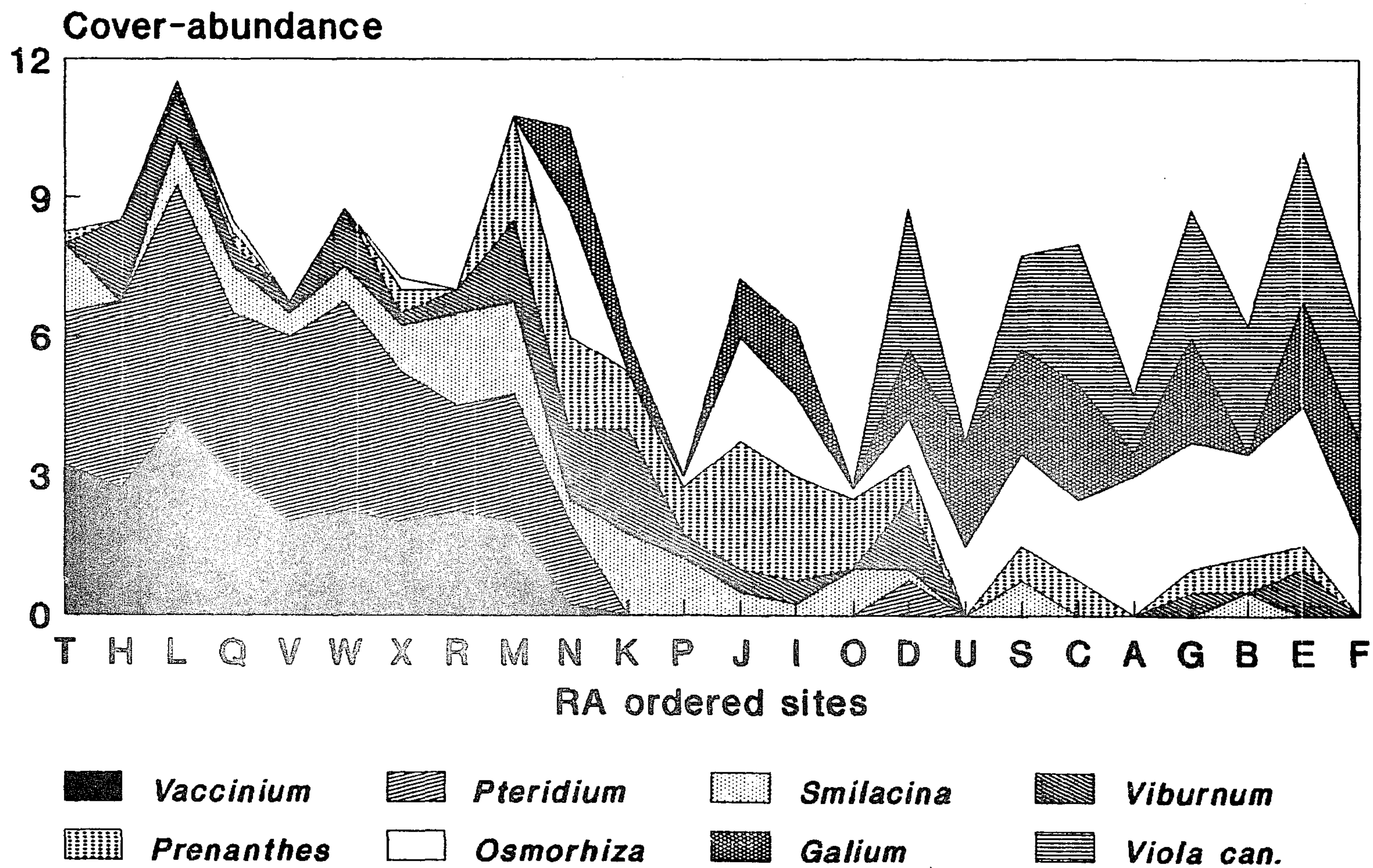

Cover-abundance
12
9
6
3
0
T H L Q V W X R M N K P J I O D U S C A G B E F
RA ordered sites
Vaccinium
Pteridium
Smilacina
Viburnum
Prenanthes
Osmorhiza
Galium
Viola can.

Table 3.2. Ranked cover-abundance values of selected ground flora species.

Site	Vaccinium angustifolium	Pteridium aquilinium	Smilacina racemosa	Viburnum acerifolium	Prenanthes alba	Osmorhiza chilensis	Galium triflorum	Viola canadense	Oryzopsis asperifolia	Mianthemum canadense
A	----	----	----	----	----	3.00	0.50	1.25	----	----
B	----	----	0.50	----	0.75	2.25	----	2.75	----	2.75
C	----	----	----	----	0.75	1.75	2.50	3.00	1.00	1.75
D	----	0.75	0.25	1.50	0.75	1.00	1.50	3.00	4.25	1.00
E	----	----	----	1.00	0.50	3.00	2.25	3.25	2.50	2.00
F	----	----	----	----	----	1.75	2.00	2.50	----	0.25
G	----	----	----	0.50	0.50	2.75	2.25	2.75	----	0.75
H	2.75	4.00	----	1.75	----	----	----	----	1.00	----
I	----	----	0.25	0.50	2.25	1.75	1.50	----	2.00	2.00
J	----	----	0.50	0.50	2.75	2.25	1.25	----	3.00	3.25
K	----	----	1.75	2.25	1.25	----	0.75	----	1.00	2.50
L	4.25	5.00	1.00	1.00	----	----	0.25	----	0.75	1.50
M	2.00	2.75	2.00	1.75	2.25	----	----	----	2.50	0.25
N	0.25	1.75	0.50	1.50	2.00	2.75	1.75	----	2.75	1.50
O	----	----	1.00	----	1.50	0.25	----	----	0.50	1.50
P	----	----	1.25	0.50	1.00	0.25	----	----	0.25	1.00
Q	3.00	3.50	1.00	0.50	0.25	0.25	----	----	1.50	1.25
R	2.25	2.25	2.00	0.50	----	----	----	----	2.00	2.00
S	----	----	0.75	----	0.75	2.00	2.25	2.00	0.50	1.50
T	3.25	3.25	1.50	----	0.25	----	----	----	1.00	0.75
U	----	----	----	----	----	1.50	2.25	----	0.50	0.50
V	2.00	4.00	0.50	0.25	----	----	----	----	1.75	1.25
W	2.25	4.50	0.75	1.25	----	----	----	----	2.75	0.50
X	2.00	3.25	1.00	0.25	0.50	0.25	----	----	3.25	1.25

Site ordination by ground flora ranked cover-abundance in relation to depositional environment

Sites T, H, and L are formed in outwash sand with sand and gravel stratification in the substratum. The ordination produced from RA of ground flora species cover-abundance values places these three sites together at the far left of the first dimension axis, with a herbaceous layer dominated by Vaccinium and Pteridium.

Sites Q, V, W, X, and R appear next along the first dimension ordination axis, with a herbaceous layer still dominated by Vaccinium and Pteridium, but of lesser coverage than that found on sites T, H, and L. Sites Q, V, W, X, and R were formed in depositional environments of outwash material containing ice-rafted loamy material or flow till in the substratum.

Sites M, K, and P were also formed in outwash with loamy inclusions in the substratum, but these sites have vegetation which differs from that of sites Q, V, W, X, and R. Site M has Prenanthes, and a larger component of Smilacina than the other sites formed in outwash with loamy inclusions. Sites K and P lack Pteridium and Vaccinium. Also, site N, which has loamy till near the surface, is placed with sites M, K, and P along the ordination axis. Examination of soil descriptions revealed that sites Q, V, W, X, and R have accumulations less than 60 cm thick of sandy clay loam or heavier textured soil in the substratum, while sites M, K, and P, have thicker accumulations.

Although the number of sites in this group is small, it appears that the vegetal ordination separated soils with thick substratum textural accumulations from those with thin accumulations.

Port Bruce till sites were all placed to the right of Port Huron sites along the first ground flora ordination axis, with the exception of site S, which may be till of yet another deposit. Site S is located on a remnant morainal feature occurring within the boundary of the Loud Creek outwash, to the northeast of the Glennie moraine (Figure 2.3) (Burgis 1977, 1981). The site is located in the general area of Port Huron deposits, but is of lower elevation than the Glennie moraine, and may be an erosional surface, possibly even the Port Bruce till with which site ordination by ground flora places it. Detailed analysis of the till fabric and mineralogy of site S would be required to determine whether it is of Port Bruce or Port Huron age, or of some other deposit. For purposes of this study, it was treated as an outlier and dropped from further analyses.

Sites C and U, which were formed in lacustrine material, were placed among the till sites by ground flora ordination. These sites have a high coverage of Osmorhiza and Galium.

The first dimension of the site ordination obtained by RA of ranked ground flora cover-abundance corresponded reasonably well with depositional environment categories, except that lacustrine sites were not distinguished. Sandy outwash sites were placed at the far left of the first axis. Sites formed in outwash with inclusions of ice-rafted till material, with less than 60 cm of accumulated loamy soil in the substratum, were placed to the right of sandy outwash sites. Sites which had more than 60 cm of loamy soil textural accumulations in the substratum were placed to the right of those sites with thinner accumulations. Till sites were placed at the right of the ordination axis, and separated according to Port Bruce or Port Huron deposition, with the exception of site S which may be eroded. Lacustrine sites C and U were placed with Port Bruce till sites. Dividing these sites into groups based on depositional environment produced groups with few members, so that the associations identified here should be verified with a larger data set.

Site ordination by ground flora ranked cover-abundance in relation to soil properties

Site scores in the first ordination axis of RA of ground flora ranked cover-abundance values, and site scores in the first PC of separate soil analyses as discussed in Chapter 2, are shown in Table 3.3. The simple correlation between ground flora ordination scores and soil field data scores, for the first axes only, was r=0.832; with mineral soil lab data the correlation was r=-0.890, and with soil data which included organic layers the correlation was

Table 3.3. Site ranks and scores from first-dimension RA ordinations of ground flora ranked cover-abundance values and overstory BA by species, and from PCA of soils data.

Site	Ground flora		Overstory		Soils-field data		Soils-laboratory data (mineral soil)		Soils-laboratory data (organic and mineral soil)	
	RA rank	RA score	RA rank	RA score	PCA rank	PCA score	PCA rank	PCA score	PCA rank	PCA score
A	20	-129	24	-175	14	-0.39	7	0.91	13	0.02
B	22	-152	21	-155	24	-1.30	6	0.93	4	0.89
C	19	-127	18	-142	10	-0.24	13	-0.08	6	0.67
D	16	-100	19	-146	16	-0.55	10	0.48	17	-0.48
E	23	-154	17	-141	15	-0.46	12	0.31	15	-0.08
F	24	-170	23	-163	20	-0.80	2	1.23	7	0.59
G	21	-151	20	-154	18	-0.63	8	0.79	12	0.13
H	2	194	4	202	3	1.66	24	-1.61	22	-1.36
I	14	-72	11	-14	21	-1.09	5	1.01	2	1.44
J	13	-68	13	-55	17	-0.62	9	0.63	8	0.35
K	11	-20	10	49	11	-0.31	11	0.43	11	0.16
L	3	193	2	448	2	1.79	20	-1.19	23	-1.33
M	9	109	6	166	12	-0.31	16	-0.35	14	-0.05
N	10	0	14	-97	23	-1.23	3	1.10	1	2.50
O	15	-73	16	-138	13	-0.38	4	1.03	3	1.25
P	12	-58	12	-23	7	0.58	14	-0.22	9	0.28
Q	4	192	3	217	8	0.56	17	-0.96	16	-0.38
R	8	155	7	135	6	0.94	19	-1.16	20	-1.01
S	18	-114	22	-159	22	-1.16	1	1.46	10	0.27
T	1	206	1	498	1	1.88	23	-1.34	24	-1.69
U	17	-113	15	-137	19	-0.72	15	0.25	5	0.74
V	5	187	9	128	5	1.16	21	-1.24	21	-1.03
W	6	180	8	129	4	1.38	22	-1.33	19	-0.95
X	7	174	5	175	9	0.23	18	-1.11	18	-0.92

r=-0.685. Correlations among these scores are all significant at alpha=0.05 for n=24. Correlations are influenced by sample size so that statistically significant r values may result from random correlations or from the influence of a variable not studied, and so may not necessarily be meaningful. However, these correlations appear to indicate that there is an association between gradients of soil properties and of herbaceous vegetation.

Different soil properties are associated with the first axes of the separate soil PCA's. The mineral soil laboratory data scores in the first PC had the highest correlation with ground flora RA scores in the first dimension; the PC of mineral soil laboratory data positively weights B horizon cations and negatively weights acidity. The association between the two gradients indicates that flora on sites with low scores on the first RA axis occur in areas of high B nutrient status, and flora on sites with high RA scores occur in areas of high acidity. The correlation of first dimension RA scores with first dimension PCA scores of soil laboratory data which included organic layers indicates that sites with low RA scores are those which have organic layers of high nutrient content, and those sites with high RA scores have organic layers with low levels of nutrients. Likewise, the correlation of first dimension RA scores with first dimension PCA scores of field data indicates that sites with low scores in both analyses are those with greater amounts of loamy textured soil.

Thus, in a general sense, the occurrence and abundance of herbaceous species is related to soil properties.

Spearman's coefficient of rank correlations were also calculated for site ranks in the first dimension of RA and in the first dimension of the several different PCA's. The correlation of site ranks in the first dimension of RA of ground flora species cover-abundance values with ranks produced by PCA of mineral soil laboratory data was $r_s=-0.770$; with PCA of laboratory data including organic layers the correlation was $r_s=-0.643$, and with PCA of field data the correlation was $r_s=0.770$. All these correlations are significant at alpha=0.05 for n=24, and the interpretations are the same as those for the simple linear correlations among site scores.

Site ordination by ground flora abundance in relation to overstory species composition and basal area

A chart of overstory species composition expressed as basal area by species ($m^2\ ha^{-1}$) is arrayed along the first ordination axis produced by RA of ground flora species abundance (Figure 3.2). Sites T, H, and L, formed in sandy outwash and dominated by _Vaccinium_ and _Pteridium_, contain black and pin oak species in the overstory (Table 3.4)[1]. Sites formed in outwash with loamy inclusions less than 60 cm thick in the substratum, including sites Q through M on

[1] Scientific names of tree species appear in Table 3.5.

Figure 3.2. Overstory basal area of selected species for sites ordinated by reciprocal averaging of ranked ground flora species cover-abundance values.

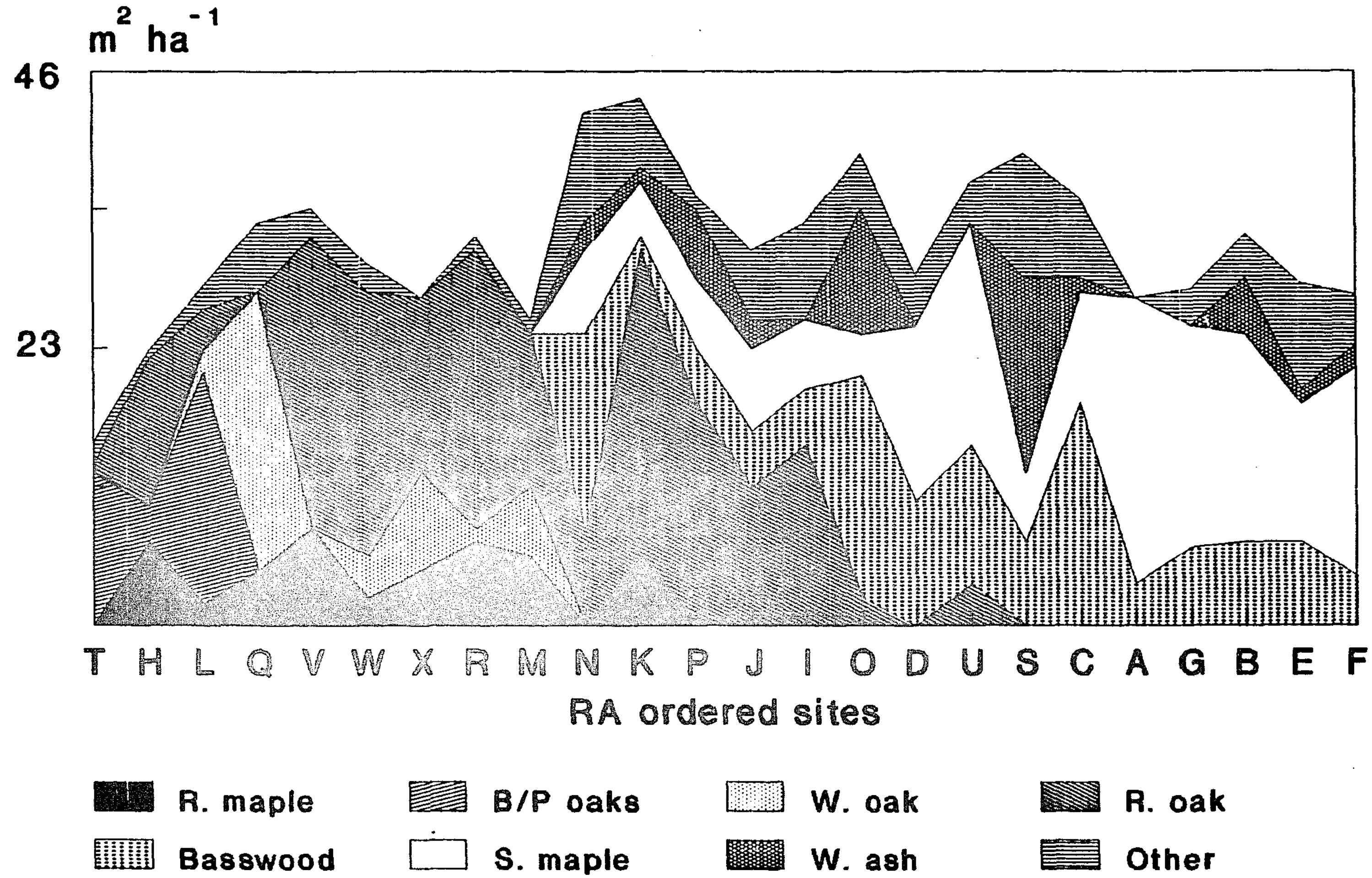

m2 ha-1
46
23
T H L Q V W X R M N K P J I O D U S C A G B E F
RA ordered sites
R. maple
B/P oaks
W. oak
R. oak
Basswood
S. maple
W. ash
Other

Table 3.4. Mean basal area of overstory species.

Site	Red maple	Black, Pin oaks	White oak	Red oak	Basswood	Sugar maple	White ash	Beech	Paper birch	Quaking aspen	Bigtooth aspen	Black cherry	Ironwood	White pine	Total BA
	<						$m^2\ ha^{-1}$							>	
A	-	-	-	-	3.4	23.6	-	-	-	-	-	-	-	-	27.1
B	-	-	-	-	6.9	17.2	4.6	0.7	-	-	3.0	-	-	-	32.1
C	-	-	-	-	18.4	9.2	1.1	0.7	-	-	5.3	-	0.7	-	35.1
D	-	-	-	-	10.3	14.5	-	-	-	-	4.1	-	-	-	28.7
E	-	-	-	-	6.9	11.5	1.1	4.6	-	-	3.4	0.7	-	-	29.4
F	-	-	-	-	4.1	17.2	1.8	3.0	-	-	1.1	-	-	-	27.1
G	-	-	-	-	6.4	18.4	-	-	-	-	3.0	-	-	-	28.2
H	6.9	3.0	-	12.2	-	-	-	-	-	-	0.7	-	-	-	22.5
I	-	-	-	14.9	4.6	5.7	-	-	4.6	1.1	1.1	-	-	1.1	33.3
J	-	-	-	11.5	4.6	6.9	2.3	3.4	-	-	-	1.1	1.1	-	31.0
K	5.7	-	-	25.3	1.1	4.6	1.1	3.4	2.3	-	-	-	-	-	43.6
L	1.8	19.1	1.8	3.4	-	-	-	-	-	-	1.8	-	-	-	27.6
M	5.7	-	5.7	12.6	-	-	-	-	-	-	-	1.1	-	-	25.3
N	-	-	-	8.0	16.1	6.9	2.3	2.3	1.1	-	-	-	2.3	3.4	42.5
O	-	-	-	2.3	18.4	3.4	10.3	1.1	-	-	2.3	-	1.1	-	39.0
P	-	-	-	18.4	4.6	5.7	5.7	1.1	-	-	-	-	-	-	35.6
Q	4.6	-	23.0	-	-	-	-	-	-	-	5.7	-	-	-	33.3
R	6.9	-	1.1	23.0	-	-	-	-	-	-	1.1	-	-	-	32.1
S	-	-	-	-	6.9	5.7	16.1	9.2	1.1	-	-	-	-	-	39.0
T	-	12.6	-	0.7	-	-	-	-	-	-	1.1	-	-	0.7	14.9
U	-	-	-	3.4	11.5	18.4	-	-	3.4	-	-	-	-	-	36.7
V	8.0	-	-	24.1	-	-	-	-	-	-	2.3	-	-	-	34.4
W	2.3	-	3.4	21.8	-	-	-	-	-	-	2.3	-	-	-	29.8
X	4.6	-	8.0	14.5	-	-	-	-	-	-	-	-	-	-	27.1

Table 3.5. Common and scientific names of tree species.

Common name	Scientific name
Red maple	Acer rubrum
Sugar maple	Acer saccharum
Northern red oak	Quercus rubra
Pin oak	Quercus palustris
Black oak	Quercus velutina
White oak	Quercus alba
Beech	Fagus grandifolia
White ash	Fraxinus americana
Basswood	Tilia americana
Black cherry	Prunus serotina
Ironwood	Ostrya virginiana
Paper birch	Betula papyrifera
Quaking aspen	Populus tremuloides
Bigtooth aspen	Populus grandidentata
Eastern white pine	Pinus strobus
Red pine	Pinus resinosa
Jack pine	Pinus banksiana

the first RA ordination axis, contain no black or pin oaks, but do contain a high basal area of northern red oak. Most of these sites also support a white oak component, but selective logging of this species for railroad ties may have eliminated and/or reduced its presence on some sites.

Sites located on Port Huron till, including sites N, J, I, and O along the ground flora ordination, support the greatest total basal area (BA) of the sites studied. Species include the northern hardwoods cover type, dominated by sugar maple and basswood species. Sites I and J support a large component of northern red oak, while sites N and O have a smaller oak component. Sites formed in Port Bruce till lack a northern red oak component and are comprised entirely of the more typical northern hardwood species.

RA of overstory basal area by species was performed in the same manner as the RA of ground flora ranked cover-abundance values. Eigenvalues of the first four vectors were, respectively, 0.753, 0.629, 0.399, and 0.255. Of the variation expressed by the first four axes, the first accounted for 37.0%, the second for 30.9%, the third for 19.6%, and the fourth for 12.5%. Scores and ranks of sites in the first dimension of the RA ordination using overstory are shown in Table 3.3. This RA ordination was performed to compare the first axis obtained from overstory data with that derived from RA of ground flora species ranked cover-abundance values. Thus, the second and higher dimensions are not discussed, even though the second dimension accounted for nearly as much variability as the first.

The ordination of overstory species composition is associated with the ordination of ground flora species cover-abundance. Spearman's coefficient of rank correlation for sites in the first dimension of RA obtained from overstory basal area was correlated with site ranks from the first dimension of RA using ground flora at $r_s=0.934$, significant at alpha of 0.05 (Table 3.3). Scores of sites in the first axes of the RA ordinations by ground flora and overstory were correlated by simple linear correlation at $r=0.905$, also significant at alpha=0.05. These correlations indicate that overstory basal area by species is associated with ground flora species abundance.

Differences in overstory composition between tills of different depositions

There are several possible explanations for the presence of oak on till sites of Port Huron deposition their absence on till sites of Port Bruce age. One explanation relates to disturbance history and methods of site selection. Harvesting disturbance was generally greater in the area which includes Port Huron sites; this difference reflects policies in forest management on different Ranger Districts. Disturbance favors the establishment of oak species, both after catastrophic disturbance such as fire or clearcutting (Whitney 1986, 1987), or within an established canopy due to gap formation through windthrow or mortality (Lorimer 1983). Because of the high disturbance level in the area of Port Huron till, many sites were not of sufficient age for sampling. Thus, sample size is limited and may be biased.

Average ages of dominant tree species on Port Bruce and Port Huron till sites were not significantly different (Table 3.6). Oak is thought to be a successional species (Host et al. 1987), and it is present on sites which are older than many of the sites which lack oak. This indicates that stands on the Port Bruce sites lacked oak at the time of establishment, particularly as there was no evidence of recent selective logging.

Table 3.6. Comparison of average age of dominant tree species on till sites of Port Bruce and Port Huron deposition.

Port Huron Site	Average age	Port Bruce Site	Average age
N	97	D	57
J	75	A	53
I	70	G	72
O	60	B	60
		E	65
		F	72
Mean	75.5	Mean	61.4
S.D.	15.6	S.D.	7.4

Variances and means are not significantly different at alpha=0.05.

Ordinations based on vegetation have sometimes been interpreted as associated with disturbance (Gauch 1982). Ground flora is believed to return to stable patterns of species composition and abundance relatively quickly following disturbance, while the longer-lived tree species require more time to attain stable composition. Because site ages were believed to be sufficient for ground flora composition to stabilize, the differences in ground flora species composition between Port Bruce and Port Huron sites indicate that overstory differences are less likely to be attributable to disturbance at some time after stand establishment.

Because differences in overstory composition coincided with the boundaries of Port Huron and Port Bruce tills, a soil difference was suspected. This possibility was examined by grouping sites according to overstory composition and comparing their soil characteristics. Soil variables which were most effective in separating Port Bruce and Port Huron tills in principal component analysis of field data were coarse fragment content, E horizon thickness, and overall texture (Chapter 2). These soil properties were compared among groups based on overstory composition to determine whether differences existed.

Groups based on overstory composition were set up as follows: Group 1 consisted of sites T, H, and L, with overstories containing black and pin oak; Group 2 included sites Q, V, W, X, R, and M, which were those sites dominated by northern red oak, with relatively low total BA, and no species of the northern hardwoods cover type present; Group 3 sites were N, K, P, J, I, and O, with overstories of northern red oak and northern hardwoods, located in areas of Port Huron glaciation; and Group 4, which included sites D, A, B, C, D, E, F, G, and U, located in areas of Port Bruce glaciation with overstories of northern hardwoods. Table 3.7 presents statistical comparisons among soil properties of these groups. Variable names and units are explained in Tables 2.2 and 2.3. Tests for significant differences between group variances and group means are according to Steel and Torrie (1980).

Silt and clay contents averaged over the upper 150 cm depth are shown in Figure 3.3. Average silt and clay

Table 3.7. Soil variable comparisons for site groups based on overstory composition.

Variable	Groups 1st	Groups 2nd	Mean <---- 1st group	S.D.	n ---->	Mean <---- 2nd group	S.D.	n ---->	F (calculated)	df(n) <- for F	df(d) for F ->	df t	Pooled s	Approx. df for t	t (calculated)
TKNSUM	4	3	8053.64	1943.54	32	7915.49	2012.46	24	1.072	23	31	54	535.53	48.7	0.258
TKNSUM	4	2	8053.64	1943.54	32	3910.69	1644.15	24	1.397	31	23	54	480.29	53.2	8.626*
TKNSUM	4	1	8053.64	1943.54	32	2962.74	579.36	12	11.253*	31	11	42	382.12	41.0	13.322*
TKNSUM	3	2	7915.49	2012.46	24	3910.69	1644.15	24	1.498	23	23	46	530.46	44.2	7.549*
TKNSUM	3	1	7915.49	2012.46	24	2962.74	579.36	12	12.066*	23	11	34	443.53	29.6	11.166*
TKNSUM	2	1	3910.69	1644.15	24	2963.74	579.36	12	8.053*	23	11	34	374.98	31.7	2.525*
TKPSUM	4	3	4820.19	1622.26	32	4769.59	2257.74	24	1.937*	23	31	54	542.80	39.8	0.093
TKPSUM	4	2	4820.19	1622.26	32	2144.29	1067.67	24	2.309*	31	23	54	360.19	53.2	7.429*
TKPSUM	4	1	4820.19	1622.26	32	1579.31	355.75	12	20.794*	31	11	42	304.61	37.7	10.639*
TKPSUM	3	2	4769.59	2257.74	24	2144.29	1067.67	24	4.472*	23	23	46	509.79	32.8	5.149*
TKPSUM	3	1	4769.59	2257.74	24	1579.31	355.75	12	40.277*	23	11	34	472.16	25.2	6.756*
TKPSUM	2	1	2144.29	1067.67	24	1579.31	355.75	12	9.007*	23	11	34	240.92	31.1	2.345*
CASUM	4	3	33520.31	21702.95	32	32263.91	22233.15	24	1.049	23	31	54	5942.70	49.0	0.211
CASUM	4	2	33520.31	21702.95	32	14902.02	18635.60	24	1.356	31	23	54	5402.74	52.9	3.446*
CASUM	4	1	33520.31	21702.95	32	6142.29	8706.91	12	6.213*	31	11	42	4586.59	41.7	5.969*
CASUM	3	2	32263.91	22233.15	24	14902.02	18635.60	24	1.423	23	23	46	5921.71	44.6	2.931*
CASUM	3	1	32263.91	22233.15	24	6142.29	8706.91	12	6.520*	23	11	34	5187.86	32.8	5.035*
CASUM	2	1	14902.02	18635.60	24	6142.29	8706.91	12	4.581*	23	11	34	4559.36	33.9	1.921
KSUM	4	3	1117.93	632.51	32	1491.80	943.62	24	2.226*	23	31	54	222.72	37.9	1.678
KSUM	4	2	1117.93	632.51	32	570.82	444.60	24	2.024*	31	23	54	144.01	53.8	3.799*
KSUM	4	1	1117.93	632.51	32	196.23	39.99	12	250.172*	31	11	42	112.41	31.7	8.199*
KSUM	3	2	1491.80	943.62	24	570.82	444.60	24	4.505*	23	23	46	212.92	32.7	4.325*
KSUM	3	1	1491.80	943.62	24	196.23	39.99	12	556.787*	23	11	34	192.96	23.2	6.714*
KSUM	2	1	570.82	444.60	24	196.23	39.99	12	123.603*	23	11	34	91.48	23.7	4.094*

*Significant difference between groups at alpha=0.05.

Table 3.7. (continued).

Variable	Groups 1st	Groups 2nd	Mean	S.D.	n	Mean	S.D.	n	F (calculated)	df(n)	df(d)	df t	Pooled s	Approx. df for t	t (calculated)
			<---- 1st group ---->			<---- 2nd group ---->				<- for F ->					
MGSUM	4	3	3373.02	2447.99	32	5078.32	3261.28	24	1.775	23	31	54	794.00	41.1	2.147*
MGSUM	4	2	3373.02	2447.99	32	1717.53	2308.93	24	1.124	31	23	54	639.85	51.2	2.587*
MGSUM	4	1	3373.02	2447.99	32	349.78	300.96	12	66.162*	31	11	42	441.38	33.4	6.849*
MGSUM	3	2	5078.32	3261.28	24	1717.53	2308.93	24	1.995	23	23	46	815.66	41.4	4.120*
MGSUM	3	1	5078.32	3261.28	24	349.78	300.96	12	117.426*	23	11	34	671.35	23.8	7.043*
MGSUM	2	1	1717.53	2308.93	24	349.78	300.96	12	58.859*	23	11	34	479.25	24.5	2.853*
CSFRSUM	4	3	6.47	8.91	32	2.17	2.60	24	11.763*	31	23	54	1.66	37.8	2.586*
CSFRSUM	4	2	6.47	8.91	32	3.29	2.11	24	17.879*	31	23	54	1.63	35.5	1.947
CSFRSUM	4	1	6.47	8.91	32	0.75	0.64	12	190.917*	31	11	42	1.59	31.9	3.607*
CSFRSUM	3	2	2.17	2.60	24	3.29	2.11	24	1.520	23	23	46	0.68	44.1	1.638
CSFRSUM	3	1	2.17	2.60	24	0.75	0.64	12	16.230*	23	11	34	0.56	28.1	2.530*
CSFRSUM	2	1	3.29	2.11	24	0.75	0.64	12	10.679*	23	11	34	0.47	30.2	5.422*
SILT150	4	3	18.91	8.21	32	20.75	11.37	24	1.918*	23	31	54	2.74	40.0	0.672
SILT150	4	2	18.91	8.21	32	7.92	7.63	24	1.158	31	23	54	2.1285	51.5	5.161*
SILT150	4	1	18.91	8.21	32	5.20	0.40	12	422.794*	31	11	42	1.4557	31.4	9.416*
SILT150	3	2	20.75	11.37	24	7.92	7.63	24	2.221*	23	23	46	2.7945	40.2	4.589*
SILT150	3	1	20.75	11.37	24	5.20	0.40	12	810.779*	23	11	34	2.3233	23.1	6.691*
SILT150	2	1	7.92	7.63	24	5.20	0.40	12	365.067*	23	11	34	1.5613	23.3	1.743
CLT150	4	3	16.08	9.28	32	20.37	12.58	24	1.837	23	31	54	3.0464	40.6	1.409
CLT150	4	2	16.08	9.28	32	9.91	9.05	24	1.051	31	23	54	2.4710	50.3	2.496*
CLT150	4	1	16.08	9.28	32	5.00	0.0	12	. *	31	11	42	1.6404	31.0	6.753*
CLT150	3	2	20.37	12.58	24	9.91	9.05	24	1.930	23	23	46	3.1630	41.8	3.307*
CLT150	3	1	20.37	12.58	24	5.00	0	12	. *	23	11	34	2.5670	23.0	5.988*
CLT150	2	1	9.91	9.05	24	5.00	0	12	. *	23	11	34	1.8480	23.0	2.658*

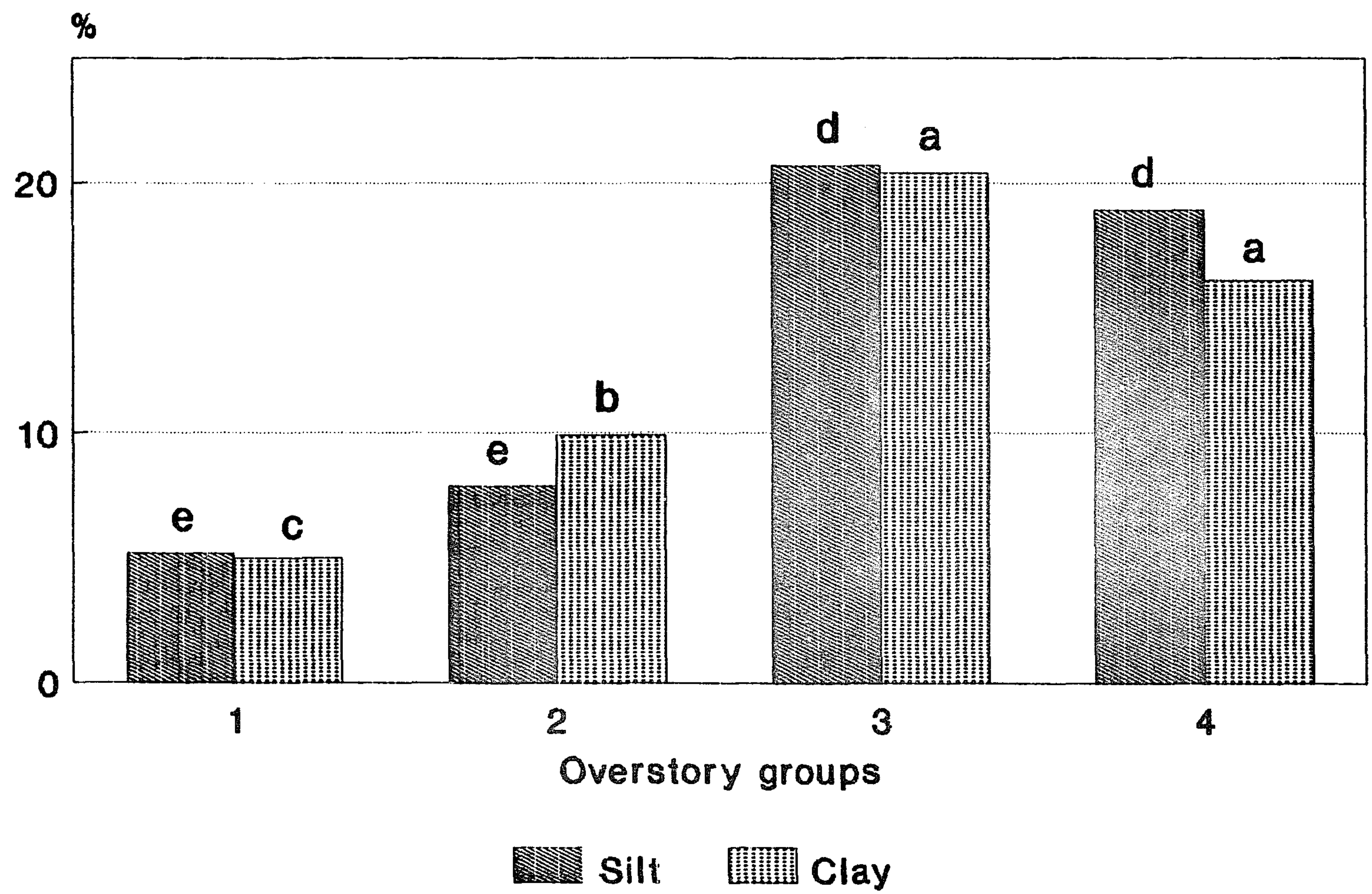
*Significant difference between groups at alpha=0.05.

Table 3.7. (continued).

Variable	Groups 1st	Groups 2nd	Mean (1st group)	S.D. (1st group)	n (1st group)	Mean (2nd group)	S.D. (2nd group)	n (2nd group)	F (calculated)	df(n) for F	df(d) for F	df t	Pooled s	Approx. df for t	t (calculated)
NMIN	4	3	113.38	41.24	32	76.94	40.91	24	1.016	31	23	54	11.0850	49.9	3.288*
NMIN	4	2	113.38	41.24	32	39.41	14.15	24	8.490*	31	23	54	7.8419	40.2	9.432*
NMIN	4	1	113.38	41.24	32	27.84	3.59	12	131.838*	31	11	42	7.3637	32.2	11.616*
NMIN	3	2	76.94	40.91	24	39.41	14.15	24	8.354*	23	23	46	8.8360	28.4	4.247*
NMIN	3	1	76.94	40.91	24	27.84	3.59	12	129.724*	23	11	34	8.4145	23.7	5.834*
NMIN	2	1	39.41	14.15	24	27.84	3.59	12	15.528*	23	11	34	3.0695	28.3	3.770*
ETHICK	4	3	3.56	1.93	8	5.03	3.53	6	3.332	5	7	12	1.5957	7.2	0.922
ETHICK	4	2	3.56	1.93	8	4.82	0.98	6	3.925	7	5	12	0.7917	10.8	1.584
ETHICK	4	1	3.56	1.93	8	2.50	2.60	3	1.804	2	7	9	1.6486	2.9	0.645
ETHICK	3	2	5.03	3.53	6	4.82	0.98	6	13.077*	5	5	10	1.4958	5.8	0.145
ETHICK	3	1	5.03	3.53	6	2.50	2.60	3	1.848	5	2	7	2.0805	5.5	1.218
ETHICK	2	1	4.82	0.98	6	2.50	2.60	3	7.078*	2	5	7	1.5521	2.3	1.493
BTHICK	4	3	104.22	34.97	32	79.50	41.43	24	1.403	23	31	54	10.4760	44.7	2.360*
BTHICK	4	2	104.22	34.97	32	52.96	22.87	24	2.340*	31	23	54	7.7466	53.1	6.617*
BTHICK	4	1	104.22	34.97	32	45.75	6.58	12	28.253*	31	11	42	6.4679	36.2	9.040*
BTHICK	3	2	79.50	41.43	24	52.96	22.87	24	3.283*	23	23	46	9.6595	35.8	2.748*
BTHICK	3	1	79.50	41.43	24	45.75	6.58	12	39.647*	23	11	34	8.6677	25.2	3.894*
BTHICK	2	1	52.96	22.87	24	45.75	6.58	12	12.076*	23	11	34	5.0391	29.6	1.431*

*Significant difference between groups at alpha=0.05.

Figure 3.3. Mean silt and clay percent of the upper 150 cm of soil for sites grouped by overstory composition.



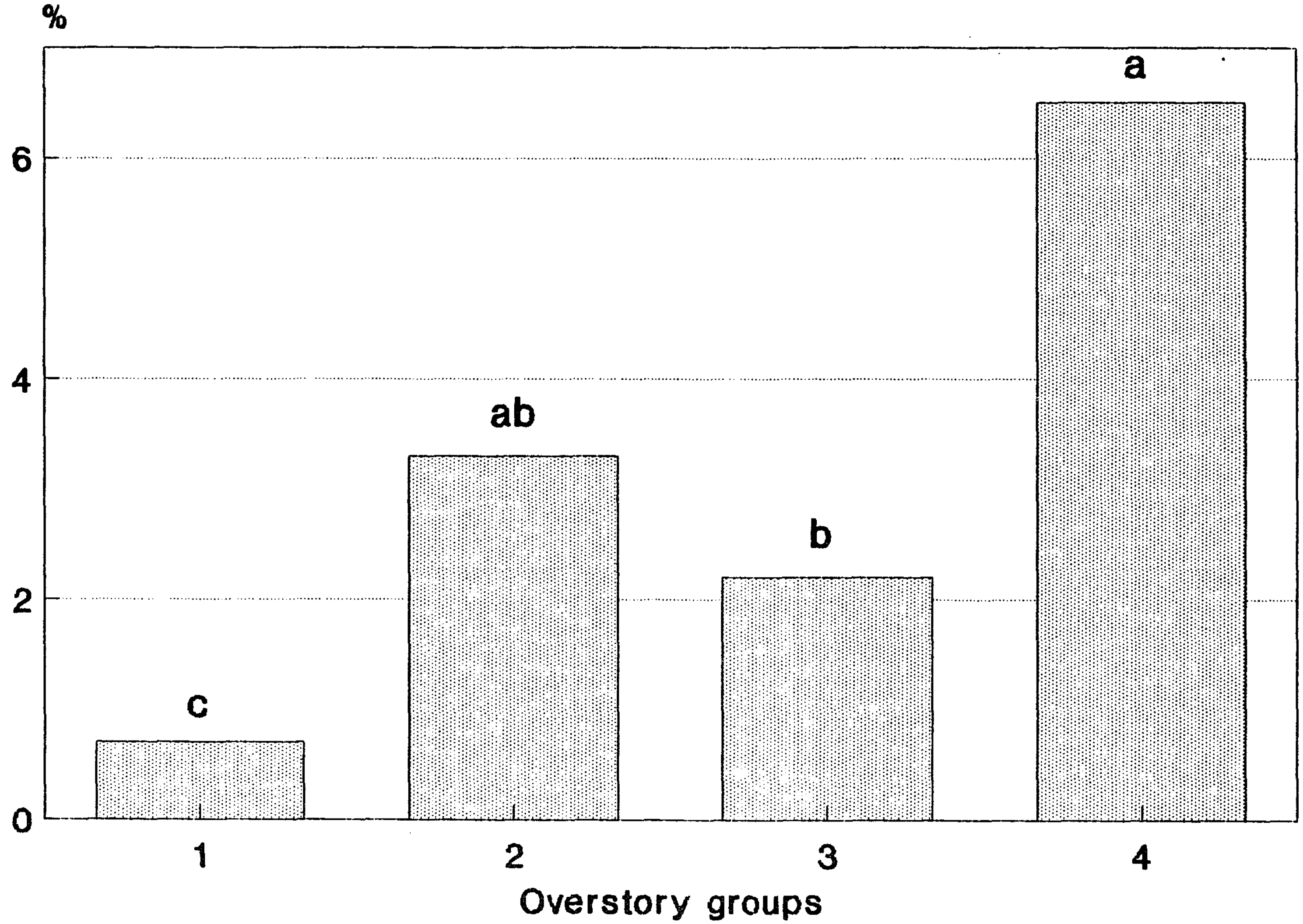
Bars with common letters are not significantly different (Table 3.7)
a, b, and c compare mean clay percent
d and e compare mean silt percent

contents were slightly greater on oak-northern hardwood sites than on northern hardwood sites, but differences were not significant. Black and pin oak sites, and sites with predominantly northern red oak overstories, had significant textural differences from the other two overstory groups (Table 3.7).

Coarse fragment contents of the site groups are presented in Figure 3.4, showing that northern hardwood sites had a significantly higher coarse fragment content than the oak-northern hardwood group (Table 3.7). Mineralogical content and weathering supply of nutrients from coarse fragments of Port Bruce and Port Huron tills were not analyzed as part of this study, but may be of importance in distinguishing between them. Field observations note the presence of weathering limestones in nearly all layers of high coarse fragment content.

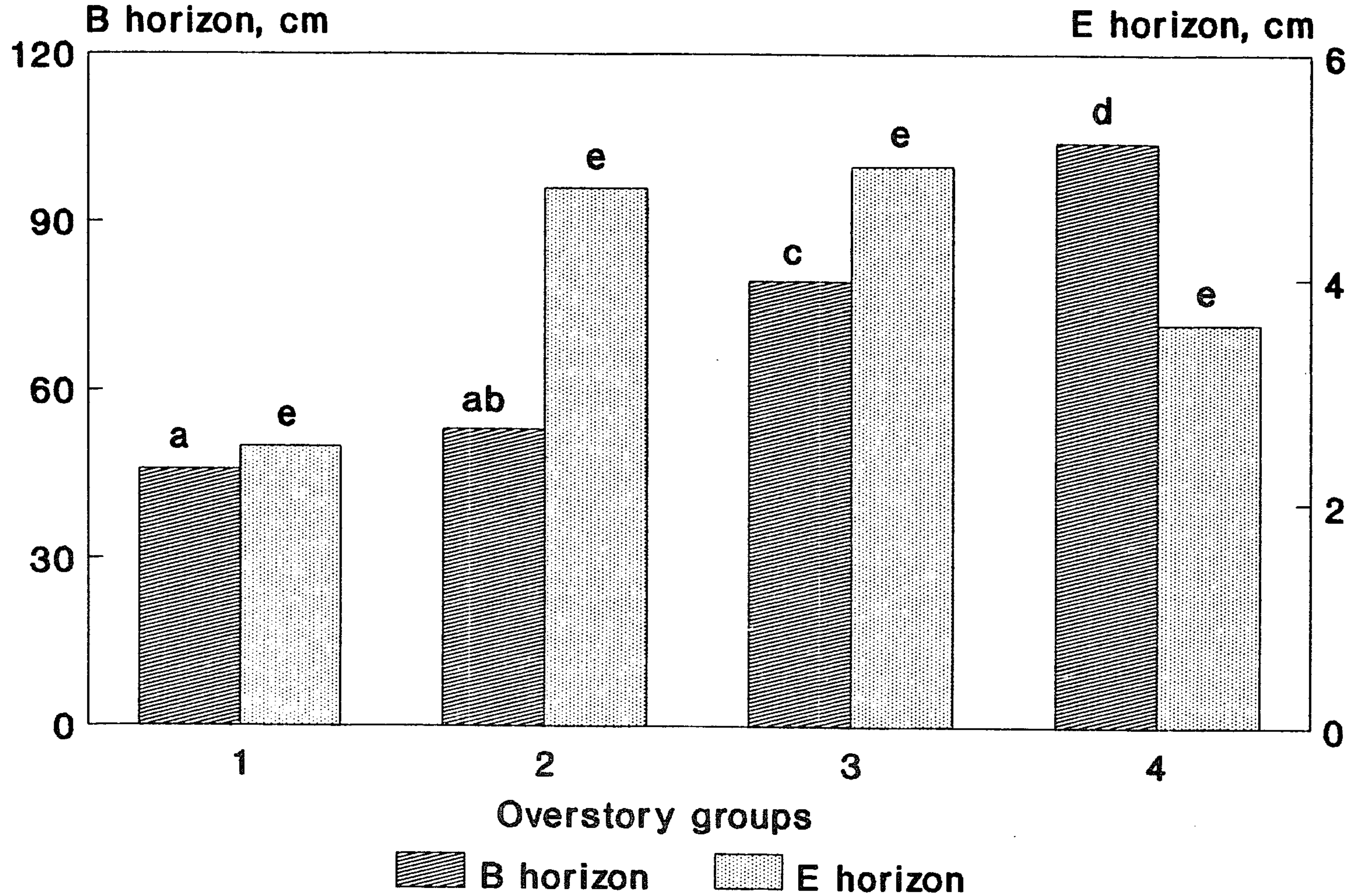
Thicknesses of the E and B horizons for the groups based on overstory composition are shown in Figure 3.5. Oak-northern hardwood sites had thicker E horizons, and northern hardwood sites had thicker B horizons, but only the difference in B horizon thickness was significant (Table 3.7). The B horizons of sites formed in till, including most sites in the oak-northern hardwood and northern hardwood overstory groups, are generally argillic, with clay translocation evident within the upper portion of dense till layers. Some sites have minor spodic development in B layers above the argillic horizon. The development of B

Figure 3.4. Mean coarse fragment content as a volume percentage of the upper 150 cm of soil for sites grouped by overstory composition.



Bars with common letters are not significantly different (Table 3.7)

Figure 3.5. Mean thickness of the E and B soil horizons for sites grouped by overstory composition.



Bars with common letters are not significantly different (Table 3.7)
a, b, c, and d compare B horizon mean thickness
e compares E horizon mean thickness

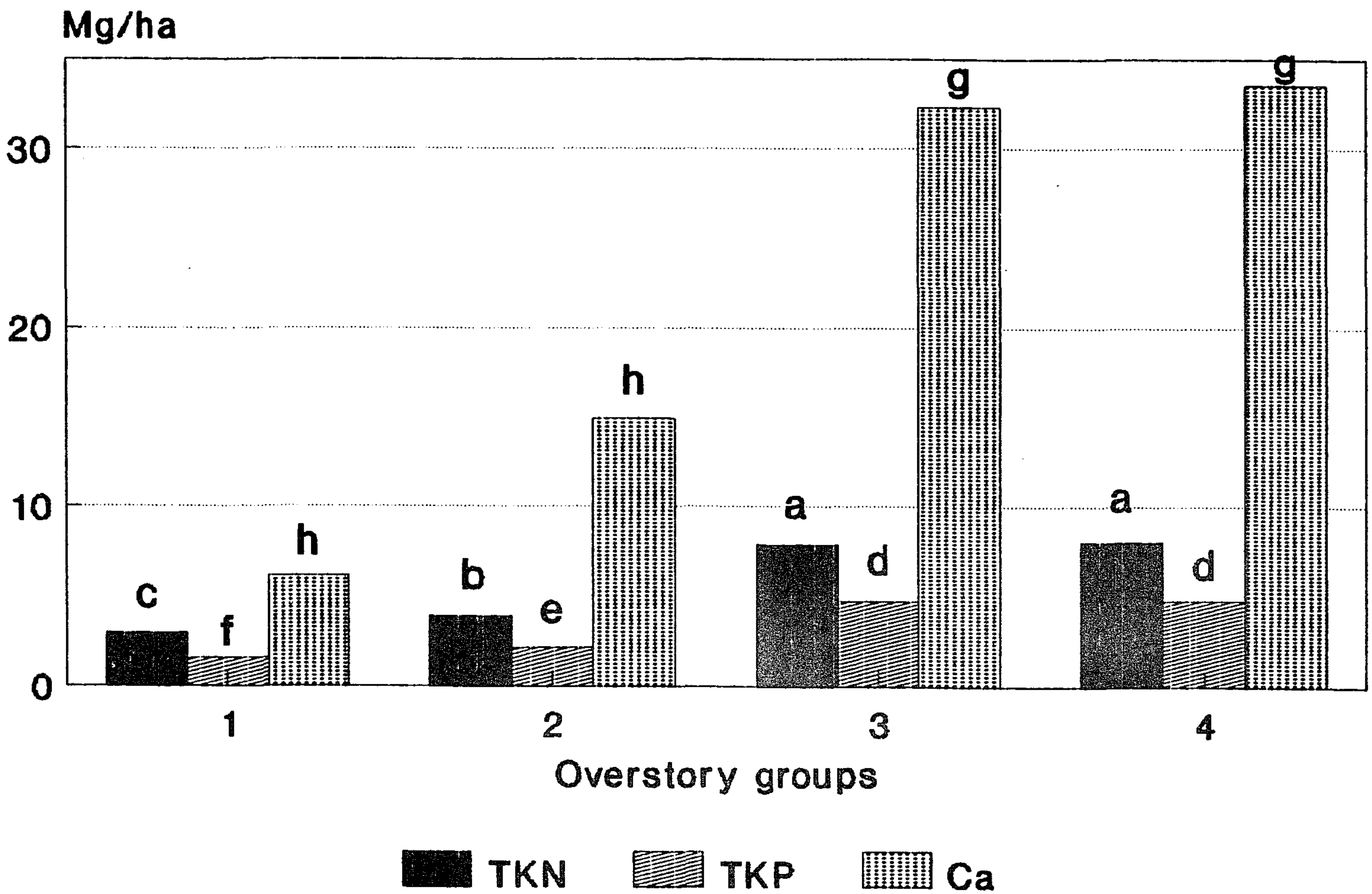
horizons may be related to the longer time since deglaciation of Port Bruce till soils, on which the northern hardwoods cover type is dominant. The development of E horizons is likely related to vegetation, with the more acidifying oak litter which is present on most Port Huron till sites contributing to eluviation.

Average soil Kjeldahl N, P, and Ca contents of the upper 150 cm are displayed in Figure 3.6. An increasing gradient in levels of these nutrients is evident between overstory groups 1 and 3, but groups 3 and 4 contain nearly identical levels of N, P, and Ca.

The content of soil nutrients Mg and K in the upper 150 cm are shown in Figure 3.7. Again, there is an increase in levels of these nutrients from Group 1 through Group 3. Differences in K content between overstory groups 3 and 4 are minor and non-significant, but Mg levels were significantly greater in the oak-northern hardwood sites of Group 3 (Table 3.7).

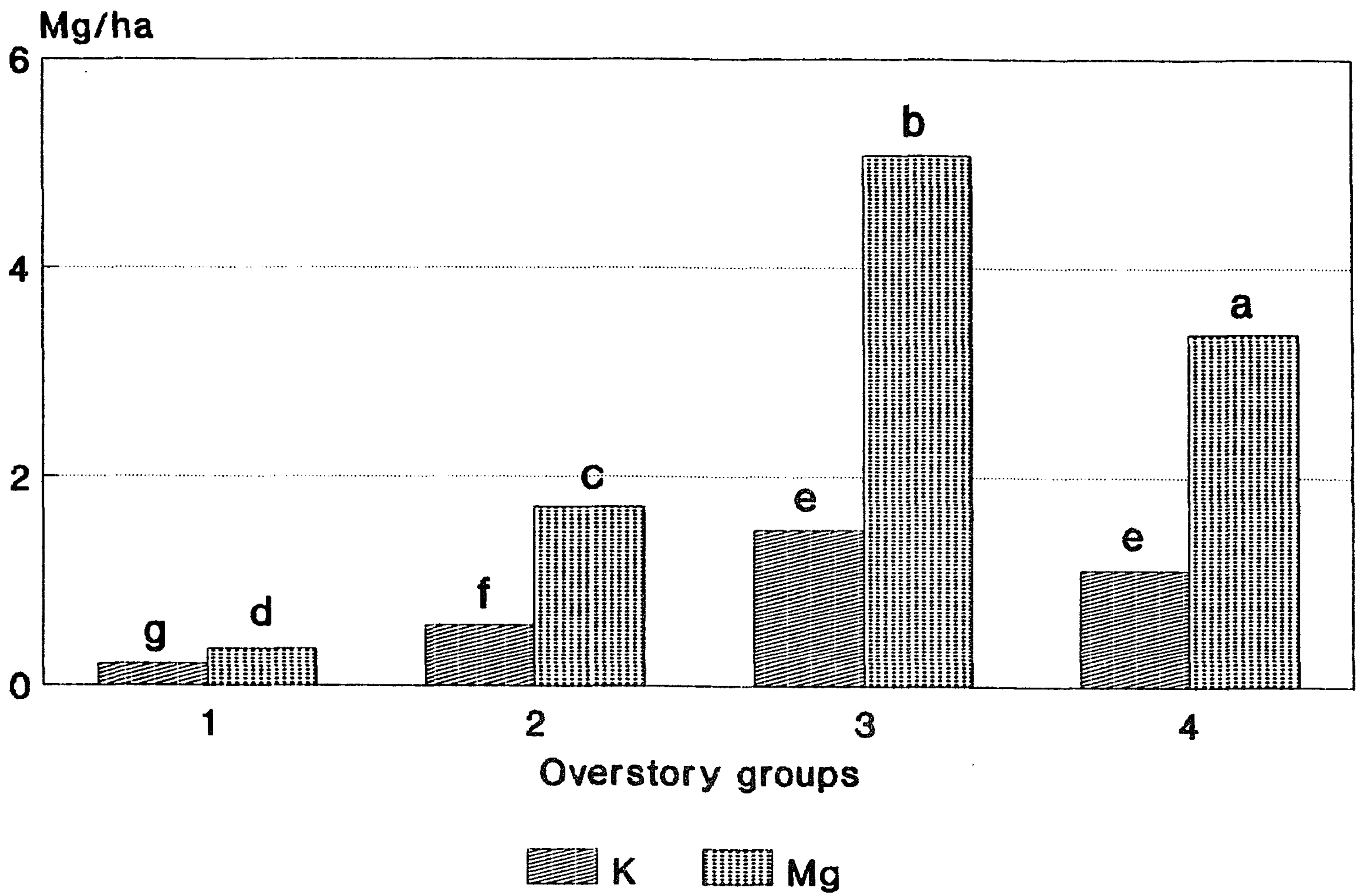
Soil properties can be divided into those which are derived from the parent material and those which are a result of climate and/or vegetation. The two different tills in this study supported different overstory and understory species; however, significant differences in soil properties associated with parent material were limited to coarse fragment content and B horizon thickness, and possibly Mg content. Although mineralogy requires further investigation, and sampling intensity may have been

Figure 3.6. Mean Kjeldahl nitrogen and phosphorous, and extractable calcium content of the upper 150 cm of soil for sites grouped by overstory composition.



Bars with common letters are not significantly different (Table 3.7)
a, b, and c compare mean TKN content
d, e, and f compare mean TKP content
g and h compare mean Ca content

Figure 3.7. Mean extractable magnesium and potassium content of the upper 150 cm of soil for sites grouped by overstory composition.



Bars with common letters are not significantly different (Table 3.7)
a, b, c, and d compare mean Mg content
e, f, and g compare mean K content

insufficient or biased, it appears that soil characteristics derived from parent material are not responsible for differences in species composition. Other possible explanations for the presence of oak on Port Huron till include climatic effects, and disturbance differences prior to stand establishment.

Climatic differences exist between sites of the two overstory groups. Sites containing oak are, for the most part, nearer Lake Huron, where temperatures are warmer and less extreme, and snowpack is thinner and of shorter duration. These are conditions which increase the regenerative and competitive ability of oak relative to that of sugar maple and basswood, so that climate may have been a factor in determining species composition differences.

Little is known of specific site history prior to acquisition of the area by the U.S.F.S. about 50 years ago, but it is known that presettlement fires periodically raged unchecked throughout the state (Whitney 1986, 1987). Fire-prone ecosystems have occupied glacial outwash since the first vegetation was established following glaciation (Brubaker 1975). Fire intensity and frequency was much greater on fire-prone ecosystems, and fire tended to travel along these areas as a corridor (Whitney 1986, 1987). It is possible that fire historically traveled through the jack pine and mixed pine ecosystems of the glacial AuSable valley (Figure 2.3), and driven by prevailing winds from the west, traveled up onto the Glennie moraine near the point where the valley curves from east-west to north-south. Whitney (1986, 1987) has proposed that the oak forests of Michigan were established as a result of catastrophic fire, and the Huron National Forest oak-northern hardwood sites may be an example. Northern hardwood sites, located mostly in the Maltby Kames which are more distant from the river corridor, may have been less impacted by fire.

The presence of red oak seedlings in the herbaceous layer corresponds with its presence in the overstory. Red oak seedlings are present on Port Huron sites and not on Port Bruce sites. However, there is little recruitment into the sapling layer. This phenomenon may be due to the poorer competitive ability of oak, and has been related to natural processes of succession (Host et al. 1987). However, oak may be a natural component of northern hardwood overstories as a gap phase species (Lorimer 1983). Gaps are present in the hardwood forests of northeastern lower Michigan, due to the mortality of aspen dating from clearcutting early in the century. Oak should be expected to mature in these gaps, but its growth may have been restricted during recent years by repeated heavy deer browsing.

Nitrogen mineralization and its association with other ecosystem components

Amounts of ammonium-N produced during an anaerobic incubation are shown in Table 3.8. The anaerobic incubation is thought to provide an index of microbial biomass levels,

Table 3.8. Ammonium nitrogen mineralized from the upper 10 cm of soil during a one week anaerobic incubation.

Site	<---- NH_4^{-}-N, g kg^{-1} oven dry soil ----> Mean	S.D.
A	83.36	29.70
B	132.03	60.08
C	105.37	14.79
D	93.50	7.58
E	102.70	33.28
F	126.64	10.40
G	113.41	41.08
H	28.97	1.02
I	110.65	42.57
J	49.12	26.12
K	43.17	8.66
L	26.54	3.05
M	50.49	32.99
N	87.07	32.03
O	112.88	45.21
P	58.72	28.69
Q	37.73	7.84
R	37.65	5.14
S	63.58	11.56
T	28.02	5.74
U	150.05	73.80
V	35.12	3.95
W	37.48	4.41
X	38.02	10.99

and hence of organic decomposition and nutrient turnover on a site (Myrold 1987). The data do not provide an actual rate of decomposition, but rather allow comparisons of relative amounts of potential mineralization among sites. The data from my study indicate that a wide range of mineralization potentials exist among ecosystems in northeastern lower Michigan. Figure 3.8 displays N mineralized for each site along the first dimension of the RA ordination by ground flora. A large increase in mineralized N along the ordination is evident, and there is a significant linear correlation of r=0.845 between N mineralized and RA site ordination scores (Figure 3.9). An even better association may be described by a non-linear prediction equation. The correlation suggests that there is an association between ground flora and mineralization potential of a site. Such an association is important for ecosystem description and forest management, since mineralization potential has been related to overstory productivity, net primary production, and N content of foliage (Keeney 1980, Powers 1980, Aber and Mellilo 1984, Pastor et al. 1984). Mineralization potential may be predicted for sites in my study area based on first dimension ordination scores from ground flora species cover-abundance values, and used to indicate relative site potential.

Mineralization potential has been shown to vary among ecosystems (Pastor et al. 1984, Zak et al. 1986).

Figure 3.8. Mean anaerobic ammonium nitrogen mineralized during a one week incubation of 10 cm soil cores, for sites ordinated by reciprocal averaging of ranked ground flora species cover-abundance values.

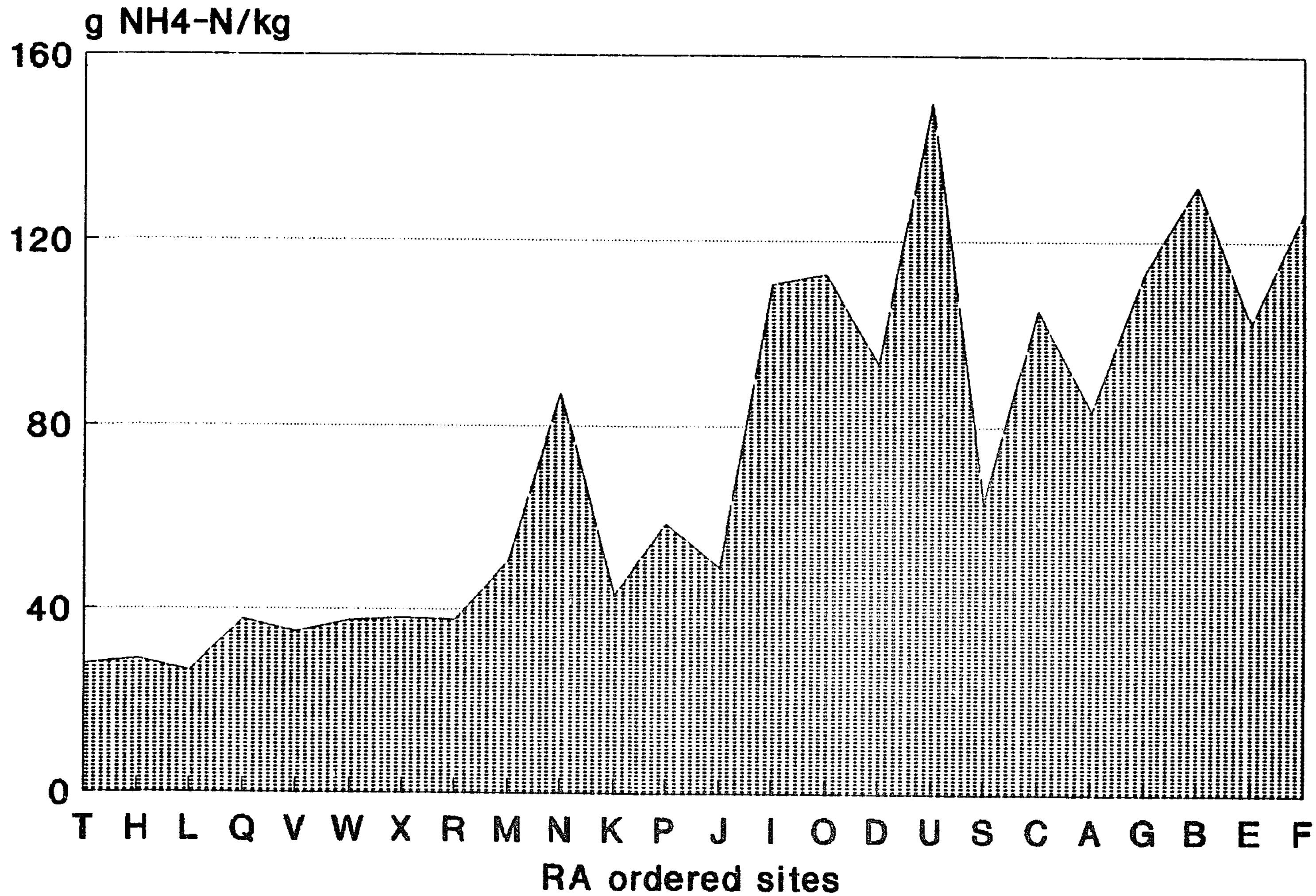
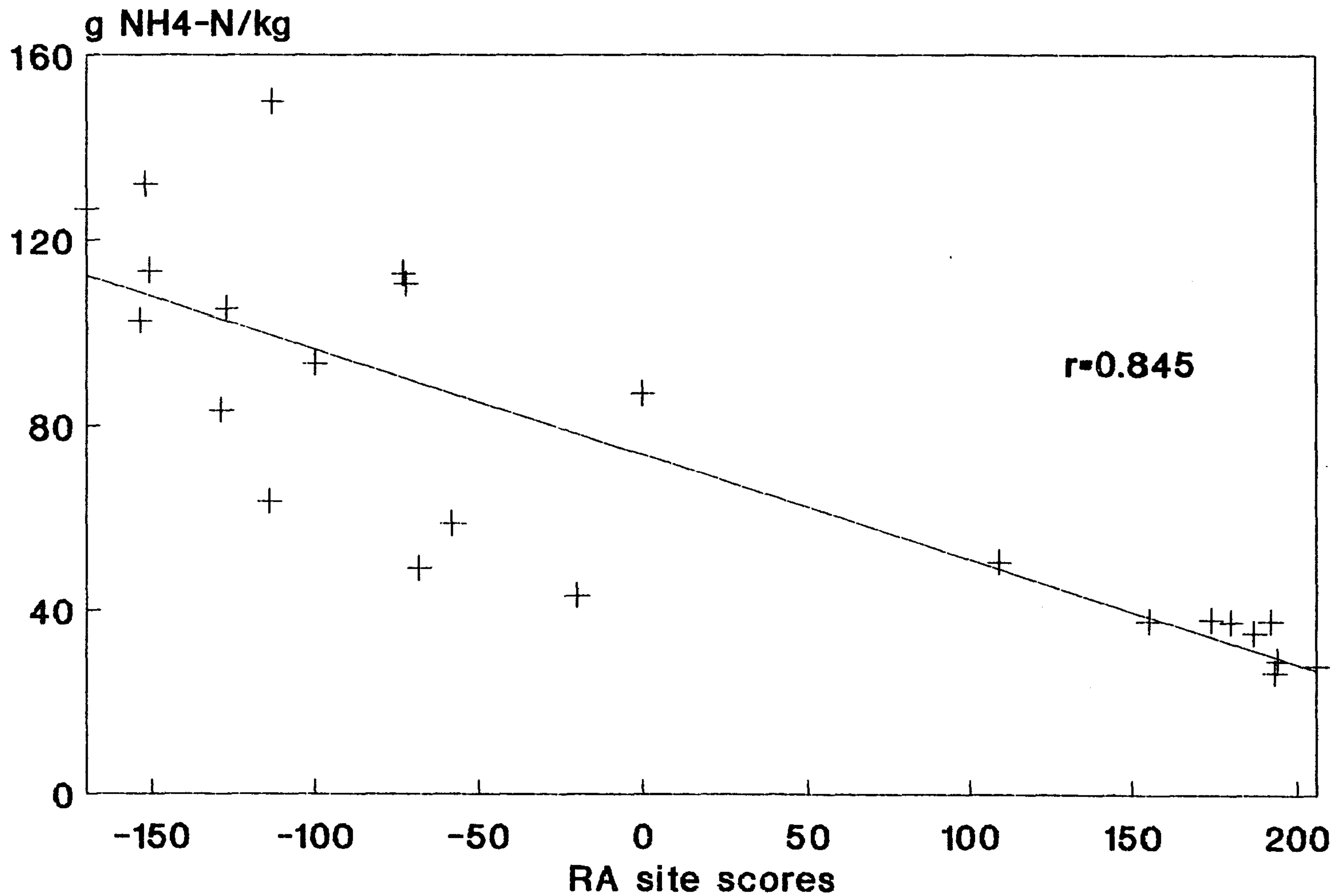

g NH4-N/kg
160
120
80
40
0
T H L Q V W X R M N K P J I O D U S C A G B E F
RA ordered sites

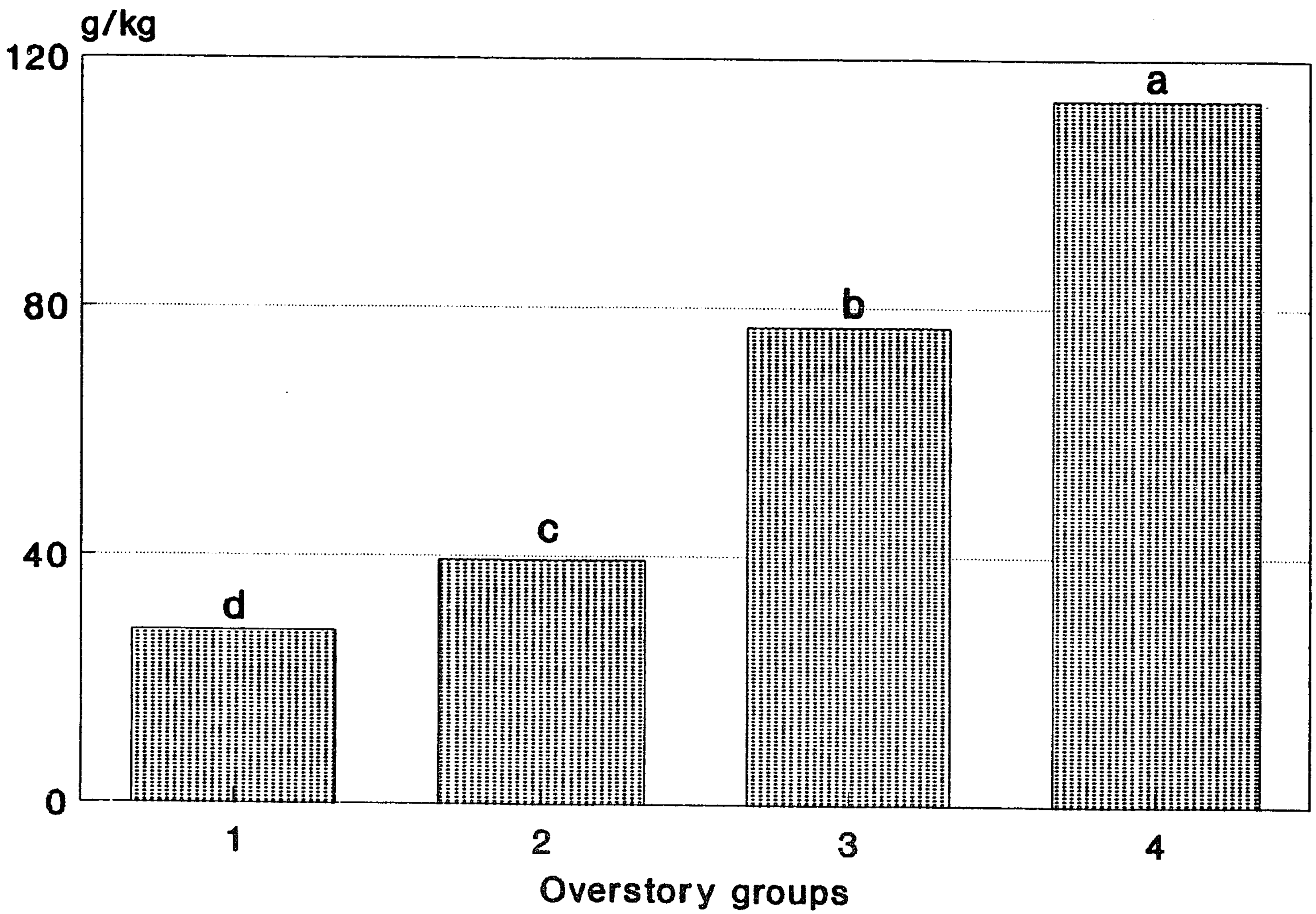
Figure 3.9. Correlation of site scores from RA of ground flora ranked cover-abundance data with amounts of ammonium nitrogen mineralized during a one week incubation of 10 cm soil cores.


g NH4-N/kg
160
120
80
40
0
r=0.845
-150
-100
-50
0
50
100
150
200
RA site scores

Comparisons among groups based on overstory composition indicated that ecosystem differences also occurred in my study area (Figure 3.10). Black-pin oak sites, northern red oak sites, oak-northern hardwood sites, and northern hardwood sites all mineralized significantly different amounts of N, with the northern hardwood sites mineralizing an average of four times as much N as the black-pin oak sites (Table 3.7). Within-site variability in N mineralization increased as the mean increased (Table 3.8), which agrees with results reported in other studies (Powers 1980, Zak et al. 1986).

Samples from the northern hardwoods overstory group mineralized significantly greater amounts of nitrogen than the oak-northern hardwoods group. This result agrees with findings in northwestern lower Michigan, where N mineralization was lower in a sugar maple-red oak ecosystem than in a sugar maple-basswood system (Zak et al. 1986). However, in Zak et al.'s study, there were notable differences in soil properties, and overstory basal area and standing volume were lower on sites which contained oak. Differences in mineralization may have been associated with stable environmental factors. In my study, soil properties were nearly identical between the oak-northern hardwood sites and the northern hardwood sites. Basal area was greater on oak-northern hardwood sites, but volume growth was slower, averaging 3.73 m^3 ha^{-1} yr^{-1} in oak-northern hardwood sites and 5.22 m^3 ha^{-1} yr^{-1} in northern hardwood

Figure 3.10. Mean anaerobic ammonium nitrogen mineralized during a one week incubation of 10 cm soil cores, for sites grouped by overstory composition.



Bars with common letters are not significantly different (Table 3.7) sites (Table 3.3). These differences in volume growth were significant at alpha=0.05 as determined by a t-test. Thus, productivity was less on the sites of lower N mineralization, which agrees with other studies. However, it is difficult to determine whether differences in species composition are a result of, or a cause of, the differences in potential mineralization.

If the difference in overstory composition between the northern hardwoods and the oak-northern hardwoods groups is indeed related to past disturbance as hypothesized, and if N mineralization is indicative of site productivity potential as noted in the literature, then disturbance at more than 75 years ago may have resulted in present-day lower site productivity. Forest managers are sensitive to losses of long-term site productivity, but there is presently no short-term technique for establishing that losses have occurred or are occurring. If a difference in N mineralization potential could be directly related to disturbance in a cause-effect relationship, a measure of the loss of site potential could be derived. This is an important possibility which should be investigated.

Site ordination by ground flora cover-abundance in relation to properties of the forest floor

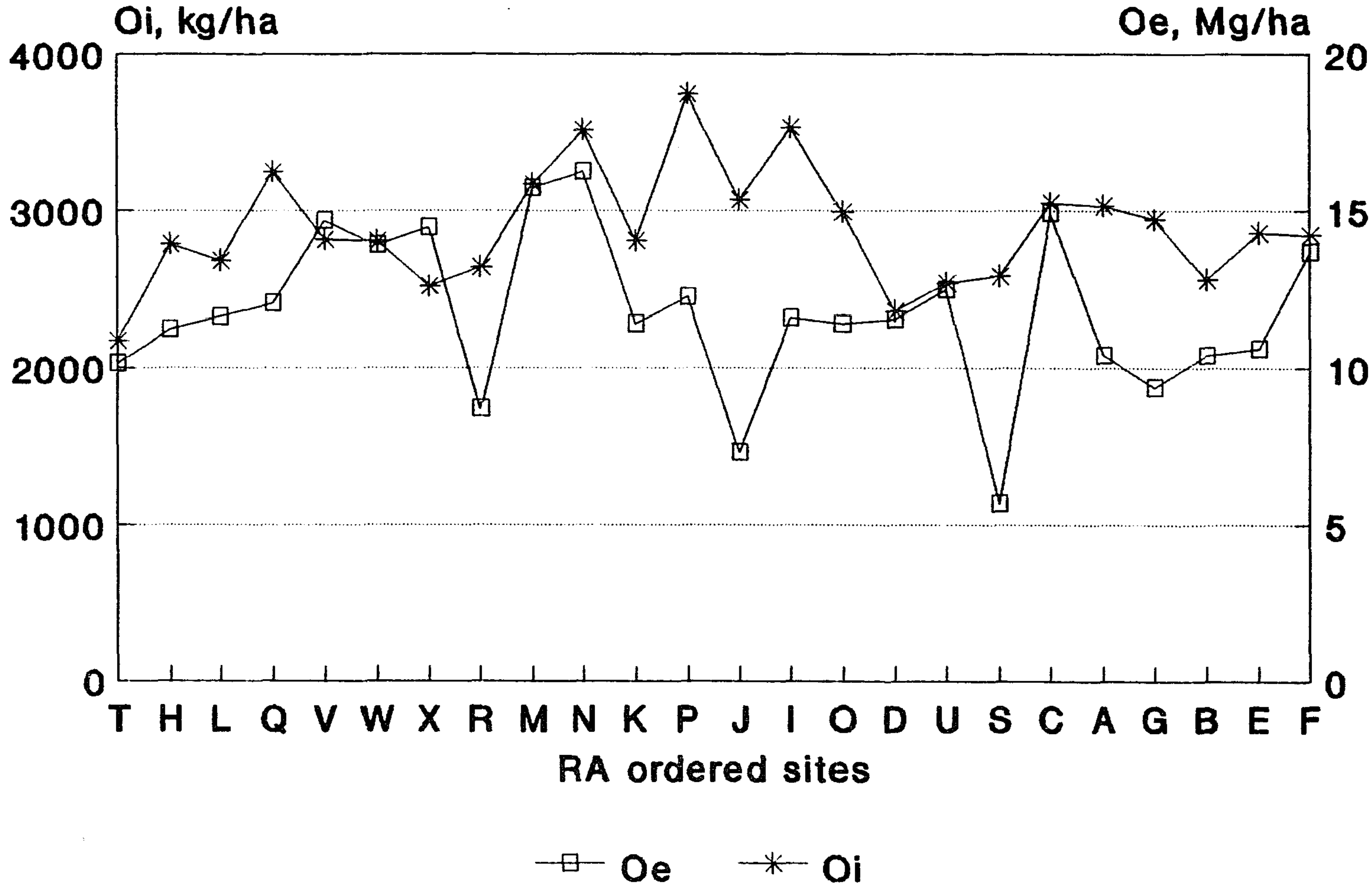
Forest floor layers sampled immediately after litterfall were separated into layers designated Oi and Oe, (i.e., undecomposed litter and partially decomposed litter).

Oven dry weights of these layers, arrayed by site along the first axis of the RA ordination of ground flora species ranked cover-abundance values, appear in Figure 3.11. The Oa layer was not present on most sites; where present, it was sampled and analyzed with soils (Appendix Table B.1).

Weight of the Oe layer averaged 11,747 kg ha^{-1}, and weight of the Oi averaged 2,867 kg ha^{-1} for the 24 study sites sampled in early November (Table 2.5). These values are somewhat lower than those reported on the Hubbard Brook Forest in an August sampling, when the F layer (comparable to the Oe) weighed 19,300 kg ha^{-1}, and the L layer (comparable to the Oi) weighed 4,300 kg ha^{-1} (Gosz et al. 1976). Weight of the F layer on the Hubbard Brook Forest did not vary significantly by sampling date, so differences in amount of Oe material between the Hubbard Brook forest and my sites in Michigan are more likely due to elevation and geographical setting.

Unexpectedly, there was no apparent trend in Oe weights among different ecosystems in my study. Sites with an overstory of northern hardwoods had an average Oe weight of 11678 kg ha^{-1}, oak-northern hardwood sites averaged 11711 kg ha^{-1}, northern red oak sites averaged 12176 kg ha^{-1}, and pin oak-black oak sites averaged 11004 kg ha^{-1}. These differences were not significantly different as determined by t-tests at alpha=0.05. Federer (1984) has reported that forest floor weight varied with species composition. Oak litter is known to be less readily decomposed than litter of

Figure 3.11. Dry weights of autumn litterfall (Oi) and partially decomposed forest floor layers (Oe) for sites ordinated by reciprocal averaging of ranked ground flora species cover-abundance values.


Oi, kg/ha
Oe, Mg/ha
4000
3000
2000
1000
0
20
15
10
5
0
T H L Q V W X R M N K P J I O D U S C A G B E F
RA ordered sites
Oe
Oi

northern hardwood species, so it was anticipated that these sites would have accumulated greater amounts of Oe. My study has also shown that nitrogen mineralization is significantly greater under northern hardwoods than oaks, and nitrogen mineralization is believed to be an index of the rate of microbial decomposition (Myrold 1987). A lower level of microbial activity would be expected to result in a greater accumulation of Oe under oak canopies. Reasons for the lack of difference between Oe weights under oak and northern hardwoods are unclear. Sample sizes calculated prior to sampling were sufficient to find significant weight differences between some individual sites as determined by t-tests, so sample sizes were believed to be sufficient for detecting unequal accumulations of Oe material.

Age of the overstory was not believed to be related to accumulations of forest floor material. This disagrees with results reported by Covington (1981), who found an increasing trend in forest floor weight with age up until maturity. Correlations of Oe weight and age were significant for my 24 sites, with $r=0.44$, but one site greatly influenced the correlation (Figure 3.12). Correlations of Oe weight with the basal areas of individual species were significant, with $r=-0.46$ for beech, and $r=-0.43$ for white ash (Table 3.9). Correlations as a measure of association are limited, as significant correlations may be obtained from sets of random numbers. Correlations of Oe weight with the basal areas of other

Figure 3.12. Correlation of partially decomposed forest floor layer (Oe) weight with average age of the overstory.

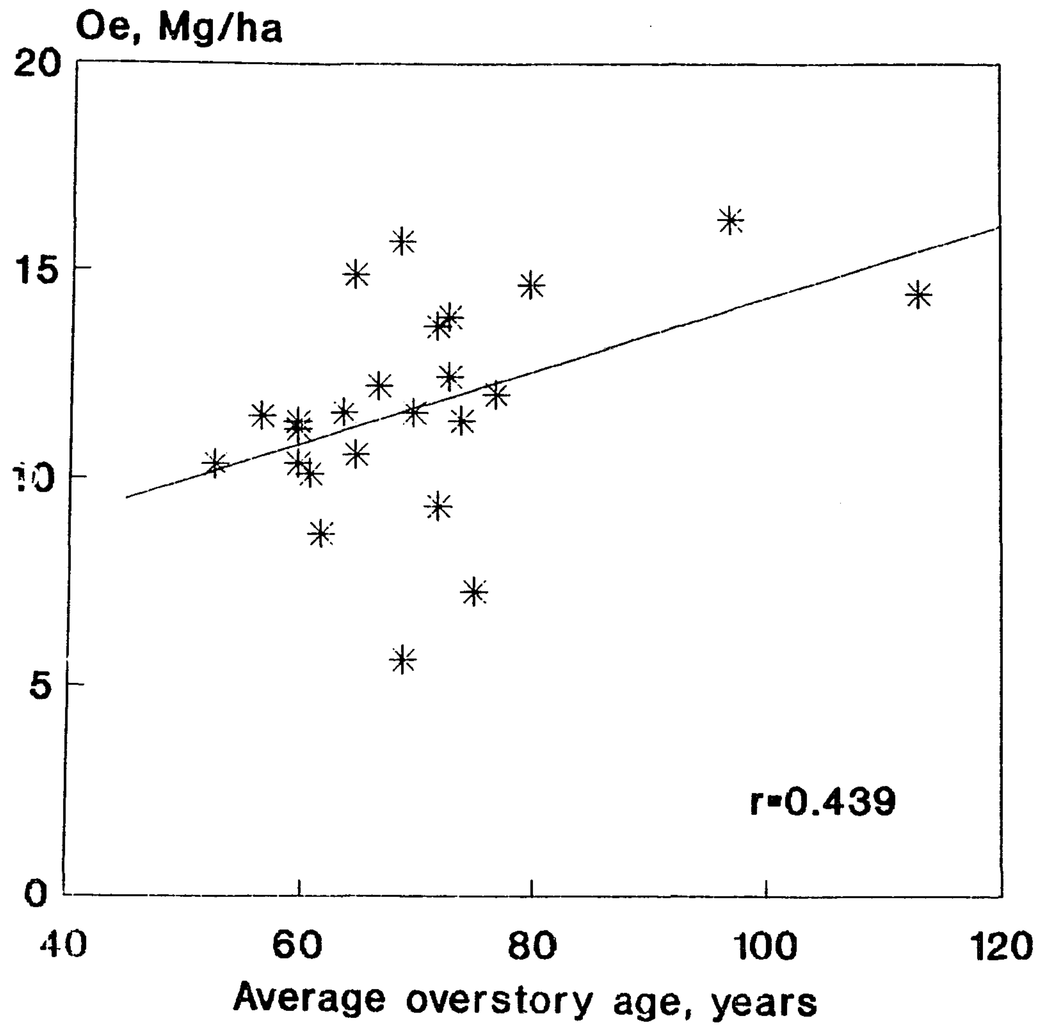

Oe, Mg/ha
20
15
10
5
0
r=0.439
40
60
80
100
120
Average overstory age, years

Table 3.9. Simple correlations among some forest floor variables and overstory basal area of selected species.

	Total BA	Oi wt.	Oe wt.	Oi TKN	Oi TKP	Oi Mg	Oi Ca	Oi K	Oe TKN	Oe TKP	Oe Mg	Oe Ca	Oe K
Total BA	1.000	0.396	0.067	0.465*	0.608*	0.541*	0.359	0.671*	0.206	0.292	0.468*	0.365	0.387
Oi wt.	0.396	1.000	0.293	0.660*	0.667*	0.702*	0.451*	0.808*	0.371	0.384	0.435*	0.416*	0.446*
Oe wt.	0.067	0.293	1.000	0.329*	0.061	0.085	0.012	0.069	0.942*	0.903*	0.613*	0.549*	0.869*
Oi TKN	0.465*	0.660*	0.329	1.000	0.835*	0.781*	0.787*	0.754*	0.504*	0.581*	0.791*	0.782*	0.560*
Oi TKP	0.608*	0.667*	0.061	0.835*	1.000	0.809*	0.738*	0.902*	0.275	0.396	0.652*	0.560*	0.423*
Oi Mg	0.541*	0.702*	0.085	0.781*	0.809*	1.000	0.768*	0.849*	0.236	0.295	0.686*	0.670*	0.331
Oi Ca	0.359	0.451*	0.012	0.787*	0.738*	0.768*	1.000	0.601*	0.115	0.257	0.629*	0.741*	0.224
Oi K	0.671*	0.808*	0.069	0.754*	0.902*	0.849*	0.601*	1.000	0.250	0.324	0.548*	0.457*	0.401
Oe TKN	0.206	0.371	0.942*	0.504*	0.275	0.236	0.115	0.250	1.000	0.976*	0.754*	0.610*	0.946*
Oe TKP	0.292	0.384	0.903*	0.581*	0.396	0.295	0.257	0.324	0.976*	1.000	0.813*	0.685*	0.969*
Oe Mg	0.468*	0.435*	0.613*	0.791*	0.652*	0.686*	0.629*	0.548*	0.754*	0.813*	1.000	0.878*	0.806*
Oe Ca	0.365	0.416*	0.549*	0.782*	0.560*	0.670*	0.741*	0.457*	0.610*	0.685*	0.878*	1.000	0.633*
Oe K	0.387	0.446*	0.869*	0.560*	0.423*	0.331	0.224	0.401	0.946*	0.969*	0.806*	0.633*	1.000
R maple	-0.049	-0.096	0.231	-0.526*	-0.451*	-0.493*	-0.694*	-0.317	0.126	0.046	-0.310	-0.432*	0.101
B,P oaks	-0.444*	-0.335	-0.089	-0.337	-0.389	-0.425*	-0.483*	-0.427*	-0.166	-0.272	-0.365	-0.357	-0.304
W oak	-0.057	0.144	0.191	-0.159	-0.229	-0.224	-0.263	-0.159	0.126	0.092	-0.107	-0.105	0.174
R oak	0.226	0.208	0.216	-0.216	-0.046	-0.136	-0.495*	0.165	0.208	0.147	-0.133	-0.290	0.231
Basswood	0.502*	0.185	0.118	0.740*	0.685*	0.642*	0.753*	0.462*	0.298	0.407*	0.714*	0.698*	0.327
S maple	0.054	-0.035	-0.166	0.372	0.216	0.369	0.755*	0.133	-0.193	-0.082	0.278	0.534*	-0.126
W ash	0.451*	0.045	-0.431*	0.088	0.288	0.323	0.225	0.285	-0.293	-0.247	0.004	-0.113	-0.190
Beech	0.384	-0.013	-0.463*	-0.035	0.162	0.254	0.164	0.239	-0.380	-0.327	-0.114	-0.155	-0.314
P birch	0.420*	0.187	-0.009	0.386	0.441*	0.277	0.160	0.540*	0.112	0.157	0.259	0.206	0.228
Age	0.237	0.149	0.439*	0.124	0.039	-0.003	-0.148	0.128	0.470*	0.470*	0.233	0.120	0.515*
RA score	0.236	0.072	-0.207	0.476*	0.433*	0.498*	0.831*	0.312	-0.149	-0.010	0.357	0.480*	-0.042
N min	0.262	0.087	0.031	0.682*	0.532*	0.519*	0.832*	0.371	0.147	0.266	0.618*	0.644*	0.242

*Correlations greater than or equal to an absolute value of 0.404 are significant at alpha=0.05 for n=24.

Table 3.9. (continued).

	R maple	B,P oaks	W oak	R oak	Basswood	S maple	W ash	Beech	P birch	Age	RA score	Nmin
Total BA	-0.049	-0.444*	-0.057	0.226	0.502*	0.054	0.451*	0.384	0.420*	0.237	0.236	0.262
Oi wt.	-0.096	-0.334	0.144	0.208	0.185	-0.035	0.045	-0.013	0.187	0.149	0.072	0.087
Oe wt.	0.231	-0.089	0.191	0.216	0.118	-0.166	-0.431*	-0.463*	-0.009	0.439*	-0.207	0.031
Oi TKN	-0.526*	-0.337	-0.159	-0.216	0.740*	0.372	0.088	-0.035	0.386	0.124	0.476*	0.681*
Oi TKP	-0.451*	-0.389	-0.229	-0.046	0.685*	0.216	0.288	0.162	0.441*	0.039	0.433*	0.532*
Oi Mg	-0.493*	-0.425*	-0.224	-0.136	0.642*	0.369	0.323	0.254	0.277	-0.003	0.498*	0.519*
Oi Ca	-0.694*	-0.483*	-0.263	-0.495*	0.753*	0.755*	0.225	0.164	0.160	-0.148	0.831*	0.832*
Oi K	-0.317	-0.427*	-0.159	0.165	0.462*	0.133	0.285	0.239	0.540*	0.128	0.312	0.372
Oe TKN	0.126	-0.166	0.126	0.208	0.298	-0.193	-0.293	-0.380	0.112	0.469*	-0.149	0.147
Oe TKP	0.046	-0.272	0.092	0.147	0.407*	-0.082	-0.247	-0.327	0.157	0.470*	-0.010	0.266
Oe Mg	-0.310	-0.365	-0.107	-0.133	0.714*	0.278	0.004	-0.114	0.259	0.233	0.357	0.618*
Oe Ca	-0.432*	-0.357	-0.105	-0.290	0.698*	0.534*	-0.113	-0.155	0.206	0.120	0.480*	0.644*
Oe K	0.101	-0.304	0.174	0.231	0.327	-0.126	-0.190	-0.314	0.228	0.515*	-0.042	0.242
R maple	1.000	-0.039	0.342	0.661*	-0.607*	-0.617*	-0.331	-0.264	-0.142	0.219	-0.625*	-0.650*
B,P oaks	-0.039	1.000	-0.053	-0.179	-0.288	-0.310	-0.165	-0.186	-0.142	-0.199	-0.481*	-0.390
W oak	0.342	-0.053	1.000	-0.054	-0.331	-0.357	-0.190	-0.214	-0.164	0.326	-0.378	-0.334
R oak	0.661*	-0.179	-0.054	1.000	-0.457*	-0.551*	-0.218	-0.159	0.173	0.306	-0.495*	-0.526*
Basswood	-0.607*	-0.288	-0.331	-0.457*	1.000	0.418*	0.383	0.182	0.146	-0.067	0.542*	0.698*
S maple	-0.617*	-0.310	-0.357	-0.551*	0.418*	1.000	0.006	0.086	0.123	-0.278	0.849*	0.794*
W ash	-0.331	-0.165	-0.190	-0.218	0.383	0.006	1.000	0.718*	-0.007	-0.112	0.300	0.163
Beech	-0.264	-0.186	-0.214	-0.159	0.182	0.086	0.718*	1.000	0.090	0.049	0.385	0.077
P birch	-0.142	-0.142	-0.164	0.173	0.146	0.123	-0.007	0.090	1.000	0.125	0.113	0.346
Age	0.219	-0.199	0.326	0.306	-0.067	-0.278	-0.112	0.049	0.125	1.000	-0.232	-0.170
RA score	-0.625*	-0.481*	-0.378	-0.495*	0.542*	0.849*	0.300	0.385	0.113	-0.232	1.000	0.845*
N min	-0.650*	-0.390	-0.334	-0.526*	0.698*	0.794*	0.162	0.077	0.346	-0.170	0.845*	1.000

*Correlations greater than or equal to an absolute value of 0.404 are significant at alpha=0.05 for n=24.

species were not significant. A non-parametric test of associations among variables, the Spearman's coefficient of rank correlation, was also performed with similar results.

At the time of sample collection, the Oe layer was thin and mixed into the mineral soil at many of the sites. The disturbance was apparently due to the action of animals, particularly deer and wild turkey, and may have obscured a general trend of Oe accumulation along the site ordination. Disturbances occurred evenly throughout sites, so an increased sampling intensity would likely not have affected the outcome.

Weights of new litterfall (Oi) are also displayed in Figure 3.11. This layer was undisturbed at the time samples were collected from the forest floor, because it had fallen so recently. The weight of new litter averaged over sites was 2,887 kg ha^{-1}. Values reported for some other studies were higher, averaging 3,419 kg ha^{-1} at Hubbard Brook (Gosz et al. 1972), 3,858 kg ha^{-1} in Ohio, and 9,510 kg ha^{-1} for a younger overstory in New Brunswick (MacLean and Wein 1977). Other studies in the Great Lakes Region reported values more comparable: 2,413 kg ha^{-1} for an aspen overstory and 3,726 kg ha^{-1} for a maple-birch-aspen overstory in Wisconsin (Crow 1978), 1,749 kg ha^{-1} for a black oak-white oak overstory, 3,179 kg ha^{-1} for a sugar maple-red oak overstory, and 2,624 kg ha^{-1} for a sugar maple-basswood overstory in northwestern lower Michigan (Zak et al. 1986). There may be a climate-related regional trend in litter production.

In my study, litter weights were greatest on sites with mixed oak-northern hardwood overstories, averaging 3,276 kg ha^{-1}. The amount of oak-northern hardwood litter was significantly greater than that produced by any other overstory group as evaluated by t-tests at alpha=0.05. Litter weight averaged 2,773 kg ha^{-1} on northern hardwood sites, 2,826 kg ha^{-1} on sites dominated by northern red oak, and 2,547 kg ha^{-1} on pin oak-black oak sites. Litter weights on northern hardwood sites, northern red oak sites, and pin oak-black oak sites were not significantly different. Weights are correlated with total basal area at r=0.40 (Table 3.9). This correlation is not significant at alpha=0.05, but is the highest correlation found for variables examined, and may be the only meaningful association with litter production other than species composition. However, species composition was also non-significantly correlated with litter weight. The basal area of black and pin oak was more highly correlated with Oi weights than was basal area of other species, with r=-0.33, a non-significant correlation. Oi weights are poorly correlated with Oe weights, having a non-significant correlation of r=0.29.

Nutrient concentrations of autumn litterfall are compared to that reported in other studies of northern deciduous forests by Gosz et al. (1972) and Boerner (1984) (Table 3.10). Analysis methods were comparable among the studies, following Likens and Bormann (1970). Ca concentrations in litter and forest floor layers on my study sites are much greater than that found on the Hubbard Brook Forest, or in Ohio. The calcareous nature of soils in northeastern lower Michigan may be responsible; ecosystems are likely saturated with Ca, and may even be limited by excess Ca in some cases. The Ca concentration of Michigan soils reflects glacial deposition of dolomitic limestone which was moved to the area from the north. Concentrations

Table 3.10. Nutrient concentrations of litter and forest floor layers at three study sites.

Nutrient, layer		Michigan study	Hubbard Brook study (Gosz et al. 1972)	Ohio study (Boerner 1984)
		< ---------------	%	-------------------- >
N:	Oi	0.92	1.196	0.815
	Oe	1.48	1.86	---
P:	Oi	0.107	0.079	0.083
	Oe	0.108	0.116	---
Ca:	Oi	2.05	0.790	0.958
	Oe	1.93	0.634	---
Mg:	Oi	0.173	0.129	0.169
	Oe	0.530	0.060	---
K:	Oi	0.239	0.456	0.479
	Oe	0.139	0.077	---
		< ---------------	ppm	-------------------- >
Zn:	Oi	46.8	137.5	---
	Oe	77.2	151.6	---
Mn:	Oi	1829	2456	---
	Oe	2549	1630	---

of N, P, K, Mg, and Mn in litter and forest floor layers are comparable among studies in the different areas. Zn concentrations are much higher at Hubbard Brook than in my study; reasons for this difference are unclear.

Nutrient contents of autumn litterfall are displayed along the first axis from ordination of sites which used RA of ground flora ranked cover-abundance values (Figures 3.13, 3.14). Kjeldahl phosphorous (P) content, and magnesium (Mg) and potassium (K) content determined from acid dissolution of dry ashed samples are shown in Figure 2.13. Potassium content is dramatically greater on Port Huron till sites, which support oak and northern hardwoods. A similar trend is evident, but of less magnitude, for Mg and P. These high levels of nutrient return are associated with amounts of litter produced, with a significant correlation of r=0.81 between Oi weight and Oi K content. Potassium content is significantly correlated with basal area of paper birch, with r=0.54. Species composition on these sites is associated with nutrient content of litter, agreeing with results reported by Pastor et al. (1984) and Zak et al. (1986).

Figure 3.14 displays Kjeldahl N and Ca content of the litterfall samples. Trends along the site ordination differ from trends of P, Mg, and K content. Nitrogen return is relatively constant, although it is significantly associated with the basal area of basswood, with r=0.74 (Table 3.9). Calcium return is greater on sites which support northern

Figure 3.13. Phosphorous, magnesium, and potassium content of autumn litterfall for sites ordinated by reciprocal averaging of ranked ground flora species cover-abundance values.

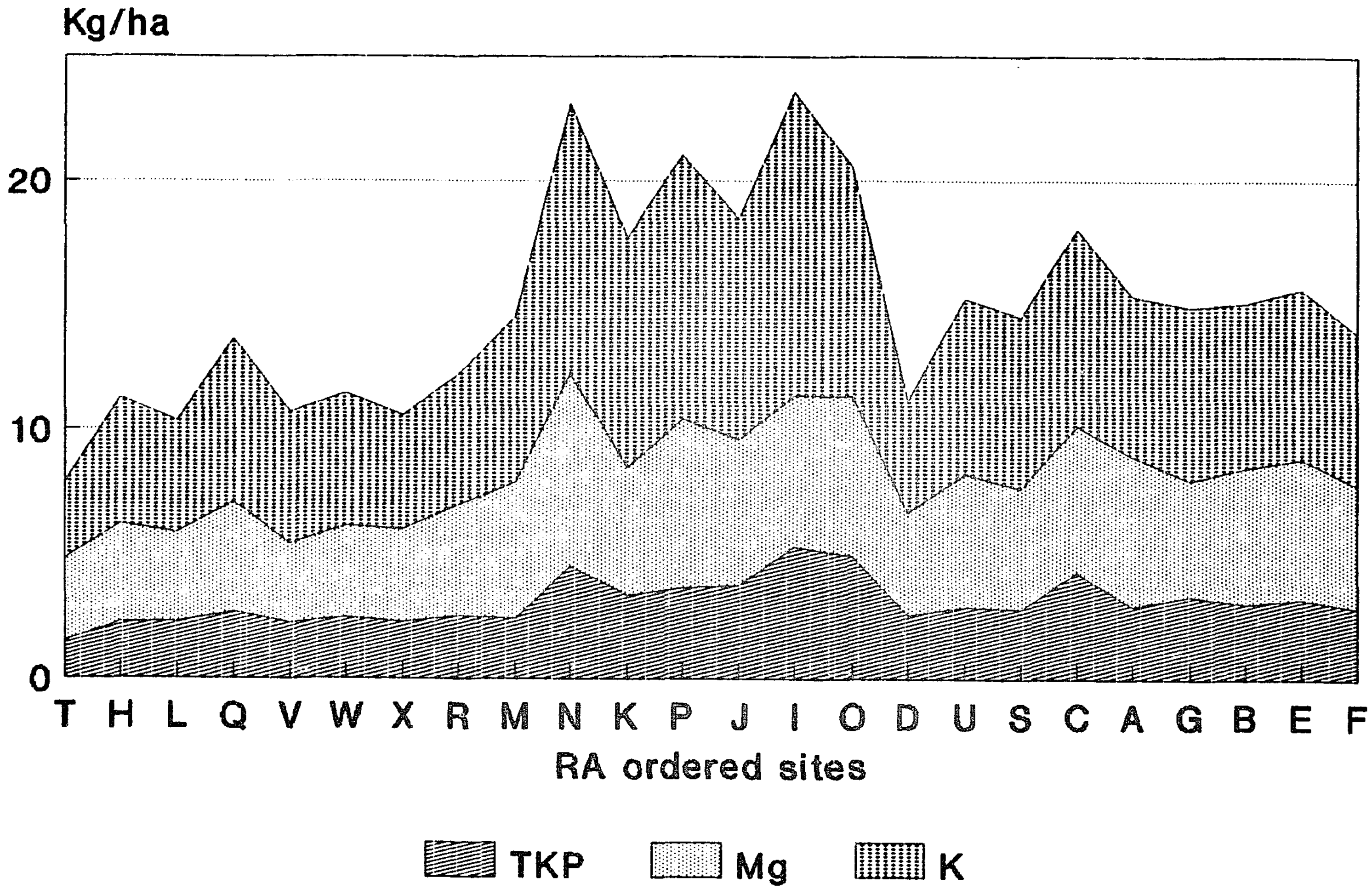
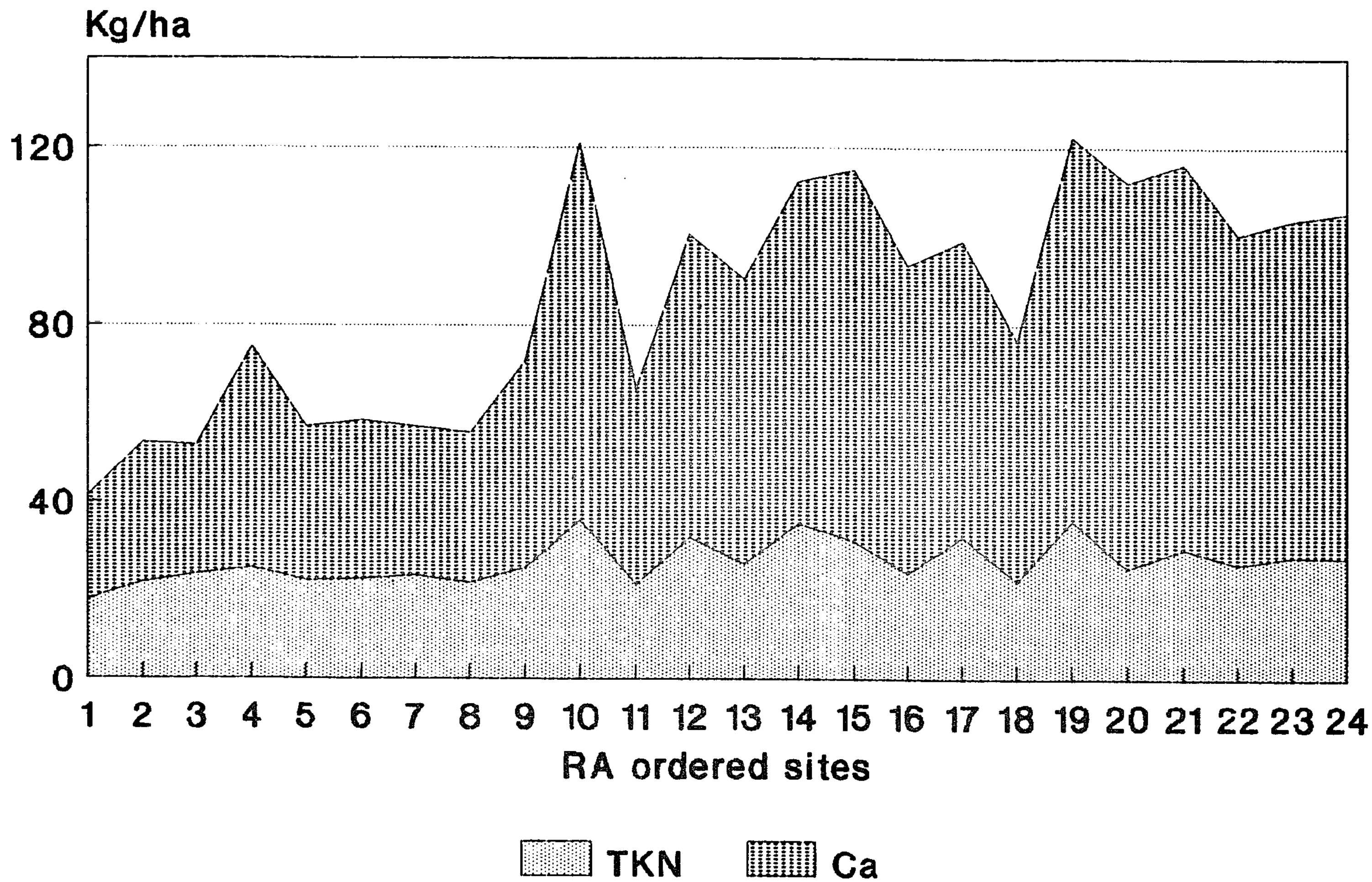

Kg/ha
20
10
0
T H L Q V W X R M N K P J I O D U S C A G B E F
RA ordered sites
TKP
Mg
K

Figure 3.14. Nitrogen and calcium content of autumn litterfall for sites ordinated by reciprocal averaging of ranked ground flora species cover-abundance values.


Kg/ha
120
80
40
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
RA ordered sites
TKN
Ca

hardwood or mixed northern hardwood overstories, as opposed to oak sites. Calcium content of litterfall is significantly correlated with site ordination scores from RA, with r=0.83 (Table 3.9). Correlations were also significant between Ca content of litterfall and basal area of sugar maple and basswood, with r=0.76 and r=0.75, respectively. There were significant negative correlations of Ca content with red maple basal area (r=-0.69). Poorer, but still significant correlations of Ca content with basal areas of black and pin oaks, and red oak, were r=-0.48 and r=-0.49, respectively (Table 3.9).

Associations of nutrient content in autumn litterfall with the ordination of sites by ground flora species ranked cover-abundance varied depending on the nutrient. Return of K, P, and Mg was associated most closely with the amount of litter produced, while return of N and especially Ca was associated with the presence of sugar maple and basswood in the overstory.

CONCLUSIONS

The ordination of upland forested sites in northeastern lower Michigan by RA of ground flora ranked cover-abundance values was associated with glacial depositional environments, with some specific features, and also with overstory species composition.

Sites at one extreme of the first axis of the ordination occurred on sands in localized outwash features within morainal areas. These sites had low overall soil nutrient content, high abundances of *Vaccinium angustifolium* and *Pteridium aquilinium* in the herbaceous layer, and supported black and pin oaks in the overstory. Litter production was lowest for these sites.

Sites which occurred on outwash sand with ice-rafted till inclusions, on ice-disintegration topography, were next to outwash sand sites on the first axis of the ordination of ground flora. These sites contained intermediate levels of soil nutrients, had lower abundances of *Vaccinium* and *Pteridium*, and were dominated by red oak in the overstory.

Sites located on two different tills, of Port Bruce and Port Huron deposition, were differentiated by the ordination of ground flora. Port Huron sites supported mixed oak-northern hardwood overstories, and contained higher abundances of *Prenanthes alba* and *Smilacina racemosa* than Port Bruce sites. Sites on Port Bruce till supported only northern hardwoods, contained high abundances of *Osmorhiza chilensis*, and also had *Viola canadensis* in the herbaceous layer. Differences in overstory composition were believed to be due to differing conditions at the time of stand establishment.

Soil physical and chemical properties of the two overstory types, oak-northern hardwoods and northern hardwoods, were compared to determine whether any of them were associated with differences in overstory species establishment. The only statistically significant differences not attributable to vegetation were coarse fragment content, thickness of the B horizon, and possibly Mg content, although Mg may be increased in the solum due in part to species composition differences. Mineralogy of the till, and weathering rates of the coarse fragments may have been a factor; these properties were not investigated in my study. It appears that the presence of red oak on some till sites and not on others is not associated with soil textures, or with the supply of major soil nutrients. Climate and site history, particularly fire intensity and frequency, may have been responsible for differences in species establishment.

The first dimensional ordination of sites by RA of ground flora was also significantly correlated with a similar RA ordination which used overstory basal area by species, and to PCA ordinations of soil field and laboratory data. These correlations indicate that there is an association among ground flora, overstory composition, and soil properties.

The ordination of sites by ranked ground flora species cover-abundance values was associated with N mineralized during anaerobic incubation. Site scores from RA were correlated with mineralized N at r=0.845. This finding is important because N mineralization has been found in other studies to be associated with overstory productivity (Keeny 1980, Powers 1980, Aber and Mellilo 1984, Pastor et al. 1984). Prediction of the mineralization rate from field-observed vegetation data would greatly simplify its estimation; present procedures require field sampling, incubation, and laboratory analysis.

N mineralized during anaerobic incubation was found to be significantly lower on sites with mixed oak-northern hardwood overstories than on northern hardwood sites, even though the soils had no significant differences in texture or in available nutrient levels, with the exception of Mg. If overstory composition differences are related to disturbance, then so may be N mineralization levels. Additional study of fire disturbance effects on N mineralization is needed; if a cause-effect relationship is established, N mineralization rates could be used to evaluate long-term effects of disturbance.

Weight of the partially decomposed forest floor layer (Oe) sampled in late October was 11,747 kg ha^{-1}, a figure somewhat lower than the 19,300 kg ha^{-1} reported on the Hubbard Brook Forest (Gosz et al. 1976). Other forest floor weights reported in the literature are not comparable, as Oi, Oe, and Oa layers were not sampled separately. Since litterfall appears to be lower in the Great Lakes region than in the northeast, perhaps forest floor accumulations are also less. More unexpectedly, there was not a discernible trend in forest floor weights among ecosystems studied here. Differences in litter production, litter quality associated with species composition, and N mineralization levels raised the expectation that forest floor weights would vary among ecosystems. Reasons for the lack of difference are unclear. Other studies of the forest floor do not make comparisons among ecosystems; however, the Hubbard Brook study noted greater accumulations of material at higher elevations, where climate slowed decomposition (Gosz et al. 1976). Additional study of the forest floor is needed.

Weight of autumn litterfall averaged 2,887 kg ha^{-1} for my study sites, a figure lower than those reported in the northeast (Gosz et al. 1972, MacLean and Wein 1977) and in Ohio (Boerner 1984), but comparable to that reported in Wisconsin (Crow 1978) and northwestern lower Michigan (Zak et al. 1986). There may be a regional climatic influence acting on litter production. Litter weights were greatest on mixed oak-northern hardwood sites, intermediate on northern hardwood sites and northern red oak sites, and lowest on black oak-pin oak sites.

Return of nutrients in autumn litterfall was significantly correlated with amount of litter produced for the nutrients P, Mg, and especially K. Return of N and particularly Ca was highly correlated with the presence of sugar maple and basswood in the overstory. This result agrees with other studies which found associations between litter quality and species composition (Pastor et al. 1984, Zak et al. 1986).

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CHAPTER IV

CONCLUSIONS

Previous chapters have focused on the ordination of sites along a gradient expressed by separate ecosystem components, including herbaceous flora, overstory composition, and soils. Also, examination of the associations of variables within and among the ecosystem components was an important part of my work. This chapter summarizes conclusions of the previous chapters, and discusses ways in which these results may be applied to the development of an ecological classification system.

PCA's were used in Chapter 2 to summarize the large number of soil variables obtained from field and laboratory investigations. Field determined variables which were most important in differentiating between sites were those related to texture, particularly depths to accumulations of soil layers with increased silt and/or clay content, and the texture of these layers. Coarse fragment content, E horizon thickness, and overall textural averages were also important in distinguishing between glacial tills of two different depositions. No single nutrient among laboratory determined variables displayed a greater amount of variability than others. Rather, there were horizon groups or depth ranges which summarized most of the variability in the data set. In PCA's of laboratory data which included organic horizons, nutrient content of the organic layers was emphasized over that of the mineral soil. When organic layers were excluded from the analysis, nutrient content of the B horizon was emphasized. Depth sums of soil nutrients exhibited less variation than horizon sums, except for those nutrient sums of the entire upper 150 cm soil depth. These nutrient sums described such a large size component of overall soil nutrient contents that no other interpretations could be derived from the PCA. Horizon summed data provided better interpretations.

There was agreement among most site ordinations with respect to the first two PC's of several different soil laboratory and field data sets. Site groupings based on glacial depositional environments were not contradicted by these PCA's. Sand sites formed in localized outwash on ice-disintegration topography were distinctly separated from sites formed in loamy till. Sites formed in outwash with ice-rafted till inclusions were placed between these two extremes along the primary axis of the plots. The second PC was usually effective in displaying a separation of Port Bruce till sites from Port Huron till sites[1], although the separation was not always distinct. Because of the correlations among results obtained from field and laboratory data sets, it is possible to infer nutrient status of a site from more easily obtained field data. It

[1]Names are according to Burgis (1977, 1981).

is also evident that there are corresponding gradients of soil texture and soil nutrient status on the study sites.

Soil variables were compared individually among groups to test for statistically significant differences. Comparisons between outwash sand sites and all other site groups were significant for nearly all nutrient and textural variables examined. Likewise, most comparisons between sites formed in sandy outwash with till inclusions and sites formed in loamy till were significant. Sites formed in till from Port Bruce and Port Huron glacial depositions, however, were not significantly different from each other except with respect to a few variables. Thus, separating these two tills into different depositional environment groups is not completely supported by analysis of soils data.

The ordination of sites by RA of ground flora species ranked cover-abundance values was associated with overstory species composition, and in a general way with depositional environments and soil characteristics. Sites at one extreme of the first ordination axis occurred on sands in localized outwash features within morainal areas. These sites had low overall soil nutrient content, high abundances of *Vaccinium angustifolium* and *Pteridium aquilinium* in the herbaceous layer, and supported black and pin oaks in the overstory. Litter production was lowest on these sites.

Sites which occurred on outwash sand with ice-rafted till inclusions were located next to outwash sand sites along the first axis of the ordination of ground flora.

These sites contained intermediate levels of soil nutrients, had lower abundances of Vaccinium and Pteridium, and were dominated by red oak in the overstory.

Sites located on tills of Port Bruce and Port Huron deposition were well differentiated on the first axis of the ordination of ground flora. Port Huron sites supported mixed oak-northern hardwood overstories, and contained higher abundances of Prenanthes alba and Smilacina racemosa than Port Bruce sites. Sites on Port Bruce till supported only northern hardwoods, contained high abundances of Osmorhiza chilensis, and also had Viola canadensis in the herbaceous layer. Differences in overstory composition were believed to be due to differing conditions at the time of stand establishment.

Soil physical and chemical properties of the two overstory types, oak-northern hardwoods and northern hardwoods, were compared to determine if they were associated with differences in overstory species establishment. The only statistically significant differences among variables not attributable to vegetation were coarse fragment content, thickness of the B horizon, and possibly Mg, although Mg content may be due in part to vegetation differences. The presence of red oak on some till sites and not on others is apparently not associated with soil textures, or with the supply of major soil nutrients. Climate and site history, particularly fire intensity and frequency, may have been responsible for differences in species establishment.

The first dimension site scores and ranks from ordination by ground flora was also significantly correlated with a similar RA ordination which used overstory basal area by species, and to PCA ordinations of soil field and laboratory data. These correlations indicate that there is an association among ground flora, overstory composition, and soil properties.

The ordination of sites by ranked ground flora species cover-abundance values was associated with N mineralized during anaerobic incubation. Site scores from RA had a linear correlation with mineralized N at $r=0.845$. This finding is important because N mineralization has been shown to be associated with overstory productivity (Aber and Mellilo 1984, Pastor et al. 1984, Keeny 1980, Powers 1980). Prediction of the mineralization rate from field-observed vegetation data may be possible for these sites.

N mineralized during anaerobic incubation was found to be significantly lower on sites with mixed oak-northern hardwood overstories than on northern hardwood sites, even though the soils had nearly identical textures and available nutrient levels. N mineralization levels may be related to disturbance as well as to inherent site quality, and could possibly be used to evaluate long-term effects of disturbance.

Weight of the partially decomposed forest floor layer was 11,747 kg ha^{-1}, a figure somewhat lower than that reported in the northeast (Gosz et al. 1976). Autumn litterfall appears to be lower in the Great Lakes region than in the northeast, and perhaps forest floor accumulations are also less. There was no trend in differing forest floor weights among ecosystems studied here. Differences in litter production, litter quality associated with species composition, and N mineralization levels were expected to result in variation among forest floor weights. Reasons for the lack of difference are unclear.

Weight of autumn litterfall averaged 2,887 kg ha^{-1}, a figure lower than those reported in the northeast (Gosz et al. 1972, MacLean and Wein 1977) and in Ohio (Boerner 1984), but comparable to that reported in Wisconsin (Crow 1978) and northwestern lower Michigan (Zak et al. 1986). There may be a regional climatic influence acting on litter production. Litter weights were greatest on mixed oak-northern hardwood sites, intermediate on northern hardwood sites and northern red oak sites, and lowest on black oak-pin oak sites.

Return of nutrients in autumn litterfall was significantly correlated with amount of litter produced for the nutrients P, Mg, and especially K. Return of N and particularly Ca was highly correlated with the presence of sugar maple and basswood in the overstory. Associations between litter quality and species composition have been noted in other studies (Zak et al. 1986, Pastor et al.

1984).

An ecological classification system for these sites could be developed based on site ordinations and descriptions, using combinations of different ecosystem components to identify sites which are ecologically distinct. Although the size of my sample is too small to adequately describe all the groups which exist in the area, some steps toward developing an ecosystem classification may be described.

My study has demonstrated that there are significant correlations among first dimension site ordinations based on ground flora ranked cover-abundance values, on overstory basal area by species, and on soil field and laboratory determined properties. Agreement among ordinations simplifies the classification procedure; in instances where there is not agreement, an arbitrary decision must be made. Such decisions are inherent in most classification systems (Wickware and Cowell 1985).

Analysis of soils data has indicated that there is a good basis for separating sites of different depositional environments, which have different kinds of surficial material resulting from glacial activity. Soil data analysis does not entirely justify separating Port Bruce till from Port Huron till, as only a few variables are significantly different between them. Also, lacustrine sites appear to be similar to till sites in texture and nutrient content, although sample size is too small within this group to be certain that it should not be separated. However, soil analysis does demonstrate that at least three depositional environment groups are present in the study area: sites formed in outwash sand from localized deposition on ice-disintegration topography, sites formed in outwash sand, containing inclusions of ice-rafted till or flow till on ice-disintegration topography, and sites formed in loamy textured till on moraines. Sites on outwash plains and in large glacial drainages were not investigated as part of my study, and will likely comprise another group of ecosystems.

These depositional environment/surficial deposit groupings do not correspond with mapped boundaries of glacial landforms as identified by Burgis (1977, 1981), as the scale of mapping used in her study is too small to distinguish localized deposits of surficial material. The different surficial deposits have a large influence on soil physical and chemical properties believed important in ecosystem function, and must be recognized in classification.

Floristic composition may be used to subdivide site groups which were developed based on depositional environments and soil properties. The 24 study sites exhibited a close association between the composition of herbaceous flora and overstory flora as evidenced by the correlation of site scores in RA; however, divisions based on flora should use herbaceous plants rather than overstory species because of the relatively rapid stabilization of plant communities following disturbance.

Soil data analysis did not completely justify separation of Port Bruce and Port Huron sites. However, these site groups differed substantially in overstory and ground flora species composition, and in levels of N mineralization. Because of the association of N mineralization levels with microbial biomass (Myrold 1987), microbial decomposition may be substantially different on soils which are very much alike. These differences in microbial activity may be a result of succession, or be a causal factor in succession; they may or may not be related to disturbance. In any event, a classification system must recognize that floristic communities can indicate an important difference in land potential even though soils are alike. For this reason, a classification system in my study area should separate sites formed in loamy till but having different floristic composition.

Another problem to consider in ecosystem classification is the effect of compensating factors. Site K belongs to the depositional environment group of sites formed in outwash with loamy till inclusions. The site has one pedon which is extremely sandy, one which has sandy loam textures, another in which sandy clay loam till is near the surface, and a fourth in which till is located deep in the profile. Ordination of soils places this site in a borderline location with till sites; ordination of flora places it firmly together with till sites. Flora may respond to the overall nutrient capital of a site through root absorption and cycling of nutrients in overstory litterfall, so that the inherently less productive microsites within an area may be enriched by nutrients captured outside the microsite and accumulated in the surface litter and soil layers. In my study area, the group of sites formed in outwash with ice-rafted till or flow till inclusions may have to be subdivided on an areal scale to quantify variability. Separate groups should be set up depending on the extent of till material in the site. The alternative, which would require these intermediate sites to be placed with till sites in the classification system, would not accommodate management objectives other than production, such as the development of trails and campsites, or more exotic operations such as wetlands amelioration.

Another classification question arises with respect to site P, which apparently has a clay layer deep in the substratum with a water table present above it. Textures above the water table are almost entirely sand. Depositionally, the site belongs to the group of sites formed in sandy outwash with till inclusions, although the origin of the clay under the water table is difficult to establish. Floristically, the site is not distinguishable from those sites formed in loamy till, but it would likely respond very differently to certain management techniques. There are examples of similar sites which have been clearcut and failed to regenerate because conditions at the sandy surface were too harsh for seedling establishment (D.T. Cleland, personal communication). Because of regeneration problems and other management concerns, site P cannot be classified together with till soils. Another subdivision of the depositional environment group is required for sites such as these, although their areal extent is likely to be small.

In summary, there at least six groups identified within my sample, and at least one more outside my sample. The groups not sampled are restricted to outwash plains and large sandy glacial drainages; these were not sampled because undisturbed examples could not be located. These sites will likely be divided into ones which occur on plains, and ones which occur on sloping areas leading into drainage valleys.

Group 1, as identified among my study sites, occurs within the boundaries of moraines as identified by Burgis (1977, 1981). It consists of sites formed in localized outwash on hilly terrain resulting from ice-disintegration as the melting glacier remained in a stagnant position. Overstories are comprised mainly of black and pin oaks, with a component of northern red oak. The herbaceous layer consists of high abundances of *Vaccinium* and *Pteridium*, with only low representation of other species. Sites T, H, and L comprise this group.

Group 2 consists of sites formed in outwash, containing pockets of loamy till which were transported as ice-rafted inclusions or as flow till. These sites have overstories dominated by northern red oak, with a sizable red maple component. Some sites have a component of white oak, which would likely be present on more sites had not selective logging diminished its abundance. The herbaceous layer contains high abundances of *Vaccinium* and *Pteridium*, but less than in Group 1, and other species are slightly more abundant. Sites Q, V, W, X, R, and M are among this group.

Group 3 is a subdivision of Group 2, with the same depositional environment and soil characteristics, but with a water table present in the substratum. The overstory consists of northern red oak, and a mixture of northern hardwood species including sugar maple, basswood, white ash, and beech. Representative flora include *Prenanthes*, *Smilacina*, *Viburnum*, and *Mianthemum*; no *Vaccinium* or *Pteridium* are present. Site P is the only example among my data, and the areal extent of this group is likely to be small.

Group 4 is another subdivision of Group 2, with the same depositional environment, but with a greater amount of till material present as inclusions than is average for the group. Based on a small sample, it is difficult to estimate the areal extent of till which should be required for this classification, but it is likely that it must be present in over half of soil borings within a site. The overstory is similar to that of Group 3, except that red maple may be present. The herbaceous flora is also similar to Group 3, but may include *Galium*. The only site in this group is K.

Group 5 sites are formed in loamy till on moraines; most have a thin surface layer of loamy sand or sandy loam. These sites may be common to all areas of Port Huron deposition, or they may be disturbance-related and occur only within a fixed distance from the glacial AuSable Valley drainage system; this question will have to be addressed during the mapping phase of implementing the ecological classification system. Overstories consist of a mixture of northern red oak and northern hardwoods in varying amounts, and the ground flora is like that of Group 4. Sites I, J, N, and O are representative of this group.

Group 6 also consists of sites formed in loamy till near the surface, on moraines. It may be restricted to till of Port Bruce deposition, or may occur on sites which were not subjected to frequent fire disturbance as a result of their location with respect to pyric ecosystems and prevailing wind patterns. The overstory contains only northern hardwood species, and most sites are dominated by sugar maple. Among the ground flora, a high abundance of *Osmorhiza* is present, and *Galium* is abundant on most sites. *Prenanthes*, *Viburnum*, and *Smilacina* are often present, but only at very low abundances. *Viola canadensis* is restricted to sites of this group. Spring ephemerals were not observed due to the lateness of sampling, but may also be important in identifying this group. Sites A, B, D, E, F, and G represent this group.

Lacustrine sites C and U, located within the boundaries of Port Bruce till, are likely to become part of Group 6. Analysis of soils and flora did not indicate that there were any differences important enough to separate them, but management practices will have to be considered. The high silt content of soils may result in an operability problem in sites of lacustrine origin.

The groups identified represent a subdivision of depositional environment groups which have statistically significant differences in soil properties. Subdivisions are based on floristic differences which are believed to be due to factors important to succession and productivity. Other subdivisions are in anticipation of management practices, both for silvicultural and for multiple-use objectives. The groups will provide a framework for ecosystem mapping, but will be refined and likely undergo additional subdivision as more sites are investigated.

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APPENDIX

Table A.1. Soil variable comparisons for site groups based on depositional environment and surficial deposit.

Variable	Groups 1st	Groups 2nd	Mean (1st group)	S.D. (1st group)	n (1st group)	Mean (2nd group)	S.D. (2nd group)	n (2nd group)	F (calc.)	df(n) for F	df(d) for F	df t	Pooled s	Approx. df for t	t (calc.)
ABRAYP	1	2	4.68	1.40	3	7.58	3.67	8	6.872	7	2	9	1.53	8.8	-1.897
ABRAYP	1	3	4.68	1.40	3	22.74	22.25	6	252.583*	5	2	7	9.12	5.1	-1.980
ABRAYP	1	4	4.68	1.40	3	14.77	4.04	5	8.327	4	2	6	1.98	5.3	-5.098*
ABRAYP	1	5	4.68	1.40	3	5.47	0.82	2	2.915	2	1	3	0.99	3.0	-0.794
ABRAYP	2	3	7.58	3.67	8	22.74	22.25	6	36.756*	5	7	12	9.18	5.2	-1.652
ABRAYP	2	4	7.58	3.67	8	14.77	4.04	5	1.212	4	7	11	2.22	8.0	-3.232*
ABRAYP	2	5	7.58	3.67	8	5.47	0.82	2	20.031	7	1	8	1.42	7.9	1.485
ABRAYP	3	4	22.74	22.25	6	14.77	4.04	5	30.332*	5	4	9	9.26	5.4	0.861
ABRAYP	3	5	22.74	22.25	6	5.47	0.82	2	736.262*	5	1	6	9.10	5.0	1.897
ABRAYP	4	5	14.77	4.04	5	5.47	0.82	2	24.274	4	1	5	1.90	4.7	4.901*
ACA	1	2	90.51	52.72	3	376.26	459.16	8	75.854*	7	2	9	165.17	7.5	-1.730
ACA	1	3	90.51	52.72	3	1551.37	574.09	6	118.579*	5	2	7	236.34	5.2	-6.181*
ACA	1	4	90.51	52.72	3	1548.26	765.91	5	211.059*	4	2	6	343.88	4.1	-4.239*
ACA	1	5	90.51	52.72	3	741.72	229.90	2	19.016*	1	2	3	165.39	1.1	-3.937
ACA	2	3	376.26	459.16	8	1551.37	574.09	6	1.563	5	7	12	285.10	9.4	-4.122*
ACA	2	4	376.26	459.16	8	1548.26	765.91	5	2.782	4	7	11	379.05	5.8	-3.092*
ACA	2	5	376.26	459.16	8	741.72	229.90	2	3.989	7	1	8	229.74	3.5	-1.591
ACA	3	4	1551.37	574.09	6	1548.26	765.91	5	1.780	4	5	9	415.03	7.3	0.007
ACA	3	5	1551.37	574.09	6	741.72	229.90	2	6.236	5	1	6	285.23	5.1	2.839*
ACA	4	5	1548.26	765.91	5	741.72	229.90	2	11.099	4	1	5	379.14	5.0	2.127
AHBUF	1	2	1.70E-4	4.37E-5	3	1.17E-4	7.14E-5	8	2.670	7	2	9	0.00	6.2	1.485
AHBUF	1	3	1.70E-4	4.37E-5	3	1.29E-6	7.49E-7	6	3404.08*	2	5	7	0.00	2.0	6.686*
AHBUF	1	4	1.70E-4	4.37E-5	3	7.99E-6	6.56E-6	5	44.377*	2	4	6	0.00	2.1	6.378*
AHBUF	1	5	1.70E-4	4.37E-5	3	4.86E-6	6.63E-6	2	43.445	2	1	3	0.00	2.1	6.435*
AHBUF	2	3	1.17E-4	7.14E-5	8	1.29E-6	7.49E-7	6	9087.26*	7	5	12	0.00	7.0	4.583*

*Significant difference between groups at alpha=0.05.

Table A.1. (continued).

Variable	Groups 1st	Groups 2nd	Mean (1st group)	S.D. (1st group)	n (1st group)	Mean (2nd group)	S.D. (2nd group)	n (2nd group)	F (calc.)	df(n) for F	df(d) for F	df t	Pooled s	Approx. df for t	t (calc.)
AHBUF	2	4	1.17E-4	7.14E-5	8	7.99E-6	6.56E-6	5	118.465*	7	4	11	0.00	7.2	4.289*
AHBUF	2	5	1.17E-4	7.14E-5	8	4.86E-6	6.63E-6	2	115.976	7	1	8	0.00	7.4	4.368*
AHBUF	3	4	1.29E-6	7.49E-7	6	7.99E-6	6.56E-6	5	76.709*	4	5	9	0.00	4.1	-2.271
AHBUF	3	5	1.29E-6	7.49E-7	6	4.86E-6	6.63E-6	2	78.354*	1	5	6	0.00	1.0	-0.760
AHBUF	4	5	7.99E-6	6.56E-6	5	4.86E-6	6.63E-6	2	1.021	1	4	5	0.00	1.9	0.566
AK	1	2	28.34	4.60	3	42.02	27.81	8	36.550*	7	2	9	10.18	7.9	-1.343
AK	1	3	28.34	4.60	3	48.78	8.72	6	3.593	5	2	7	4.44	6.8	-4.602*
AK	1	4	28.34	4.60	3	77.93	35.76	5	60.434*	4	2	6	16.21	4.2	-3.059*
AK	1	5	28.34	4.60	3	35.84	5.63	2	1.498	1	2	3	4.79	1.9	-1.567
AK	2	3	42.02	27.81	8	48.78	8.72	6	10.171*	7	5	12	10.46	8.7	-0.646
AK	2	4	42.02	27.81	8	77.93	35.76	5	1.653	4	7	11	18.77	7.0	-1.913
AK	2	5	42.02	27.81	8	35.84	5.63	2	24.400	7	1	8	10.61	8.0	0.583
AK	3	4	48.78	8.72	6	77.93	35.76	5	16.818*	4	5	9	16.38	4.4	-1.779
AK	3	5	48.78	8.72	6	35.84	5.63	2	2.399	5	1	6	5.34	2.9	2.423
AK	4	5	77.93	35.76	5	35.84	5.63	2	40.344	4	1	5	16.48	4.4	2.554
AMG	1	2	16.98	4.36	3	45.83	39.44	8	81.828*	7	2	9	14.17	7.4	-2.036
AMG	1	3	16.98	4.36	3	89.33	17.36	6	15.854	5	2	7	7.52	6.1	-9.620*
AMG	1	4	16.98	4.36	3	150.51	72.54	5	276.810*	4	2	6	32.54	4.0	-4.104*
AMG	1	5	16.98	4.36	3	52.65	25.28	2	33.619	1	2	3	18.05	1.0	-1.976
AMG	2	3	45.83	39.44	8	89.33	17.36	6	5.161	7	5	12	15.64	10.1	-2.781*
AMG	2	4	45.83	39.44	8	150.51	72.54	5	3.383	4	7	11	35.31	5.5	-2.965*
AMG	2	5	45.83	39.44	8	52.65	25.28	2	2.434	7	1	8	22.67	2.5	-0.301
AMG	3	4	89.33	17.36	6	150.51	72.54	5	17.460*	4	5	9	33.21	4.4	-1.842
AMG	3	5	89.33	17.36	6	52.65	25.28	2	2.121	1	5	6	19.23	1.3	1.908
AMG	4	5	150.51	72.54	5	52.65	25.28	2	8.234	4	1	5	37.04	5.0	2.642*

*Significant difference between groups at alpha=0.05.

Table A.1. (continued).

Variable	Groups 1st	Groups 2nd	Mean <---- 1st group	S.D. 1st group	n ---->	Mean <---- 2nd group	S.D. 2nd group	n ---->	F (calc.)	df(n) <- for F	df(d) for F ->	df of t	Pooled s	Approx. df for t	t (calc.)
ATKN	1	2	834.24	112.21	3	972.78	543.51	8	23.461	7	2	9	202.79	8.3	-0.683
ATKN	1	3	834.24	112.21	3	1983.30	443.74	6	15.638	5	2	7	192.39	6.1	-5.973*
ATKN	1	4	834.24	112.21	3	1791.89	494.23	5	19.400	4	2	6	230.33	4.6	-4.158*
ATKN	1	5	834.24	112.21	3	909.47	7.55	2	220.887	2	1	3	65.00	2.0	-1.157
ATKN	2	3	972.78	543.51	8	1983.30	443.74	6	1.500	7	5	12	264.09	11.9	-3.826*
ATKN	2	4	972.78	543.51	8	1791.89	494.23	5	1.209	7	4	11	292.88	9.3	-2.797*
ATKN	2	5	972.78	543.51	8	909.47	7.55	2	5182.28*	7	1	8	192.23	7.0	0.329
ATKN	3	4	1983.30	443.74	6	1791.89	494.23	5	1.241	4	5	9	285.78	8.2	0.670
ATKN	3	5	1983.30	443.74	6	909.47	7.55	2	3454.33*	5	1	6	181.23	5.0	5.925*
ATKN	4	5	1791.89	494.23	5	909.47	7.55	2	4285.13*	4	1	5	221.09	4.0	3.991*
ATKP	1	2	81.40	31.28	3	69.59	26.72	8	1.370	2	7	9	20.38	3.2	0.579
ATKP	1	3	81.40	31.28	3	274.27	131.95	6	17.794	5	2	7	56.82	6.0	-3.395*
ATKP	1	4	81.40	31.28	3	191.84	43.50	5	1.934	4	2	6	26.54	5.6	-4.161*
ATKP	1	5	81.40	31.28	3	76.79	3.14	2	99.237	2	1	3	18.20	2.1	0.253
ATKP	2	3	69.59	26.72	8	274.27	131.95	6	24.386*	5	7	12	54.69	5.3	-3.743*
ATKP	2	4	69.59	26.72	8	191.84	43.50	5	2.650	4	7	11	21.63	5.9	-5.653*
ATKP	2	5	69.59	26.72	8	76.79	3.14	2	72.413	7	1	8	9.70	7.6	-0.742
ATKP	3	4	274.27	131.95	6	191.84	43.50	5	9.201	5	4	9	57.27	6.3	1.439
ATKP	3	5	274.27	131.95	6	76.79	3.14	2	1765.87*	5	1	6	53.91	5.0	3.663*
ATKP	4	5	191.84	43.50	5	76.79	3.14	2	191.920	4	1	5	19.58	4.1	5.876*
BBRAYP	1	2	215.85	53.31	3	211.56	113.22	8	4.511	7	2	9	50.49	8.0	0.085
BBRAYP	1	3	215.85	53.31	3	242.85	247.17	6	21.497	5	2	7	105.50	5.8	-0.256
BBRAYP	1	4	215.85	53.31	3	245.57	271.11	5	25.863	4	2	6	125.09	4.5	-0.238
BBRAYP	1	5	215.85	53.31	3	335.69	431.55	2	65.531*	1	2	3	306.70	1.0	-0.391
BBRAYP	2	3	211.56	113.22	8	242.85	247.17	6	4.766	5	7	12	108.56	6.6	-0.288

*Significant difference between groups at alpha=0.05.

Table A.1. (continued).

Variable	Groups 1st	Groups 2nd	Mean <---- 1st group	S.D.	n ---->	Mean <---- 2nd group	S.D.	n ---->	F (calc.)	df(n) <- for F	df(d) ->	df t	Pooled s	Approx. df for t	t (calc.)
BBRAYP	2	4	211.56	113.22	8	245.57	271.11	5	5.734*	4	7	11	127.68	4.9	-0.266
BBRAYP	2	5	211.56	113.22	8	335.69	431.55	2	14.528*	1	7	8	307.77	1.0	-0.403
BBRAYP	3	4	242.85	247.17	6	245.57	271.11	5	1.203	4	5	9	157.74	8.3	-0.017
BBRAYP	3	5	242.85	247.17	6	335.69	431.55	2	3.048	1	5	6	321.40	1.2	-0.289
BBRAYP	4	5	245.57	271.11	5	335.69	431.55	2	2.534	1	4	5	328.36	1.3	-0.274
BCA	1	2	202.40	233.99	3	3075.30	4522.47	8	373.557*	7	2	9	1604.63	7.1	-1.790
BCA	1	3	202.40	233.99	3	21763.69	8379.42	6	1282.43*	5	2	7	3423.55	5.0	-6.298*
BCA	1	4	202.40	233.99	3	17966.94	8730.39	5	1392.11*	4	2	6	3906.69	4.0	-4.547*
BCA	1	5	202.40	233.99	3	6873.67	165.55	2	1.998	2	1	3	178.76	2.9	-37.320*
BCA	2	3	3075.30	4522.47	8	21763.69	8379.42	6	3.433	5	7	12	3776.11	7.2	-4.949*
BCA	2	4	3075.30	4522.47	8	17966.94	8730.39	5	3.727	4	7	11	4219.07	5.4	-3.530*
BCA	2	5	3075.30	4522.47	8	6873.67	165.55	2	746.265	7	1	8	1603.21	7.1	-2.369*
BCA	3	4	21763.69	8379.42	6	17966.94	8730.39	5	1.086	4	5	9	5190.99	8.5	0.731
BCA	3	5	21763.69	8379.42	6	6873.67	165.55	2	2561.94*	5	1	6	3422.89	5.0	4.350*
BCA	4	5	17966.94	8730.39	5	6873.67	165.55	2	2781.05*	4	1	5	3906.10	4.0	2.840*
BHBUF	1	2	3.09E-4	9.18E-5	3	2.92E-4	1.04E-4	8	1.283	7	2	9	0.00	4.1	0.264
BHBUF	1	3	3.09E-4	9.18E-5	3	1.51E-4	1.23E-4	6	1.795	5	2	7	0.00	5.4	2.164
BHBUF	1	4	3.09E-4	9.18E-5	3	7.94E-5	3.63E-5	5	6.395	2	4	6	0.00	2.4	4.142*
BHBUF	1	5	3.09E-4	9.18E-5	3	9.76E-5	3.85E-5	2	5.685	2	1	3	0.00	2.8	3.548*
BHBUF	2	3	2.92E-4	1.04E-4	8	1.51E-4	1.23E-4	6	1.399	5	7	12	0.00	9.8	2.266*
BHBUF	2	4	2.92E-4	1.04E-4	8	7.94E-5	3.63E-5	5	8.208	7	4	11	0.00	9.4	5.289*
BHBUF	2	5	2.92E-4	1.04E-4	8	9.76E-5	3.85E-5	2	7.297	7	1	8	0.00	5.4	4.249*
BHBUF	3	4	1.51E-4	1.23E-4	6	7.94E-5	3.63E-5	5	11.481*	5	4	9	0.00	6.0	1.357
BHBUF	3	5	1.51E-4	1.23E-4	6	9.76E-5	3.85E-5	2	10.207	5	1	6	0.00	5.8	0.935
BHBUF	4	5	7.94E-5	3.63E-5	5	9.76E-5	3.85E-5	2	1.125	1	4	5	0.00	1.8	-0.574

*Significant difference between groups at alpha=0.05.

Table A.1. (continued).

Variable	Groups 1st	Groups 2nd	Mean	S.D.	n	Mean	S.D.	n	F (calc.)	df(n)	df(d)	df t	Pooled s	Approx. df for t	t (calc.)
			<---- 1st group ---->			<---- 2nd group ---->				<- for F ->					
BK	1	2	62.77	11.59	3	281.79	396.82	8	1172.25*	7	2	9	140.46	7.0	-1.559
BK	1	3	62.77	11.59	3	827.89	399.85	6	1190.22*	5	2	7	163.38	5.0	-4.683*
BK	1	4	62.77	11.59	3	1037.60	276.10	5	567.500*	4	2	6	123.66	4.0	-7.883*
BK	1	5	62.77	11.59	3	598.97	1.41	2	67.566	2	1	3	6.77	2.1	-79.257*
BK	2	3	281.79	396.82	8	827.89	399.85	6	1.015	5	7	12	215.24	10.9	-2.537*
BK	2	4	281.79	396.82	8	1037.60	276.10	5	2.066	7	4	11	186.89	10.8	-4.044*
BK	2	5	281.79	396.82	8	598.97	1.41	2	79204.3*	7	1	8	140.30	7.0	-2.261
BK	3	4	827.89	399.85	6	1037.60	276.10	5	2.097	5	4	9	204.68	8.8	-1.025
BK	3	5	827.89	399.85	6	598.97	1.41	2	80418.5*	5	1	6	163.24	5.0	1.402
BK	4	5	1037.60	276.10	5	598.97	1.41	2	38343.8*	4	1	5	123.48	4.0	3.552*
BMG	1	2	45.12	47.83	3	643.25	1141.01	8	569.086*	7	2	9	404.35	7.1	-1.479
BMG	1	3	45.12	47.83	3	2207.65	1265.69	6	700.251*	5	2	7	517.45	5.0	-4.179*
BMG	1	4	45.12	47.83	3	3291.20	798.29	5	278.561*	4	2	6	358.07	4.0	-9.065*
BMG	1	5	45.12	47.83	3	1340.61	513.90	2	115.440*	1	2	3	364.43	1.0	-3.555
BMG	2	3	643.25	1141.01	8	2207.65	1265.69	6	1.230	5	7	12	655.54	10.2	-2.386*
BMG	2	4	643.25	1141.01	8	3291.20	798.29	5	2.043	7	4	11	538.69	10.7	-4.915*
BMG	2	5	643.25	1141.01	8	1340.61	513.90	2	4.930	7	1	8	542.94	4.1	-1.284
BMG	3	4	2207.65	1265.69	6	3291.20	798.29	5	2.514	5	4	9	628.05	8.5	-1.725
BMG	3	5	2207.65	1265.69	6	1340.61	513.90	2	6.066	5	1	6	631.70	5.0	1.373
BMG	4	5	3291.20	798.29	5	1340.61	513.90	2	2.413	4	1	5	509.41	3.1	3.829*
BTKN	1	2	1380.56	223.86	3	2079.58	1006.35	8	20.209	7	2	9	378.55	8.5	-1.847
BTKN	1	3	1380.56	223.86	3	5285.16	657.39	6	8.624	5	2	7	297.88	6.7	-13.108*
BTKN	1	4	1380.56	223.86	3	4360.15	656.37	5	8.597	4	2	6	320.73	5.3	-9.290*
BTKN	1	5	1380.56	223.86	3	3591.39	560.06	2	6.259	1	2	3	416.58	1.2	-5.307*
BTKN	2	3	2079.58	1006.35	8	5285.16	657.39	6	2.343	7	5	12	445.67	11.9	-7.193*

*Significant difference between groups at alpha=0.05.

Table A.1. (continued).

Variable	Groups 1st	Groups 2nd	Mean	S.D.	n	Mean	S.D.	n	F (calc.)	df(n)	df(d)	df t	Pooled s	Approx. df for t	t (calc.)
			<---- 1st group ---->			<---- 2nd group ---->				<- for F ->					
BTKN	2	4	2079.58	1006.35	8	4360.15	656.37	5	2.351	7	4	11	461.26	10.9	-4.944*
BTKN	2	5	2079.58	1006.35	8	3591.39	560.06	2	3.229	7	1	8	532.38	3.0	-2.840*
BTKN	3	4	5285.16	657.39	6	4360.15	656.37	5	1.003	5	4	9	397.73	8.6	2.326*
BTKN	3	5	5285.16	657.39	6	3591.39	560.06	2	1.378	5	1	6	478.39	2.0	3.541*
BTKN	4	5	4360.15	656.37	5	3591.39	560.06	2	1.373	4	1	5	492.95	2.2	1.560
BTKP	1	2	795.78	167.90	3	1076.57	796.22	8	22.489	7	2	9	297.73	8.3	-0.943
BTKP	1	3	795.78	167.90	3	3502.52	1156.37	6	47.434*	5	2	7	481.94	5.4	-5.616*
BTKP	1	4	795.78	167.90	3	3128.50	1477.15	5	77.401*	4	2	6	667.68	4.2	-3.494*
BTKP	1	5	795.78	167.90	3	2464.24	1898.03	2	127.792*	1	2	3	1345.61	1.0	-1.240
BTKP	2	3	1076.57	796.22	8	3502.52	1156.37	6	2.109	5	7	12	549.65	8.4	-4.414*
BTKP	2	4	1076.57	796.22	8	3128.50	1477.15	5	3.442	4	7	11	718.08	5.5	-2.858*
BTKP	2	5	1076.57	796.22	8	2464.24	1898.03	2	5.683	1	7	8	1371.31	1.1	-1.012
BTKP	3	4	3502.52	1156.37	6	3128.50	1477.15	5	1.632	4	5	9	811.95	7.6	0.461
BTKP	3	5	3502.52	1156.37	6	2464.24	1898.03	2	2.694	1	5	6	1422.72	1.3	0.730
BTKP	4	5	3128.50	1477.15	5	2464.24	1898.03	2	1.651	1	4	5	1495.88	1.5	0.444
CASUM	1	2	6142.29	4467.95	3	16206.79	10661.37	8	5.694	7	2	9	4567.53	8.5	-2.203*
CASUM	1	3	6142.29	4467.95	3	36664.01	14961.42	6	11.213	5	2	7	6630.35	6.4	-4.603*
CASUM	1	4	6142.29	4467.95	3	43492.64	14240.23	5	10.158	4	2	6	6871.03	5.1	-5.436*
CASUM	1	5	6142.29	4467.95	3	24089.22	13905.86	2	9.687	1	2	3	10165.66	1.1	-1.765
CASUM	2	3	16206.79	10661.37	8	36664.01	14961.42	6	1.969	5	7	12	7177.43	8.6	-2.850*
CASUM	2	4	16206.79	10661.37	8	43492.64	14240.23	5	1.784	4	7	11	7400.33	6.8	-3.687*
CASUM	2	5	16206.79	10661.37	8	24089.22	13905.86	2	1.701	1	7	8	10530.65	1.3	-0.749
CASUM	3	4	36664.01	14961.42	6	43492.64	14240.23	5	1.104	5	4	9	8824.07	8.8	-0.774
CASUM	3	5	36664.01	14961.42	6	24089.22	13905.86	2	1.158	5	1	6	11575.57	1.9	1.086
CASUM	4	5	43492.64	14240.23	5	24089.22	13905.86	2	1.049	4	1	5	11715.09	1.9	1.656

*Significant difference between groups at alpha=0.05.

Table A.1. (continued).

Variable	Groups 1st	Groups 2nd	Mean (1st group)	S.D. (1st group)	n (1st group)	Mean (2nd group)	S.D. (2nd group)	n (2nd group)	F (calc.)	df(n) for F	df(d) for F	df t	Pooled s	Approx. df for t	t (calc.)
CBRAYP	1	2	181.92	37.46	3	104.13	53.11	8	2.010	7	2	9	28.64	5.3	2.716*
CBRAYP	1	3	181.92	37.46	3	15.18	11.30	6	10.990*	2	5	7	22.11	2.2	7.540*
CBRAYP	1	4	181.92	37.46	3	33.74	21.88	5	2.931	2	4	6	23.74	2.8	6.242*
CBRAYP	1	5	181.92	37.46	3	45.08	26.73	2	1.964	2	1	3	28.72	2.9	4.764*
CBRAYP	2	3	104.13	53.11	8	15.18	11.30	6	22.090*	7	5	12	19.34	7.8	4.600*
CBRAYP	2	4	104.13	53.11	8	33.74	21.88	5	5.892	7	4	11	21.17	10.0	3.324*
CBRAYP	2	5	104.13	53.11	8	45.08	26.73	2	3.948	7	1	8	26.64	3.5	2.216
CBRAYP	3	4	15.18	11.30	6	33.74	21.88	5	3.749	4	5	9	10.82	5.7	-1.716
CBRAYP	3	5	15.18	11.30	6	45.08	26.73	2	5.596	1	5	6	19.46	1.1	-1.537
CBRAYP	4	5	33.74	21.88	5	45.08	26.73	2	1.492	1	4	5	21.28	1.6	-0.533
CCA	1	2	5710.76	4381.73	3	12522.89	8923.80	8	4.148	7	2	9	4044.02	7.7	-1.684
CCA	1	3	5710.76	4381.73	3	13006.72	10966.67	6	6.264	5	2	7	5142.42	6.9	-1.419
CCA	1	4	5710.76	4381.73	3	23663.78	9434.93	5	4.636	4	2	6	4919.70	5.9	-3.649*
CCA	1	5	5710.76	4381.73	3	15996.15	13926.60	2	10.102	1	2	3	10167.35	1.1	-1.012
CCA	2	3	12522.89	8923.80	8	13006.72	10966.67	6	1.510	5	7	12	5477.13	9.5	-0.088
CCA	2	4	12522.89	8923.80	8	23663.78	9434.93	5	1.118	4	7	11	5268.57	8.2	-2.115
CCA	2	5	12522.89	8923.80	8	15996.15	13926.60	2	2.436	1	7	8	10340.67	1.2	-0.336
CCA	3	4	13006.72	10966.67	6	23663.78	9434.93	5	1.351	5	4	9	6152.09	9.0	-1.732
CCA	3	5	13006.72	10966.67	6	15996.15	13926.60	2	1.613	1	5	6	10817.57	1.4	-0.276
CCA	4	5	23663.78	9434.93	5	15996.15	13926.60	2	2.179	1	4	5	10713.48	1.4	0.716
CHBUF	1	2	1.08E-4	5.19E-5	3	6.98E-5	4.57E-5	8	1.290	2	7	9	0.00	3.3	1.122
CHBUF	1	3	1.08E-4	5.19E-5	3	5.26E-6	6.69E-6	6	60.184*	2	5	7	0.00	2.0	3.415
CHBUF	1	4	1.08E-4	5.19E-5	3	7.86E-6	8.07E-6	5	41.361*	2	4	6	0.00	2.1	3.318
CHBUF	1	5	1.08E-4	5.19E-5	3	1.50E-5	1.42E-6	2	1335.85*	2	1	3	0.00	2.0	3.102
CHBUF	2	3	6.98E-5	4.57E-5	8	5.26E-6	6.69E-6	6	46.664*	7	5	12	0.00	7.4	3.939*

*Significant difference between groups at alpha=0.05.

Table A.1. (continued).

Variable	Groups 1st	Groups 2nd	Mean <---- 1st group	S.D. 1st group	n 1st group ---->	Mean <---- 2nd group	S.D. 2nd group	n 2nd group ---->	F (calc.)	df(n) <- for F	df(d) for F ->	df t	Pooled s	Approx. df for t	t (calc.)
CHBUF	2	4	6.98E-5	4.57E-5	8	7.86E-6	8.07E-6	5	32.069*	7	4	11	0.00	7.7	3.741*
CHBUF	2	5	6.98E-5	4.57E-5	8	1.50E-5	1.42E-6	2	1035.75*	7	1	8	0.00	7.1	3.385*
CHBUF	3	4	5.26E-6	6.69E-6	6	7.86E-6	8.07E-6	5	1.455	4	5	9	0.00	7.8	-0.574
CHBUF	3	5	5.26E-6	6.69E-6	6	1.50E-5	1.42E-6	2	22.196	5	1	6	0.00	5.9	-3.347*
CHBUF	4	5	7.86E-6	8.07E-6	5	1.50E-5	1.42E-6	2	32.298	4	1	5	0.00	4.5	-1.906
CK	1	2	88.91	28.96	3	340.24	138.66	8	22.925	7	2	9	51.80	8.3	-4.852*
CK	1	3	88.91	28.96	3	222.36	268.45	6	85.927*	5	2	7	110.86	5.2	-1.204
CK	1	4	88.91	28.96	3	570.38	267.97	5	85.620*	4	2	6	121.00	4.2	-3.979*
CK	1	5	88.91	28.96	3	450.19	143.29	2	24.481	1	2	3	102.69	1.1	-3.518*
CK	2	3	340.24	138.66	8	222.36	268.45	6	3.748	5	7	12	120.06	7.0	0.982
CK	2	4	340.24	138.66	8	570.38	267.97	5	3.735	4	7	11	129.48	5.4	-1.777
CK	2	5	340.24	138.66	8	450.19	143.29	2	1.068	1	7	8	112.56	1.5	-0.977
CK	3	4	222.36	268.45	6	570.38	267.97	5	1.004	5	4	9	162.40	8.6	-2.143
CK	3	5	222.36	268.45	6	450.19	143.29	2	3.510	5	1	6	149.25	3.7	-1.526
CK	4	5	570.38	267.97	5	450.19	143.29	2	3.497	4	1	5	156.93	3.9	0.766
CMG	1	2	275.85	156.86	3	1286.62	826.33	8	27.751	7	2	9	305.87	8.1	-3.305*
CMG	1	3	275.85	156.86	3	933.44	1235.97	6	62.086*	5	2	7	512.65	5.3	-1.283
CMG	1	4	275.85	156.86	3	2742.50	1158.58	5	54.554*	4	2	6	525.99	4.2	-4.690*
CMG	1	5	275.85	156.86	3	2316.37	2109.96	2	180.936*	1	2	3	1494.71	1.0	-1.365
CMG	2	3	1286.62	826.33	8	933.44	1235.97	6	2.237	5	7	12	583.06	8.3	0.606
CMG	2	4	1286.62	826.33	8	2742.50	1158.58	5	1.966	4	7	11	594.82	6.6	-2.448*
CMG	2	5	1286.62	826.33	8	2316.37	2109.96	2	6.520	1	7	8	1520.30	1.1	-0.677
CMG	3	4	933.44	1235.97	6	2742.50	1158.58	5	1.138	5	4	9	723.23	8.8	-2.501*
CMG	3	5	933.44	1235.97	6	2316.37	2109.96	2	2.914	1	5	6	1574.98	1.2	-0.878
CMG	4	5	2742.50	1158.58	5	2316.37	2109.96	2	3.317	1	4	5	1579.38	1.3	0.270

*Significant difference between groups at alpha=0.05.

Table A.1. (continued).

Variable	Groups 1st	Groups 2nd	Mean (1st group)	S.D. (1st group)	n (1st group)	Mean (2nd group)	S.D. (2nd group)	n (2nd group)	F (calc.)	df(n) for F	df(d) for F	df t	Pooled s	Approx. df for t	t (calc.)
CTKN	1	2	581.97	98.28	3	1277.38	553.73	8	31.744	7	2	9	203.83	8.0	-3.412*
CTKN	1	3	581.97	98.28	3	944.84	1021.90	6	108.115*	5	2	7	421.03	5.2	-0.862
CTKN	1	4	581.97	98.28	3	2181.66	1618.97	5	271.361*	4	2	6	726.25	4.0	-2.203
CTKN	1	5	581.97	98.28	3	2283.36	1965.52	2	399.967*	1	2	3	1390.99	1.0	-1.223
CTKN	2	3	1277.38	553.73	8	944.84	1021.90	6	3.406	5	7	12	460.84	7.2	0.722
CTKN	2	4	1277.38	553.73	8	2181.66	1618.97	5	8.548*	4	7	11	750.03	4.6	-1.206
CTKN	2	5	1277.38	553.73	8	2283.36	1965.52	2	12.600*	1	7	8	1403.55	1.0	-0.717
CTKN	3	4	944.84	1021.90	6	2181.66	1618.97	5	2.510	4	5	9	835.62	6.5	-1.480
CTKN	3	5	944.84	1021.90	6	2283.36	1965.52	2	3.699	1	5	6	1451.10	1.2	-0.922
CTKN	4	5	2181.66	1618.97	5	2283.36	1965.52	2	1.474	1	4	5	1567.11	1.6	-0.065
CTKP	1	2	690.67	11.20	3	1207.94	446.87	8	1591.94*	7	2	9	158.12	7.0	-3.271*
CTKP	1	3	690.67	11.20	3	1015.08	783.83	6	4897.88*	5	2	7	320.06	5.0	-1.014
CTKP	1	4	690.67	11.20	3	2246.86	1091.06	5	9489.89*	4	2	6	487.98	4.0	-3.189*
CTKP	1	5	690.67	11.20	3	2300.10	1618.63	2	20886.2*	1	2	3	1144.56	1.0	-1.406
CTKP	2	3	1207.94	446.87	8	1015.08	783.83	6	3.077	5	7	12	356.88	7.4	0.540
CTKP	2	4	1207.94	446.87	8	2246.86	1091.06	5	5.961*	4	7	11	512.88	4.9	-2.026
CTKP	2	5	1207.94	446.87	8	2300.10	1618.63	2	13.120*	1	7	8	1155.40	1.0	-0.945
CTKP	3	4	1015.08	783.83	6	2246.86	1091.06	5	1.938	4	5	9	583.51	7.1	-2.111
CTKP	3	5	1015.08	783.83	6	2300.10	1618.63	2	4.264	1	5	6	1188.44	1.2	-1.081
CTKP	4	5	2246.86	1091.06	5	2300.10	1618.63	2	2.201	1	4	5	1244.21	1.4	-0.043
KSUM	1	2	196.23	40.12	3	688.74	452.32	8	127.107*	7	2	9	161.59	7.3	-3.048*
KSUM	1	3	196.23	40.12	3	1119.70	605.25	6	227.587*	5	2	7	248.18	5.1	-3.721*
KSUM	1	4	196.23	40.12	3	1712.58	413.41	5	106.179*	4	2	6	186.33	4.1	-8.138*
KSUM	1	5	196.23	40.12	3	1112.61	143.95	2	12.874	1	2	3	104.39	1.1	-8.778
KSUM	2	3	688.74	452.32	8	1119.70	605.25	6	1.791	5	7	12	294.33	8.9	-1.464

*Significant difference between groups at alpha=0.05.

Table A.1. (continued).

Variable	Groups 1st	Groups 2nd	Mean <---- 1st group	S.D.	n ---->	Mean <---- 2nd group	S.D.	n ---->	F (calc.)	df(n) <- for F	df(d) for F ->	df t	Pooled s	Approx. df for t	t (calc.)
KSUM	2	4	688.74	452.32	8	1712.58	413.41	5	1.197	7	4	11	244.45	9.3	-4.188*
KSUM	2	5	688.74	452.32	8	1112.61	143.95	2	9.873	7	1	8	189.57	6.4	-2.236
KSUM	3	4	1119.70	605.25	6	1712.58	413.41	5	2.143	5	4	9	308.60	8.7	-1.921
KSUM	3	5	1119.70	605.25	6	1112.61	143.95	2	17.679	5	1	6	267.24	6.0	0.027
KSUM	4	5	1712.58	413.41	5	1112.61	143.95	2	8.248	4	1	5	211.05	5.0	2.843*
MGSUM	1	2	349.78	192.91	3	1993.97	1412.15	8	53.586*	7	2	9	511.54	7.6	-3.214*
MGSUM	1	3	349.78	192.91	3	3251.19	2350.27	6	148.431*	5	2	7	965.94	5.1	-3.004*
MGSUM	1	4	349.78	192.91	3	6209.01	1162.89	5	36.339	4	2	6	531.85	4.4	-11.017*
MGSUM	1	5	349.78	192.91	3	3738.51	2645.52	2	188.067	1	2	3	1873.98	1.0	-1.808
MGSUM	2	3	1993.97	1412.15	8	3251.19	2350.27	6	2.770	5	7	12	1081.62	7.7	-1.162
MGSUM	2	4	1993.97	1412.15	8	6209.01	1162.89	5	1.475	7	4	11	720.93	9.9	-5.847*
MGSUM	2	5	1993.97	1412.15	8	3738.51	2645.52	2	3.510	1	7	8	1936.15	1.1	-0.901
MGSUM	3	4	3251.19	2350.27	6	6209.01	1162.89	5	4.085	5	4	9	1091.37	7.6	-2.710*
MGSUM	3	5	3251.19	2350.27	6	3738.51	2645.52	2	1.267	1	5	6	2102.38	1.6	-0.232
MGSUM	4	5	6209.01	1162.89	5	3738.51	2645.52	2	5.175	1	4	5	1941.61	1.2	1.272
OECA	1	2	110.55	11.73	3	188.97	37.76	8	10.363	7	2	9	14.97	9.0	-5.239*
OECA	1	3	110.55	11.73	3	263.86	63.24	6	29.066	5	2	7	26.69	5.6	-5.744*
OECA	1	4	110.55	11.73	3	240.89	149.77	5	163.025*	4	2	6	67.32	4.1	-1.936
OECA	1	5	110.55	11.73	3	401.18	70.92	2	36.555	1	2	3	50.60	1.0	-5.743*
OECA	2	3	188.97	37.76	8	263.86	63.24	6	2.805	5	7	12	29.07	7.6	-2.577*
OECA	2	4	188.97	37.76	8	240.89	149.77	5	15.732*	4	7	11	68.30	4.3	-0.760
OECA	2	5	188.97	37.76	8	401.18	70.92	2	3.528	1	7	8	51.89	1.1	-4.089*
OECA	3	4	263.86	63.24	6	240.89	149.77	5	5.609	4	5	9	71.78	5.2	0.320
OECA	3	5	263.86	63.24	6	401.18	70.92	2	1.258	1	5	6	56.40	1.6	-2.435
OECA	4	5	240.89	149.77	5	401.18	70.92	2	4.460	4	1	5	83.67	4.3	-1.916

*Significant difference between groups at alpha=0.05.

Table A.1. (continued).

Variable	Groups 1st	Groups 2nd	Mean (1st group)	S.D. (1st group)	n (1st group)	Mean (2nd group)	S.D. (2nd group)	n (2nd group)	F (calc.)	df(n) for F	df(d) for F	df t	Pooled s	Approx. df for t	t (calc.)
OEK	1	2	12.00	1.03	3	17.99	3.01	8	8.540	7	2	9	1.22	9.0	-4.914*
OEK	1	3	12.00	1.03	3	14.44	3.05	6	8.768	5	2	7	1.38	6.7	-1.768
OEK	1	4	12.00	1.03	3	17.08	7.65	5	55.163*	4	2	6	3.47	4.2	-1.463
OEK	1	5	12.00	1.03	3	20.16	2.95	2	8.203	1	2	3	2.17	1.2	-3.762*
OEK	2	3	17.99	3.01	8	14.44	3.05	6	1.027	5	7	12	1.64	10.8	2.167
OEK	2	4	17.99	3.01	8	17.08	7.65	5	6.459*	4	7	11	3.58	4.8	0.254
OEK	2	5	17.99	3.01	8	20.16	2.95	2	1.041	7	1	8	2.34	1.6	-0.927
OEK	3	4	14.44	3.05	6	17.08	7.65	5	6.291	4	5	9	3.64	5.1	-0.725
OEK	3	5	14.44	3.05	6	20.16	2.95	2	1.069	5	1	6	2.43	1.8	-2.355
OEK	4	5	17.08	7.65	5	20.16	2.95	2	6.725	4	1	5	4.01	4.8	-0.769
OEMG	1	2	8.23	0.83	3	13.65	1.87	8	5.076	7	2	9	0.82	8.3	-6.638*
OEMG	1	3	8.23	0.83	3	15.64	4.02	6	23.458	5	2	7	1.71	5.8	-4.334*
OEMG	1	4	8.23	0.83	3	18.59	10.76	5	168.062*	4	2	6	4.84	4.1	-2.142
OEMG	1	5	8.23	0.83	3	23.27	3.26	2	15.427	1	2	3	2.35	1.1	-6.388*
OEMG	2	3	13.65	1.87	8	15.64	4.02	6	4.621	5	7	12	1.77	6.6	-1.125
OEMG	2	4	13.65	1.87	8	18.59	10.76	5	33.109*	4	7	11	4.86	4.2	-1.017
OEMG	2	5	13.65	1.87	8	23.27	3.26	2	3.039	1	7	8	2.40	1.2	-4.011*
OEMG	3	4	15.64	4.02	6	18.59	10.76	5	7.164	4	5	9	5.08	4.9	-0.580
OEMG	3	5	15.64	4.02	6	23.27	3.26	2	1.521	5	1	6	2.83	2.2	-2.696*
OEMG	4	5	18.59	10.76	5	23.27	3.26	2	10.894	4	1	5	5.34	5.0	-0.877
OETKN	1	2	145.82	4.92	3	195.43	45.06	8	83.879*	7	2	9	16.18	7.4	-3.066*
OETKN	1	3	145.82	4.92	3	143.82	38.72	6	61.936*	5	2	7	16.06	5.3	0.125
OETKN	1	4	145.82	4.92	3	169.40	102.88	5	437.252*	4	2	6	46.10	4.0	-0.512
OETKN	1	5	145.82	4.92	3	244.64	53.06	2	116.307*	1	2	3	37.63	1.0	-2.626
OETKN	2	3	195.43	45.06	8	143.82	38.72	6	1.354	7	5	12	22.44	11.7	2.300*

*Significant difference between groups at alpha=0.05.

Table A.1. (continued).

Variable	Groups 1st	Groups 2nd	Mean <---- 1st group	S.D.	n ---->	Mean <---- 2nd group	S.D.	n ---->	F (calc.)	df(n) <- for F	df(d) ->	df t	Pooled s	Approx. df for t	t (calc.)
OETKN	2	4	195.43	45.06	8	169.40	102.88	5	5.213	4	7	11	48.69	5.0	0.535
OETKN	2	5	195.43	45.06	8	244.64	53.06	2	1.387	1	7	8	40.76	1.4	-1.207
OETKN	3	4	143.82	38.72	6	169.40	102.88	5	7.060	4	5	9	48.65	4.9	-0.526
OETKN	3	5	143.82	38.72	6	244.64	53.06	2	1.878	1	5	6	40.71	1.4	-2.476*
OETKN	4	5	169.40	102.88	5	244.64	53.06	2	3.759	4	1	5	59.37	4.0	-1.267
OETKP	1	2	9.47	0.60	3	13.60	3.01	8	25.167	7	2	9	1.12	8.2	-3.690*
OETKP	1	3	9.47	0.60	3	11.29	2.43	6	16.403	5	2	7	1.05	6.1	-1.732
OETKP	1	4	9.47	0.60	3	12.93	6.84	5	129.960*	4	2	6	3.08	4.1	-1.124
OETKP	1	5	9.47	0.60	3	17.57	4.69	2	61.100*	1	2	3	3.33	1.0	-2.429
OETKP	2	3	13.60	3.01	8	11.29	2.43	6	1.534	7	5	12	1.45	11.9	1.588
OETKP	2	4	13.60	3.01	8	12.93	6.84	5	5.164	4	7	11	3.24	5.0	0.207
OETKP	2	5	13.60	3.01	8	17.57	4.69	2	2.428	1	7	8	3.48	1.2	-1.140
OETKP	3	4	11.29	2.43	6	12.93	6.84	5	7.923*	4	5	9	3.22	4.8	-0.510
OETKP	3	5	11.29	2.43	6	17.57	4.69	2	3.725	1	5	6	3.46	1.2	-1.814
OETKP	4	5	12.93	6.84	5	17.57	4.69	2	2.127	4	1	5	4.51	2.9	-1.028
OICA	1	2	28.07	4.30	3	43.38	11.87	8	7.620	7	2	9	4.88	8.9	-3.140*
OICA	1	3	28.07	4.30	3	78.36	7.08	6	2.711	5	2	7	3.81	6.4	-13.199*
OICA	1	4	28.07	4.30	3	72.78	13.28	5	9.538	4	2	6	6.44	5.2	-6.946*
OICA	1	5	28.07	4.30	3	76.49	14.17	2	10.859	1	2	3	10.32	1.1	-4.691*
OICA	2	3	43.38	11.87	8	78.36	7.08	6	2.811	7	5	12	5.10	11.6	-6.865*
OICA	2	4	43.38	11.87	8	72.78	13.28	5	1.252	4	7	11	7.27	7.9	-4.043*
OICA	2	5	43.38	11.87	8	76.49	14.17	2	1.425	1	7	8	10.86	1.4	-3.048*
OICA	3	4	78.36	7.08	6	72.78	13.28	5	3.518	4	5	9	6.61	5.9	0.845
OICA	3	5	78.36	7.08	6	76.49	14.17	2	4.006	1	5	6	10.43	1.2	0.179
OICA	4	5	72.78	13.28	5	76.49	14.17	2	1.139	1	4	5	11.65	1.8	-0.319

*Significant difference between groups at alpha=0.05.

Table A.1. (continued).

Variable	Groups 1st	2nd	Mean	S.D.	n	Mean	S.D.	n	F	df(n)	df(d)	df	Pooled	Approx.	t
			<---- 1st group	---->		<---- 2nd group	---->		(calc.)	<- for F	->	t	s	df for t	(calc.)
OIK	1	2	4.21	1.02	3	6.69	2.14	8	4.402	7	2	9	0.96	7.9	-2.587*
OIK	1	3	4.21	1.02	3	6.23	0.90	6	1.284	2	5	7	0.69	3.6	-2.910*
OIK	1	4	4.21	1.02	3	9.59	2.04	5	4.000	4	2	6	1.09	6.0	-4.955*
OIK	1	5	4.21	1.02	3	7.46	0.60	2	2.890	2	1	3	0.73	3.0	-4.478*
OIK	2	3	6.69	2.14	8	6.23	0.90	6	5.654	7	5	12	0.84	9.9	0.547
OIK	2	4	6.69	2.14	8	9.59	2.04	5	1.100	7	4	11	1.19	9.0	-2.447*
OIK	2	5	6.69	2.14	8	7.46	0.60	2	12.721	7	1	8	0.87	7.1	-0.888
OIK	3	4	6.23	0.90	6	9.59	2.04	5	5.138	4	5	9	0.98	5.3	-3.416*
OIK	3	5	6.23	0.90	6	7.46	0.60	2	2.250	5	1	6	0.56	2.8	-2.192
OIK	4	5	9.59	2.04	5	7.46	0.60	2	11.560	4	1	5	1.01	5.0	2.117
OIMG	1	2	3.60	0.31	3	4.61	1.17	8	14.245	7	2	9	0.45	8.8	-2.241
OIMG	1	3	3.60	0.31	3	5.13	0.70	6	5.099	5	2	7	0.34	7.0	-4.537*
OIMG	1	4	3.60	0.31	3	6.20	1.04	5	11.255	4	2	6	0.50	5.1	-5.217*
OIMG	1	5	3.60	0.31	3	5.62	0.36	2	1.349	1	2	3	0.31	2.0	-6.491*
OIMG	2	3	4.61	1.17	8	5.13	0.70	6	2.794	7	5	12	0.50	11.6	-1.034
OIMG	2	4	4.61	1.17	8	6.20	1.04	5	1.266	7	4	11	0.62	9.5	-2.554*
OIMG	2	5	4.61	1.17	8	5.62	0.36	2	10.562	7	1	8	0.49	6.6	-2.079
OIMG	3	4	5.13	0.70	6	6.20	1.04	5	2.207	4	5	9	0.55	6.8	-1.960
OIMG	3	5	5.13	0.70	6	5.62	0.36	2	3.781	5	1	6	0.38	3.9	-1.280
OIMG	4	5	6.20	1.04	5	5.62	0.36	2	8.346	4	1	5	0.53	5.0	1.094
OITKN	1	2	21.15	2.81	3	24.25	3.49	8	1.543	7	2	9	2.04	4.5	-1.521
OITKN	1	3	21.15	2.81	3	26.75	2.00	6	1.974	2	5	7	1.82	3.1	-3.083*
OITKN	1	4	21.15	2.81	3	30.19	5.88	5	4.379	4	2	6	3.09	5.9	-2.926*
OITKN	1	5	21.15	2.81	3	34.14	2.49	2	1.274	2	1	3	2.39	2.5	-5.426*
OITKN	2	3	24.25	3.49	8	26.75	2.00	6	3.045	7	5	12	1.48	11.4	-1.690

*Significant difference between groups at alpha=0.05.

Table A.1. (continued).

Variable	Groups 1st	Groups 2nd	Mean (1st group)	S.D. (1st group)	n (1st group)	Mean (2nd group)	S.D. (2nd group)	n (2nd group)	F (calc.)	df(n) for F	df(d) for F	df t	Pooled s	Approx. df for t	t (calc.)
OITKN	2	4	24.25	3.49	8	30.19	5.88	5	2.839	4	7	11	2.90	5.8	-2.045
OITKN	2	5	24.25	3.49	8	34.14	2.49	2	1.965	7	1	8	2.15	2.1	-4.600*
OITKN	3	4	26.75	2.00	6	30.19	5.88	5	8.644*	4	5	9	2.75	4.8	-1.249
OITKN	3	5	26.75	2.00	6	34.14	2.49	2	1.550	1	5	6	1.94	1.5	-3.808*
OITKN	4	5	30.19	5.88	5	34.14	2.49	2	5.576	4	1	5	3.16	4.7	-1.248
OITKP	1	2	2.00	0.44	3	2.68	0.52	8	1.397	7	2	9	0.31	4.3	-2.168
OITKP	1	3	2.00	0.44	3	2.99	0.28	6	2.469	2	5	7	0.28	2.8	-3.554*
OITKP	1	4	2.00	0.44	3	4.26	1.00	5	5.165	4	2	6	0.51	5.8	-4.394*
OITKP	1	5	2.00	0.44	3	3.58	0.99	2	5.062	1	2	3	0.74	1.3	-2.122
OITKP	2	3	2.68	0.52	8	2.99	0.28	6	3.449	7	5	12	0.22	11.1	-1.432
OITKP	2	4	2.68	0.52	8	4.26	1.00	5	3.698	4	7	11	0.48	5.4	-3.268*
OITKP	2	5	2.68	0.52	8	3.58	0.99	2	3.625	1	7	8	0.72	1.1	-1.243
OITKP	3	4	2.99	0.28	6	4.26	1.00	5	12.755*	4	5	9	0.46	4.5	-2.751*
OITKP	3	5	2.99	0.28	6	3.58	0.99	2	12.501*	1	5	6	0.71	1.1	-0.832
OITKP	4	5	4.26	1.00	5	3.58	0.99	2	1.020	4	1	5	0.83	1.9	0.819
TKNSUM	1	2	2963.74	328.86	3	4549.42	1638.90	8	24.836	7	2	9	609.75	8.3	-2.601*
TKNSUM	1	3	2963.74	328.86	3	8383.86	1412.19	6	18.440	5	2	7	606.98	6.0	-8.930*
TKNSUM	1	4	2963.74	328.86	3	8533.30	1436.40	5	19.078	4	2	6	669.85	4.7	-8.315*
TKNSUM	1	5	2963.74	328.86	3	7062.99	1342.35	2	16.661	1	2	3	967.99	1.1	-4.235*
TKNSUM	2	3	4549.42	1638.90	8	8383.86	1412.19	6	1.347	7	5	12	817.39	11.7	-4.691*
TKNSUM	2	4	4549.42	1638.90	8	8533.30	1436.40	5	1.302	7	4	11	865.10	9.5	-4.605*
TKNSUM	2	5	4549.42	1638.90	8	7062.99	1342.35	2	1.491	7	1	8	1112.07	1.8	-2.260
TKNSUM	3	4	8383.86	1412.19	6	8533.30	1436.40	5	1.035	4	5	9	863.15	8.6	-0.173
TKNSUM	3	5	8383.86	1412.19	6	7062.99	1342.35	2	1.107	5	1	6	1110.55	1.8	1.189
TKNSUM	4	5	8533.30	1436.40	5	7062.99	1342.35	2	1.145	4	1	5	1146.12	2.0	1.283

*Significant difference between groups at alpha=0.05.

Table A.1. (continued).

Variable	Groups 1st	Groups 2nd	Mean (1st group)	S.D. (1st group)	n (1st group)	Mean (2nd group)	S.D. (2nd group)	n (2nd group)	F (calc.)	df(n) for F	df(d) for F	df t	Pooled s	Approx. df for t	t (calc.)
TKPSUM	1	2	1579.31	181.29	3	2370.37	880.11	8	23.568	7	2	9	328.30	8.3	-2.410*
TKPSUM	1	3	1579.31	181.29	3	4806.16	1457.11	6	64.601*	5	2	7	604.00	5.3	-5.342*
TKPSUM	1	4	1579.31	181.29	3	5584.38	1542.83	5	72.425*	4	2	6	697.87	4.2	-5.739*
TKPSUM	1	5	1579.31	181.29	3	4862.28	281.94	2	2.419	1	2	3	225.17	1.6	-14.580*
TKPSUM	2	3	2370.37	880.11	8	4806.16	1457.11	6	2.741	5	7	12	671.33	7.7	-3.628*
TKPSUM	2	4	2370.37	880.11	8	5584.38	1542.83	5	3.073	4	7	11	756.89	5.7	-4.246*
TKPSUM	2	5	2370.37	880.11	8	4862.28	281.94	2	9.745	7	1	8	369.55	6.4	-6.743*
TKPSUM	3	4	4806.16	1457.11	6	5584.38	1542.83	5	1.121	4	5	9	911.00	8.4	-0.854
TKPSUM	3	5	4806.16	1457.11	6	4862.28	281.94	2	26.710	5	1	6	627.38	5.8	-0.089
TKPSUM	4	5	5584.38	1542.83	5	4862.28	281.94	2	29.945	4	1	5	718.20	4.6	1.005
ATHICK	1	2	4.50	0.87	3	3.91	1.45	8	2.808	7	2	9	0.72	6.4	0.829
ATHICK	1	3	4.50	0.87	3	5.79	2.16	6	6.247	5	2	7	1.02	6.9	-1.272
ATHICK	1	4	4.50	0.87	3	5.50	3.02	5	12.167	4	2	6	1.44	5.0	-0.694
ATHICK	1	5	4.50	0.87	3	2.87	0.88	2	1.042	1	2	3	0.80	2.2	2.030
ATHICK	2	3	3.91	1.45	8	5.79	2.16	6	2.225	5	7	12	1.02	8.3	-1.845
ATHICK	2	4	3.91	1.45	8	5.50	3.02	5	4.333	4	7	11	1.45	5.2	-1.103
ATHICK	2	5	3.91	1.45	8	2.87	0.88	2	2.696	7	1	8	0.81	2.6	1.275
ATHICK	3	4	5.79	2.16	6	5.50	3.02	5	1.948	4	5	9	1.61	7.1	0.181
ATHICK	3	5	5.79	2.16	6	2.87	0.88	2	5.997	5	1	6	1.08	5.0	2.695*
ATHICK	4	5	5.50	3.02	5	2.87	0.88	2	11.680	4	1	5	1.49	5.0	1.764
ETHICK	1	2	2.50	2.60	3	5.53	1.93	8	1.813	2	7	9	1.65	2.9	-1.836
ETHICK	1	3	2.50	2.60	3	2.95	1.72	6	2.284	2	5	7	1.66	2.9	-0.272
ETHICK	1	4	2.50	2.60	3	3.64	2.86	5	1.212	4	2	6	1.97	4.7	-0.578
ETHICK	1	5	2.50	2.60	3	5.40	1.56	2	2.789	2	1	3	1.86	3.0	-1.559
ETHICK	2	3	5.53	1.93	8	2.95	1.72	6	1.260	7	5	12	0.98	11.5	2.631*

*Significant difference between groups at alpha=0.05.

Table A.1. (continued).

Variable	Groups 1st	2nd	Mean <---- 1st group	S.D.	n ---->	Mean <---- 2nd group	S.D.	n ---->	F (calc.)	df(n) <- for F	df(d) ->	df t	Pooled s	Approx. df for t	t (calc.)
ETHICK	2	4	5.53	1.93	8	3.64	2.86	5	2.197	4	7	11	1.45	6.3	1.301
ETHICK	2	5	5.53	1.93	8	5.40	1.56	2	1.538	7	1	8	1.29	1.9	0.097
ETHICK	3	4	2.95	1.72	6	3.64	2.86	5	2.768	4	5	9	1.46	6.3	-0.473
ETHICK	3	5	2.95	1.72	6	5.40	1.56	2	1.221	5	1	6	1.30	1.9	-1.878
ETHICK	4	5	3.64	2.86	5	5.40	1.56	2	3.379	4	1	5	1.69	3.8	-1.043
BTHICK	1	2	45.75	3.03	3	60.84	26.37	8	75.703*	7	2	9	9.49	7.5	-1.591
BTHICK	1	3	45.75	3.03	3	109.71	18.53	6	37.362	5	2	7	7.76	5.5	-8.238*
BTHICK	1	4	45.75	3.03	3	80.40	13.81	5	20.764	4	2	6	6.42	4.6	-5.397*
BTHICK	1	5	45.75	3.03	3	87.75	50.56	2	278.218*	1	2	3	35.79	1.0	-1.173
BTHICK	2	3	60.84	26.37	8	109.71	18.53	6	2.026	7	5	12	12.01	12.0	-4.070*
BTHICK	2	4	60.84	26.37	8	80.40	13.81	5	3.646	7	4	11	11.18	10.8	-1.749
BTHICK	2	5	60.84	26.37	8	87.75	50.56	2	3.675	1	7	8	36.95	1.1	-0.728
BTHICK	3	4	109.71	18.53	6	80.40	13.81	5	1.799	5	4	9	9.77	8.9	3.001*
BTHICK	3	5	109.71	18.53	6	87.75	50.56	2	7.447	1	5	6	36.54	1.1	0.601
BTHICK	4	5	80.40	13.81	5	87.75	50.56	2	13.399*	1	4	5	36.28	1.1	-0.203
BSTHICK	1	2	41.97	6.66	3	37.98	6.68	8	1.007	7	2	9	4.51	3.6	0.885
BSTHICK	1	3	41.97	6.66	3	24.07	12.30	6	3.412	5	2	7	6.32	6.8	2.831*
BSTHICK	1	4	41.97	6.66	3	4.80	6.66	5	1.000	2	4	6	4.86	4.3	7.644*
BSTHICK	1	5	41.97	6.66	3	28.80	16.97	2	6.496	1	2	3	12.60	1.2	1.045
BSTHICK	2	3	37.98	6.68	8	24.07	12.30	6	3.389	5	7	12	5.55	7.2	2.506*
BSTHICK	2	4	37.98	6.68	8	4.80	6.66	5	1.007	7	4	11	3.80	8.7	8.729*
BSTHICK	2	5	37.98	6.68	8	28.80	16.97	2	6.453	1	7	8	12.23	1.1	0.750
BSTHICK	3	4	24.07	12.30	6	4.80	6.66	5	3.413	5	4	9	5.84	7.9	3.300*
BSTHICK	3	5	24.07	12.30	6	28.80	16.97	2	1.904	1	5	6	13.01	1.4	-0.364
BSTHICK	4	5	4.80	6.66	5	28.80	16.97	2	6.497	1	4	5	12.36	1.1	-1.941

*Significant difference between groups at alpha=0.05.

Table A.1. (continued).

Variable	Groups 1st	Groups 2nd	Mean	S.D.	n	Mean	S.D.	n	F (calc.)	df(n)	df(d)	df t	Pooled s	Approx. df for t	t (calc.)
			<---- 1st group ---->			<---- 2nd group ---->				<- for F ->					
BTTHICK	1	2	0.00	0.00	3	1.79	5.06	8	.	7	2	9	1.79	7.0	-1.000
BTTHICK	1	3	0.00	0.00	3	0.00	0.00	6	.	2	5	7	0.00	.	.
BTTHICK	1	4	0.00	0.00	3	37.98	12.97	5	.	4	2	6	5.80	4.0	-6.549*
BTTHICK	1	5	0.00	0.00	3	15.50	21.92	2	.	1	2	3	15.50	1.0	-1.000
BTTHICK	2	3	1.79	5.06	8	0.00	0.00	6	.	7	5	12	1.79	7.0	1.000
BTTHICK	2	4	1.79	5.06	8	37.98	12.97	5	6.579*	4	7	11	6.07	4.8	-5.964*
BTTHICK	2	5	1.79	5.06	8	15.50	21.92	2	18.798*	1	7	8	15.60	1.0	-0.879
BTTHICK	3	4	0.00	0.00	6	37.98	12.97	5	.	4	5	9	5.80	4.0	-6.549*
BTTHICK	3	5	0.00	0.00	6	15.50	21.92	2	.	1	5	6	15.50	1.0	-1.000
BTTHICK	4	5	37.98	12.97	5	15.50	21.92	2	2.857	1	4	5	16.55	1.3	1.358
CTHICK	1	2	99.75	3.85	3	87.50	19.30	8	25.160	7	2	9	7.18	8.2	1.707
CTHICK	1	3	99.75	3.85	3	36.79	14.32	6	13.849	5	2	7	6.26	6.2	10.065*
CTHICK	1	4	99.75	3.85	3	64.15	15.29	5	15.790	4	2	6	7.19	4.8	4.950*
CTHICK	1	5	99.75	3.85	3	59.50	49.85	2	167.772*	1	2	3	35.32	1.0	1.140
CTHICK	2	3	87.50	19.30	8	36.79	14.32	6	1.817	7	5	12	8.99	12.0	5.642*
CTHICK	2	4	87.50	19.30	8	64.15	15.29	5	1.593	7	4	11	9.66	10.2	2.417*
CTHICK	2	5	87.50	19.30	8	59.50	49.85	2	6.668	1	7	8	35.90	1.1	0.780
CTHICK	3	4	36.79	14.32	6	64.15	15.29	5	1.140	4	5	9	9.00	8.4	-3.040*
CTHICK	3	5	36.79	14.32	6	59.50	49.85	2	12.115*	1	5	6	35.73	1.1	-0.636
CTHICK	4	5	64.15	15.29	5	59.50	49.85	2	10.625	1	4	5	35.91	1.1	0.129
ACLAY	1	2	5.00	0.00	3	4.87	1.75	8	.	7	2	9	0.62	7.0	0.202
ACLAY	1	3	5.00	0.00	3	11.67	1.46	6	.	5	2	7	0.60	5.0	-11.159*
ACLAY	1	4	5.00	0.00	3	8.95	1.14	5	.	4	2	6	0.51	4.0	-7.765*
ACLAY	1	5	5.00	0.00	3	9.75	2.12	2	.	1	2	3	1.50	1.0	-3.167
ACLAY	2	3	4.87	1.75	8	11.67	1.46	6	1.434	7	5	12	0.86	11.8	-7.890*

*Significant difference between groups at alpha=0.05.

Table A.1. (continued).

Variable	Groups 1st	Groups 2nd	Mean (1st group)	S.D. (1st group)	n (1st group)	Mean (2nd group)	S.D. (2nd group)	n (2nd group)	F (calc.)	df(n) for F	df(d) for F	df t	Pooled s	Approx. df for t	t (calc.)
ACLAY	2	4	4.87	1.75	8	8.95	1.14	5	2.374	7	4	11	0.80	10.9	-5.083*
ACLAY	2	5	4.87	1.75	8	9.75	2.12	2	1.465	1	7	8	1.62	1.4	-3.004*
ACLAY	3	4	11.67	1.46	6	8.95	1.14	5	1.655	5	4	9	0.78	9.0	3.462*
ACLAY	3	5	11.67	1.46	6	9.75	2.12	2	2.101	1	5	6	1.61	1.3	1.187
ACLAY	4	5	8.95	1.14	5	9.75	2.12	2	3.478	1	4	5	1.58	1.2	-0.505
ACSFR	1	2	0.17	0.19	3	0.25	0.21	8	1.240	7	2	9	0.13	4.0	-0.545
ACSFR	1	3	0.17	0.19	3	2.24	1.27	6	45.395*	5	2	7	0.53	5.4	-3.888*
ACSFR	1	4	0.17	0.19	3	0.84	0.60	5	10.154	4	2	6	0.29	5.1	-2.291
ACSFR	1	5	0.17	0.19	3	0.82	0.53	2	7.895	1	2	3	0.39	1.2	-1.664
ACSFR	2	3	0.25	0.21	8	2.24	1.27	6	36.600*	5	7	12	0.52	5.2	-3.796*
ACSFR	2	4	0.25	0.21	8	0.84	0.60	5	8.187*	4	7	11	0.28	4.6	-2.125
ACSFR	2	5	0.25	0.21	8	0.82	0.53	2	6.365	1	7	8	0.38	1.1	-1.512
ACSFR	3	4	2.24	1.27	6	0.84	0.60	5	4.470	5	4	9	0.58	7.4	2.390*
ACSFR	3	5	2.24	1.27	6	0.82	0.53	2	5.750	5	1	6	0.64	4.9	2.206
ACSFR	4	5	0.84	0.60	5	0.82	0.53	2	1.286	4	1	5	0.46	2.2	0.033
ASAND	1	2	87.67	4.04	3	75.69	26.49	8	42.963*	7	2	9	9.65	7.8	1.241
ASAND	1	3	87.67	4.04	3	60.50	4.32	6	1.145	5	2	7	2.93	4.4	9.285*
ASAND	1	4	87.67	4.04	3	60.35	14.48	5	12.845	4	2	6	6.89	4.9	3.968*
ASAND	1	5	87.67	4.04	3	64.37	11.84	2	8.589	1	2	3	8.69	1.2	2.679
ASAND	2	3	75.69	26.49	8	60.50	4.32	6	37.526*	7	5	12	9.53	7.5	1.594
ASAND	2	4	75.69	26.49	8	60.35	14.48	5	3.345	7	4	11	11.39	10.9	1.347
ASAND	2	5	75.69	26.49	8	64.37	11.84	2	5.002	7	1	8	12.56	4.1	0.900
ASAND	3	4	60.50	4.32	6	60.35	14.48	5	11.219*	4	5	9	6.71	4.6	0.022
ASAND	3	5	60.50	4.32	6	64.37	11.84	2	7.502	1	5	6	8.56	1.1	-0.453
ASAND	4	5	60.35	14.48	5	64.37	11.84	2	1.496	4	1	5	10.59	2.3	-0.380

*Significant difference between groups at alpha=0.05.

Table A.1. (continued).

Variable	Groups 1st	Groups 2nd	Mean (1st group)	S.D. (1st group)	n (1st group)	Mean (2nd group)	S.D. (2nd group)	n (2nd group)	F (calc.)	df(n) for F	df(d) for F	df t	Pooled s	Approx. df for t	t (calc.)
ASILT	1	2	7.33	4.04	3	6.94	5.10	8	1.594	7	2	9	2.95	4.6	0.134
ASILT	1	3	7.33	4.04	3	27.83	2.87	6	1.982	2	5	7	2.61	3.1	-7.851*
ASILT	1	4	7.33	4.04	3	20.70	2.58	5	2.449	2	4	6	2.60	3.0	-5.134*
ASILT	1	5	7.33	4.04	3	25.87	9.72	2	5.788	1	2	3	7.26	1.2	-2.554
ASILT	2	3	6.94	5.10	8	27.83	2.87	6	3.158	7	5	12	2.15	11.3	-9.714*
ASILT	2	4	6.94	5.10	8	20.70	2.58	5	3.903	7	4	11	2.14	10.8	-6.425*
ASILT	2	5	6.94	5.10	8	25.87	9.72	2	3.631	1	7	8	7.11	1.1	-2.664*
ASILT	3	4	27.83	2.87	6	20.70	2.58	5	1.236	5	4	9	1.65	8.9	4.335*
ASILT	3	5	27.83	2.87	6	25.87	9.72	2	11.470*	1	5	6	6.97	1.1	0.281
ASILT	4	5	20.70	2.58	5	25.87	9.72	2	14.175*	1	4	5	6.97	1.1	-0.742
BCLAV	1	2	5.00	0.00	3	6.75	3.02	8	.	7	2	9	1.07	7.0	-1.638
BCLAV	1	3	5.00	0.00	3	15.92	5.98	6	.	5	2	7	2.44	5.0	-4.469*
BCLAV	1	4	5.00	0.00	3	20.62	1.40	5	.	4	2	6	0.63	4.0	-24.938*
BCLAV	1	5	5.00	0.00	3	12.43	5.98	2	.	1	2	3	4.22	1.0	-1.757
BCLAV	2	3	6.75	3.02	8	15.92	5.98	6	3.938	5	7	12	2.67	6.9	-3.440*
BCLAV	2	4	6.75	3.02	8	20.62	1.40	5	4.633	7	4	11	1.24	10.5	-11.222*
BCLAV	2	5	6.75	3.02	8	12.43	5.98	2	3.926	1	7	8	4.36	1.1	-1.303
BCLAV	3	4	15.92	5.98	6	20.62	1.40	5	18.243*	5	4	9	2.52	5.6	-1.867
BCLAV	3	5	15.92	5.98	6	12.43	5.98	2	1.003	5	1	6	4.88	1.7	0.715
BCLAV	4	5	20.62	1.40	5	12.43	5.98	2	18.189*	1	4	5	4.27	1.0	1.920
BCSFR	1	2	2.17	0.66	3	5.42	3.57	8	29.377*	7	2	9	1.32	8.1	-2.467*
BCSFR	1	3	2.17	0.66	3	8.79	8.51	6	167.003*	5	2	7	3.50	5.1	-1.895
BCSFR	1	4	2.17	0.66	3	2.70	2.12	5	10.404	4	2	6	1.02	5.1	-0.521
BCSFR	1	5	2.17	0.66	3	1.95	0.42	2	2.411	2	1	3	0.48	3.0	0.447
BCSFR	2	3	5.42	3.57	8	8.79	8.51	6	5.685*	5	7	12	3.70	6.3	-0.912

*Significant difference between groups at alpha=0.05.

Table A.1. (continued).

Variable	Groups 1st	Groups 2nd	Mean <---- 1st group ---->	S.D.	n	Mean <---- 2nd group ---->	S.D.	n	F (calc.)	df(n) <- for F ->	df(d)	df t	Pooled s	Approx. df for t	t (calc.)
BCSFR	2	4	5.42	3.57	8	2.70	2.12	5	2.824	7	4	11	1.58	11.0	1.721
BCSFR	2	5	5.42	3.57	8	1.95	0.42	2	70.825	7	1	8	1.30	7.6	2.673*
BCSFR	3	4	8.79	8.51	6	2.70	2.12	5	16.051*	5	4	9	3.60	5.7	1.691
BCSFR	3	5	8.79	8.51	6	1.95	0.42	2	402.624	5	1	6	3.49	5.1	1.961
BCSFR	4	5	2.70	2.12	5	1.95	0.42	2	25.083	4	1	5	1.00	4.7	0.753
BSAND	1	2	89.67	0.56	3	83.46	7.38	8	171.723*	7	2	9	2.63	7.2	2.365*
BSAND	1	3	89.67	0.56	3	61.32	12.53	6	495.757*	5	2	7	5.13	5.0	5.531*
BSAND	1	4	89.67	0.56	3	51.72	9.53	5	286.914*	4	2	6	4.28	4.0	8.875*
BSAND	1	5	89.67	0.56	3	67.29	18.30	2	1056.43*	1	2	3	12.94	1.0	1.730
BSAND	2	3	83.46	7.38	8	61.32	12.53	6	2.887	5	7	12	5.74	7.6	3.855*
BSAND	2	4	83.46	7.38	8	51.72	9.53	5	1.671	4	7	11	5.00	7.0	6.350*
BSAND	2	5	83.46	7.38	8	67.29	18.30	2	6.152	1	7	8	13.20	1.1	1.225
BSAND	3	4	61.32	12.53	6	51.72	9.53	5	1.728	5	4	9	6.66	9.0	1.441
BSAND	3	5	61.32	12.53	6	67.29	18.30	2	2.131	1	5	6	13.91	1.3	-0.429
BSAND	4	5	51.72	9.53	5	67.29	18.30	2	3.682	1	4	5	13.62	1.2	-1.143
BSILT	1	2	5.33	0.56	3	9.80	4.51	8	64.092*	7	2	9	1.63	7.5	-2.752*
BSILT	1	3	5.33	0.56	3	22.78	7.49	6	177.100*	5	2	7	3.08	5.1	-5.677*
BSILT	1	4	5.33	0.56	3	27.66	9.35	5	276.116*	4	2	6	4.20	4.0	-5.323*
BSILT	1	5	5.33	0.56	3	20.29	12.32	2	479.102*	1	2	3	8.72	1.0	-1.716
BSILT	2	3	9.80	4.51	8	22.78	7.49	6	2.763	5	7	12	3.45	7.7	-3.765*
BSILT	2	4	9.80	4.51	8	27.66	9.35	5	4.308	4	7	11	4.48	5.2	-3.990*
BSILT	2	5	9.80	4.51	8	20.29	12.32	2	7.475	1	7	8	8.86	1.1	-1.184
BSILT	3	4	22.78	7.49	6	27.66	9.35	5	1.559	4	5	9	5.18	7.7	-0.941
BSILT	3	5	22.78	7.49	6	20.29	12.32	2	2.705	1	5	6	9.23	1.3	0.270
BSILT	4	5	27.66	9.35	5	20.29	12.32	2	1.735	1	4	5	9.66	1.5	0.763

*Significant difference between groups at alpha=0.05.

Table A.1. (continued).

Variable	Groups 1st	Groups 2nd	Mean (1st group)	S.D. (1st group)	n (1st group)	Mean (2nd group)	S.D. (2nd group)	n (2nd group)	F (calc.)	df(n) for F	df(d) for F	df t	Pooled s	Approx. df for t	t (calc.)
CCLAY	1	2	5.00	0.00	3	11.47	8.28	8	.	7	2	9	2.93	7.0	-2.210
CCLAY	1	3	5.00	0.00	3	14.85	12.23	6	.	5	2	7	4.99	5.0	-1.973
CCLAY	1	4	5.00	0.00	3	35.49	13.89	5	.	4	2	6	6.21	4.0	-4.908*
CCLAY	1	5	5.00	0.00	3	27.14	12.99	2	.	1	2	3	9.19	1.0	-2.410
CCLAY	2	3	11.47	8.28	8	14.85	12.23	6	2.181	5	7	12	5.79	8.3	-0.584
CCLAY	2	4	11.47	8.28	8	35.49	13.89	5	2.812	4	7	11	6.87	5.8	-3.497*
CCLAY	2	5	11.47	8.28	8	27.14	12.99	2	2.461	1	7	8	9.64	1.2	-1.625
CCLAY	3	4	14.85	12.23	6	35.49	13.89	5	1.289	4	5	9	7.97	8.1	-2.589*
CCLAY	3	5	14.85	12.23	6	27.14	12.99	2	1.128	1	5	6	10.46	1.6	-1.175
CCLAY	4	5	35.49	13.89	5	27.14	12.99	2	1.143	4	1	5	11.09	2.0	0.752
CSAND	1	2	90.00	0.00	3	78.08	13.89	8	.	7	2	9	4.91	7.0	2.426*
CSAND	1	3	90.00	0.00	3	58.34	20.58	6	.	5	2	7	8.40	5.0	3.768*
CSAND	1	4	90.00	0.00	3	42.64	21.67	5	.	4	2	6	9.69	4.0	4.888*
CSAND	1	5	90.00	0.00	3	56.58	23.45	2	.	1	2	3	16.58	1.0	2.015
CSAND	2	3	78.08	13.89	8	58.34	20.58	6	2.194	5	7	12	9.73	8.3	2.029
CSAND	2	4	78.08	13.89	8	42.64	21.67	5	2.432	4	7	11	10.86	6.1	3.263*
CSAND	2	5	78.08	13.89	8	56.58	23.45	2	2.850	1	7	8	17.30	1.2	1.243
CSAND	3	4	58.34	20.58	6	42.64	21.67	5	1.108	4	5	9	12.82	8.5	1.224
CSAND	3	5	58.34	20.58	6	56.58	23.45	2	1.299	1	5	6	18.59	1.6	0.094
CSAND	4	5	42.64	21.67	5	56.58	23.45	2	1.172	1	4	5	19.21	1.7	-0.726
CSILT	1	2	5.00	0.00	3	7.32	3.93	8	.	7	2	9	1.39	7.0	-1.670
CSILT	1	3	5.00	0.00	3	10.14	6.32	6	.	5	2	7	2.58	5.0	-1.992
CSILT	1	4	5.00	0.00	3	21.87	8.10	5	.	4	2	6	3.62	4.0	-4.659*
CSILT	1	5	5.00	0.00	3	16.27	10.46	2	.	1	2	3	7.40	1.0	-1.524
CSILT	2	3	7.32	3.93	8	10.14	6.32	6	2.591	5	7	12	2.93	7.8	-0.963

*Significant difference between groups at alpha=0.05.

Table A.1. (continued).

Variable	Groups 1st	Groups 2nd	Mean	S.D.	n	Mean	S.D.	n	F (calc.)	df(n)	df(d)	df t	Pooled s	Approx. df for t	t (calc.)
			<---- 1st group ---->			<---- 2nd group ---->				<- for F ->					
CSILT	2	4	7.32	3.93	8	21.87	8.10	5	4.249	4	7	11	3.88	5.2	-3.752*
CSILT	2	5	7.32	3.93	8	16.27	10.46	2	7.088	1	7	8	7.52	1.1	-1.190
CSILT	3	4	10.14	6.32	6	21.87	8.10	5	1.639	4	5	9	4.45	7.5	-2.637*
CSILT	3	5	10.14	6.32	6	16.27	10.46	2	2.735	1	5	6	7.83	1.3	-0.783
CSILT	4	5	21.87	8.10	5	16.27	10.46	2	1.668	1	4	5	8.23	1.5	0.680
OEWT	1	2	11003.56	764.57	3	12902.92	2249.91	8	8.659	7	2	9	909.74	9.0	-2.088
OEWT	1	3	11003.56	764.57	3	11002.00	1485.69	6	3.776	5	2	7	750.16	6.9	0.002
OEWT	1	4	11003.56	764.57	3	10455.27	4131.21	5	29.195	4	2	6	1899.54	4.4	0.289
OEWT	1	5	11003.56	764.57	3	13705.83	1718.98	2	5.055	1	2	3	1293.18	1.3	-2.090
OEWT	2	3	12902.92	2249.91	8	11002.00	1485.69	6	2.293	7	5	12	1000.32	11.9	1.900
OEWT	2	4	12902.92	2249.91	8	10455.27	4131.21	5	3.372	4	7	11	2011.50	5.5	1.217
OEWT	2	5	12902.92	2249.91	8	13705.83	1718.98	2	1.713	7	1	8	1452.66	2.0	-0.553
OEWT	3	4	11002.00	1485.69	6	10455.27	4131.21	5	7.732*	4	5	9	1944.55	4.9	0.281
OEWT	3	5	11002.00	1485.69	6	13705.83	1718.98	2	1.339	1	5	6	1358.43	1.5	-1.990
OEWT	4	5	10455.27	4131.21	5	13705.83	1718.98	2	5.776	4	1	5	2211.52	4.7	-1.470
OIWT	1	2	2547.89	327.35	3	2969.54	397.80	8	1.477	7	2	9	235.58	4.4	-1.790
OIWT	1	3	2547.89	327.35	3	2766.22	252.99	6	1.674	2	5	7	215.38	3.3	-1.014
OIWT	1	4	2547.89	327.35	3	3137.87	397.18	5	1.472	4	2	6	259.37	5.1	-2.275
OIWT	1	5	2547.89	327.35	3	2794.17	359.45	2	1.206	1	2	3	316.73	2.1	-0.778
OIWT	2	3	2969.54	397.80	8	2766.22	252.99	6	2.472	7	5	12	174.49	11.8	1.165
OIWT	2	4	2969.54	397.80	8	3137.87	397.18	5	1.003	7	4	11	226.56	8.6	-0.743
OIWT	2	5	2969.54	397.80	8	2794.17	359.45	2	1.225	7	1	8	290.48	1.7	0.604
OIWT	3	4	2766.22	252.99	6	3137.87	397.18	5	2.465	4	5	9	205.47	6.6	-1.809
OIWT	3	5	2766.22	252.99	6	2794.17	359.45	2	2.019	1	5	6	274.35	1.4	-0.102
OIWT	4	5	3137.87	397.18	5	2794.17	359.45	2	1.221	4	1	5	310.08	2.1	1.108

*Significant difference between groups at alpha=0.05.

Table A.1. (continued).

Variable	Groups 1st	2nd	Mean <---- 1st group	S.D.	n ---->	Mean <---- 2nd group	S.D.	n ---->	F (calc.)	df(n) <- for F	df(d) ->	df t	Pooled s	Approx. df for t	t (calc.)
DEPLS	1	2	406.67	161.66	3	140.37	155.17	8	1.085	2	7	9	108.26	3.5	2.460
DEPLS	1	3	406.67	161.66	3	338.33	250.45	6	2.400	5	2	7	138.44	6.1	0.494
DEPLS	1	4	406.67	161.66	3	191.20	231.04	5	2.043	4	2	6	139.24	5.7	1.547
DEPLS	1	5	406.67	161.66	3	60.50	64.35	2	6.312	2	1	3	103.83	2.8	3.334*
DEPLS	2	3	140.37	155.17	8	338.33	250.45	6	2.605	5	7	12	116.03	7.8	-1.706
DEPLS	2	4	140.37	155.17	8	191.20	231.04	5	2.217	4	7	11	116.98	6.3	-0.434
DEPLS	2	5	140.37	155.17	8	60.50	64.35	2	5.815	7	1	8	71.27	4.6	1.121
DEPLS	3	4	338.33	250.45	6	191.20	231.04	5	1.175	5	4	9	145.36	8.9	1.012
DEPLS	3	5	338.33	250.45	6	60.50	64.35	2	15.150	5	1	6	111.91	6.0	2.483*
DEPLS	4	5	191.20	231.04	5	60.50	64.35	2	12.892	4	1	5	112.90	5.0	1.158
DEPSCL	1	2	500.00	0.00	3	286.12	186.12	8	.	7	2	9	65.80	7.0	3.250*
DEPSCL	1	3	500.00	0.00	3	80.67	35.01	6	.	5	2	7	14.29	5.0	29.337*
DEPSCL	1	4	500.00	0.00	3	56.80	8.04	5	.	4	2	6	3.60	4.0	123.206*
DEPSCL	1	5	500.00	0.00	3	112.50	102.53	2	.	1	2	3	72.50	1.0	5.345
DEPSCL	2	3	286.12	186.12	8	80.67	35.01	6	28.257*	7	5	12	67.34	7.7	3.051*
DEPSCL	2	4	286.12	186.12	8	56.80	8.04	5	535.392*	7	4	11	65.90	7.0	3.480*
DEPSCL	2	5	286.12	186.12	8	112.50	102.53	2	3.295	7	1	8	97.91	3.0	1.773
DEPSCL	3	4	80.67	35.01	6	56.80	8.04	5	18.947*	5	4	9	14.74	5.6	1.619
DEPSCL	3	5	80.67	35.01	6	112.50	102.53	2	8.576	1	5	6	73.90	1.1	-0.431
DEPSCL	4	5	56.80	8.04	5	112.50	102.53	2	162.481*	1	4	5	72.59	1.0	-0.767
DEPSL	1	2	500.00	0.00	3	218.25	150.42	8	.	7	2	9	53.18	7.0	5.298*
DEPSL	1	3	500.00	0.00	3	29.17	20.78	6	.	5	2	7	8.48	5.0	55.503*
DEPSL	1	4	500.00	0.00	3	22.20	6.26	5	.	4	2	6	2.80	4.0	170.643*
DEPSL	1	5	500.00	0.00	3	126.00	22.63	2	.	1	2	3	16.00	1.0	23.375*
DEPSL	2	3	218.25	150.42	8	29.17	20.78	6	52.406*	7	5	12	53.85	7.4	3.511*

*Significant difference between groups at alpha=0.05.

Table A.1. (continued).

Variable	Groups 1st	Groups 2nd	Mean <---- 1st group	S.D.	n ---->	Mean <---- 2nd group	S.D.	n ---->	F (calc.)	df(n) <- for F	df(d) ->	df t	Pooled s	Approx. df for t	t (calc.)
DEPSL	2	4	218.25	150.42	8	22.20	6.26	5	577.221*	7	4	11	53.26	7.0	3.681*
DEPSL	2	5	218.25	150.42	8	126.00	22.63	2	44.193	7	1	8	55.54	7.9	1.661
DEPSL	3	4	29.17	20.78	6	22.20	6.26	5	11.014*	5	4	9	8.93	6.1	0.780
DEPSL	3	5	29.17	20.78	6	126.00	22.63	2	1.186	1	5	6	18.11	1.6	-5.347*
DEPSL	4	5	22.20	6.26	5	126.00	22.63	2	13.061*	1	4	5	16.24	1.1	-6.390
DEPTEX	1	2	500.00	0.00	3	146.25	77.26	8	.	7	2	9	27.31	7.0	12.951*
DEPTEX	1	3	500.00	0.00	3	58.00	32.83	6	.	5	2	7	13.40	5.0	32.981*
DEPTEX	1	4	500.00	0.00	3	43.80	4.55	5	.	4	2	6	2.03	4.0	224.210*
DEPTEX	1	5	500.00	0.00	3	100.00	111.72	2	.	1	2	3	79.00	1.0	5.063
DEPTEX	2	3	146.25	77.26	8	58.00	32.83	6	5.539	7	5	12	30.43	10.0	2.901*
DEPTEX	2	4	146.25	77.26	8	43.80	4.55	5	288.347*	7	4	11	27.39	7.1	3.740*
DEPTEX	2	5	146.25	77.26	8	100.00	111.72	2	2.091	1	7	8	83.59	1.3	0.553
DEPTEX	3	4	58.00	32.83	6	43.80	4.55	5	52.058*	5	4	9	13.56	5.2	1.048
DEPTEX	3	5	58.00	32.83	6	100.00	111.72	2	11.583*	1	5	6	80.13	1.1	-0.524
DEPTEX	4	5	43.80	4.55	5	100.00	111.72	2	602.995*	1	4	5	79.03	1.0	-0.711
TEXC	1	2	5.00	0.00	3	16.25	9.75	8	.	7	2	9	3.45	7.0	-3.263*
TEXC	1	3	5.00	0.00	3	26.17	8.40	6	.	5	2	7	3.43	5.0	-6.172*
TEXC	1	4	5.00	0.00	3	30.20	3.19	5	.	4	2	6	1.43	4.0	-17.644*
TEXC	1	5	5.00	0.00	3	31.50	4.95	2	.	1	2	3	3.50	1.0	-7.571*
TEXC	2	3	16.25	9.75	8	26.17	8.40	6	1.347	7	5	12	4.86	11.7	-2.039
TEXC	2	4	16.25	9.75	8	30.20	3.19	5	9.321*	7	4	11	3.73	9.1	-3.738*
TEXC	2	5	16.25	9.75	8	31.50	4.95	2	3.880	7	1	8	4.91	3.4	-3.104*
TEXC	3	4	26.17	8.40	6	30.20	3.19	5	6.918	5	4	9	3.71	6.6	-1.086
TEXC	3	5	26.17	8.40	6	31.50	4.95	2	2.880	5	1	6	4.90	3.2	-1.088
TEXC	4	5	30.20	3.19	5	31.50	4.95	2	2.402	1	4	5	3.78	1.4	-0.344

*Significant difference between groups at alpha=0.05.

Table A.1. (continued).

Variable	Groups 1st	2nd	Mean	S.D.	n	Mean	S.D.	n	F (calc.)	df(n)	df(d)	df t	Pooled s	Approx. df for t	t (calc.)
			<---- 1st group ---->			<---- 2nd group ---->				<- for F ->					
TEXS	1	2	90.00	0.00	3	50.88	22.50	8	.	7	2	9	7.95	7.0	4.919*
TEXS	1	3	90.00	0.00	3	50.50	20.10	6	.	5	2	7	8.20	5.0	4.814*
TEXS	1	4	90.00	0.00	3	42.80	21.08	5	.	4	2	6	9.43	4.0	5.008*
TEXS	1	5	90.00	0.00	3	33.50	33.23	2	.	1	2	3	23.50	1.0	2.404
TEXS	2	3	50.88	22.50	8	50.50	20.10	6	1.253	7	5	12	11.43	11.5	0.033
TEXS	2	4	50.88	22.50	8	42.80	21.08	5	1.139	7	4	11	12.33	9.1	0.655
TEXS	2	5	50.88	22.50	8	33.50	33.23	2	2.182	1	7	8	24.81	1.2	0.700
TEXS	3	4	50.50	20.10	6	42.80	21.08	5	1.100	4	5	9	12.50	8.5	0.616
TEXS	3	5	50.50	20.10	6	33.50	33.23	2	2.735	1	5	6	24.89	1.3	0.683
TEXS	4	5	42.80	21.08	5	33.50	33.23	2	2.486	1	4	5	25.32	1.3	0.367
TEXSI	1	2	5.00	0.00	3	32.88	17.37	8	.	7	2	9	6.14	7.0	-4.538*
TEXSI	1	3	5.00	0.00	3	23.33	16.02	6	.	5	2	7	6.54	5.0	-2.803*
TEXSI	1	4	5.00	0.00	3	27.00	17.89	5	.	4	2	6	8.00	4.0	-2.750
TEXSI	1	5	5.00	0.00	3	35.00	28.28	2	.	1	2	3	20.00	1.0	-1.500
TEXSI	2	3	32.88	17.37	8	23.33	16.02	6	1.176	7	5	12	8.97	11.4	1.063
TEXSI	2	4	32.88	17.37	8	27.00	17.89	5	1.060	4	7	11	10.09	8.4	0.582
TEXSI	2	5	32.88	17.37	8	35.00	28.28	2	2.650	1	7	8	20.92	1.2	-0.102
TEXSI	3	4	23.33	16.02	6	27.00	17.89	5	1.247	4	5	9	10.33	8.2	-0.355
TEXSI	3	5	23.33	16.02	6	35.00	28.28	2	3.117	1	5	6	21.04	1.2	-0.554
TEXSI	4	5	27.00	17.89	5	35.00	28.28	2	2.500	1	4	5	21.54	1.3	-0.371
BIC	1	2	0.67	0.38	3	2.91	1.24	8	10.523	7	2	9	0.49	9.0	-4.567*
BIC	1	3	0.67	0.38	3	4.79	0.33	6	1.321	2	5	7	0.26	3.6	-15.935*
BIC	1	4	0.67	0.38	3	4.90	0.22	5	2.917	2	4	6	0.24	2.8	-17.486*
BIC	1	5	0.67	0.38	3	4.75	0.35	2	1.167	2	1	3	0.33	2.4	-12.250*
BIC	2	3	2.91	1.24	8	4.79	0.33	6	13.898*	7	5	12	0.46	8.3	-4.112*

*Significant difference between groups at alpha=0.05.

Table A.1. (continued).

Variable	Groups		Mean	S.D.	n	Mean	S.D.	n	F	df(n)	df(d)	df	Pooled	Approx.	t
	1st	2nd	<---- 1st group ---->			<---- 2nd group ---->			(calc.)	<- for F ->		t	s	df for t	(calc.)
BIC	2	4	2.91	1.24	8	4.90	0.22	5	30.692*	7	4	11	0.45	7.7	-4.438*
BIC	2	5	2.91	1.24	8	4.75	0.35	2	12.277*	7	1	8	0.50	7.1	-3.656*
BIC	3	4	4.79	0.33	6	4.90	0.22	5	2.208	5	4	9	0.17	8.7	-0.643
BIC	3	5	4.79	0.33	6	4.75	0.35	2	1.132	1	5	6	0.28	1.6	0.146
BIC	4	5	4.90	0.22	5	4.75	0.35	2	2.500	1	4	5	0.27	1.3	0.557
CLT150	1	2	5.00	0.00	3	11.38	10.41	8	.	7	2	9	3.68	7.0	-1.733
CLT150	1	3	5.00	0.00	3	26.17	8.40	6	.	5	2	7	3.43	5.0	-6.172*
CLT150	1	4	5.00	0.00	3	27.40	6.07	5	.	4	2	6	2.71	4.0	-8.257*
CLT150	1	5	5.00	0.00	3	20.00	21.21	2	.	1	2	3	15.00	1.0	-1.000
CLT150	2	3	11.38	10.41	8	26.17	8.40	6	1.534	7	5	12	5.03	11.9	-2.941
CLT150	2	4	11.38	10.41	8	27.40	6.07	5	2.942	7	4	11	4.57	11.0	-3.506
CLT150	2	5	11.38	10.41	8	20.00	21.21	2	4.156	1	7	8	15.44	1.1	-0.558
CLT150	3	4	26.17	8.40	6	27.40	6.07	5	1.918	5	4	9	4.37	8.9	-0.282
CLT150	3	5	26.17	8.40	6	20.00	21.21	2	6.377	1	5	6	15.39	1.1	0.401
CLT150	4	5	27.40	6.07	5	20.00	21.21	2	12.228*	1	4	5	15.24	1.1	0.485
SLT150	1	2	90.00	0.00	3	77.75	15.36	8	.	7	2	9	5.43	7.0	2.256
SLT150	1	3	90.00	0.00	3	50.50	20.10	6	.	5	2	7	8.20	5.0	4.814*
SLT150	1	4	90.00	0.00	3	44.60	20.40	5	.	4	2	6	9.12	4.0	4.976*
SLT150	1	5	90.00	0.00	3	46.50	51.62	2	.	1	2	3	36.50	1.0	1.192
SLT150	2	3	77.75	15.36	8	50.50	20.10	6	1.712	5	7	12	9.84	9.1	2.770*
SLT150	2	4	77.75	15.36	8	44.60	20.40	5	1.765	4	7	11	10.62	6.8	3.122*
SLT150	2	5	77.75	15.36	8	46.50	51.62	2	11.294*	1	7	8	36.90	1.0	0.847
SLT150	3	4	50.50	20.10	6	44.60	20.40	5	1.031	4	5	9	12.27	8.6	0.481
SLT150	3	5	50.50	20.10	6	46.50	51.62	2	6.597	1	5	6	37.41	1.1	0.107
SLT150	4	5	44.60	20.40	5	46.50	51.62	2	6.400	1	4	5	37.62	1.1	-0.051

*Significant difference between groups at alpha=0.05.

Table A.1. (continued).

Variable	Groups 1st	Groups 2nd	Mean	S.D.	n	Mean	S.D.	n	F (calc.)	df(n)	df(d)	df t	Pooled s	Approx. df for t	t (calc.)
			<---- 1st group ---->			<---- 2nd group ---->				<- for F ->					
SILT150	1	2	5.00	0.00	3	10.88	7.30	8	.	7	2	9	2.58	7.0	-2.277
SILT150	1	3	5.00	0.00	3	23.33	16.02	6	.	5	2	7	6.54	5.0	-2.803*
SILT150	1	4	5.00	0.00	3	28.00	18.57	5	.	4	2	6	8.31	4.0	-2.769
SILT150	1	5	5.00	0.00	3	33.50	30.41	2	.	1	2	3	21.50	1.0	-1.326
SILT150	2	3	10.88	7.30	8	23.33	16.02	6	4.818	5	7	12	7.03	6.6	-1.772
SILT150	2	4	10.88	7.30	8	28.00	18.57	5	6.477*	4	7	11	8.70	4.8	-1.969
SILT150	2	5	10.88	7.30	8	33.50	30.41	2	17.356*	1	7	8	21.65	1.0	-1.045
SILT150	3	4	23.33	16.02	6	28.00	18.57	5	1.344	4	5	9	10.57	8.0	-0.441
SILT150	3	5	23.33	16.02	6	33.50	30.41	2	3.602	1	5	6	22.47	1.2	-0.452
SILT150	4	5	28.00	18.57	5	33.50	30.41	2	2.680	1	4	5	23.05	1.3	-0.239
CGT150	1	2	5.00	0.00	3	21.00	10.78	8	.	7	2	9	3.81	7.0	-4.197*
CGT150	1	3	5.00	0.00	3	29.17	2.86	6	.	5	2	7	1.17	5.0	-20.714*
CGT150	1	4	5.00	0.00	3	31.60	3.51	5	.	4	2	6	1.57	4.0	-16.960*
CGT150	1	5	5.00	0.00	3	25.00	14.14	2	.	1	2	3	10.00	1.0	-2.000
CGT150	2	3	21.00	10.78	8	29.17	2.86	6	14.239*	7	5	12	3.99	8.3	-2.048
CGT150	2	4	21.00	10.78	8	31.60	3.51	5	9.454*	7	4	11	4.12	9.1	-2.571*
CGT150	2	5	21.00	10.78	8	25.00	14.14	2	1.720	1	7	8	10.70	1.3	-0.374
CGT150	3	4	29.17	2.86	6	31.60	3.51	5	1.506	4	5	9	1.95	7.8	-1.245
CGT150	3	5	29.17	2.86	6	25.00	14.14	2	24.490*	1	5	6	10.07	1.0	0.414
CGT150	4	5	31.60	3.51	5	25.00	14.14	2	16.260*	1	4	5	10.12	1.0	0.652
SGT150	1	2	87.67	4.04	3	46.50	22.25	8	30.297	7	2	9	8.20	8.1	5.018*
SGT150	1	3	87.67	4.04	3	49.17	19.19	6	22.541	5	2	7	8.17	5.8	4.710*
SGT150	1	4	87.67	4.04	3	33.40	23.50	5	33.814	4	2	6	10.77	4.4	5.041*
SGT150	1	5	87.67	4.04	3	15.00	7.07	2	3.061	1	2	3	5.52	1.4	13.170*
SGT150	2	3	46.50	22.25	8	49.17	19.19	6	1.344	7	5	12	11.10	11.7	-0.240

*Significant difference between groups at alpha=0.05.

Table A.1. (continued).

Variable	Groups 1st	Groups 2nd	Mean <---- 1st group	S.D. 1st group	n 1st group ---->	Mean <---- 2nd group	S.D. 2nd group	n 2nd group ---->	F (calc.)	df(n) <- for F	df(d) for F ->	df t	Pooled s	Approx. df for t	t (calc.)
SGT150	2	4	46.50	22.25	8	33.40	23.50	5	1.116	4	7	11	13.13	8.3	0.998
SGT150	2	5	46.50	22.25	8	15.00	7.07	2	9.897	7	1	8	9.32	6.4	3.380*
SGT150	3	4	49.17	19.19	6	33.40	23.50	5	1.500	4	5	9	13.11	7.8	1.203
SGT150	3	5	49.17	19.19	6	15.00	7.07	2	7.363	5	1	6	9.29	5.4	3.677*
SGT150	4	5	33.40	23.50	5	15.00	7.07	2	11.046	4	1	5	11.64	5.0	1.581
SIGT150	1	2	7.33	4.04	3	32.50	18.32	8	20.554	7	2	9	6.89	8.4	-3.655*
SIGT150	1	3	7.33	4.04	3	21.67	16.33	6	16.327	5	2	7	7.06	6.1	-2.029
SIGT150	1	4	7.33	4.04	3	35.00	20.00	5	24.490	4	2	6	9.24	4.5	-2.993*
SIGT150	1	5	7.33	4.04	3	60.00	7.07	2	3.061	1	2	3	5.52	1.4	-9.545*
SIGT150	2	3	32.50	18.32	8	21.67	16.33	6	1.259	7	5	12	9.30	11.5	1.165
SIGT150	2	4	32.50	18.32	8	35.00	20.00	5	1.191	4	7	11	11.04	8.0	-0.226
SIGT150	2	5	32.50	18.32	8	60.00	7.07	2	6.714	7	1	8	8.18	5.1	-3.361*
SIGT150	3	4	21.67	16.33	6	35.00	20.00	5	1.500	4	5	9	11.16	7.8	-1.195
SIGT150	3	5	21.67	16.33	6	60.00	7.07	2	5.333	5	1	6	8.33	4.7	-4.600*
SIGT150	4	5	35.00	20.00	5	60.00	7.07	2	8.000	4	1	5	10.25	5.0	-2.440
CLAY450	1	2	5.00	0.00	3	21.00	10.78	8	.	7	2	9	3.81	7.0	-4.197*
CLAY450	1	3	5.00	0.00	3	29.17	2.86	6	.	5	2	7	1.17	5.0	-20.714*
CLAY450	1	4	5.00	0.00	3	31.60	3.51	5	.	4	2	6	1.57	4.0	-16.960*
CLAY450	1	5	5.00	0.00	3	31.50	4.95	2	.	1	2	3	3.50	1.0	-7.571
CLAY450	2	3	21.00	10.78	8	29.17	2.86	6	14.239*	7	5	12	3.99	8.3	-2.048
CLAY450	2	4	21.00	10.78	8	31.60	3.51	5	9.454*	7	4	11	4.12	9.1	-2.571*
CLAY450	2	5	21.00	10.78	8	31.50	4.95	2	4.746	7	1	8	5.18	4.0	-2.029
CLAY450	3	4	29.17	2.86	6	31.60	3.51	5	1.506	4	5	9	1.95	7.8	-1.245
CLAY450	3	5	29.17	2.86	6	31.50	4.95	2	3.000	1	5	6	3.69	1.2	-0.632
CLAY450	4	5	31.60	3.51	5	31.50	4.95	2	1.992	1	4	5	3.84	1.4	0.026

*Significant difference between groups at alpha=0.05.

Table A.1. (continued).

Variable	Groups 1st	Groups 2nd	Mean	S.D.	n	Mean	S.D.	n	F (calc.)	df(n)	df(d)	df t	Pooled s	Approx. df for t	t (calc.)
			<---- 1st group ---->			<---- 2nd group ---->				<- for F ->					
SAND450	1	2	87.67	4.04	3	46.50	22.25	8	30.297	7	2	9	8.20	8.1	5.018*
SAND450	1	3	87.67	4.04	3	49.17	19.19	6	22.541	5	2	7	8.17	5.8	4.710*
SAND450	1	4	87.67	4.04	3	33.40	23.50	5	33.814	4	2	6	10.77	4.4	5.041*
SAND450	1	5	87.67	4.04	3	33.50	33.23	2	67.622*	1	2	3	23.62	1.0	2.294
SAND450	2	3	46.50	22.25	8	49.17	19.19	6	1.344	7	5	12	11.10	11.7	-0.240
SAND450	2	4	46.50	22.25	8	33.40	23.50	5	1.116	4	7	11	13.13	8.3	0.998
SAND450	2	5	46.50	22.25	8	33.50	33.23	2	2.232	1	7	8	24.78	1.2	0.525
SAND450	3	4	49.17	19.19	6	33.40	23.50	5	1.500	4	5	9	13.11	7.8	1.203
SAND450	3	5	49.17	19.19	6	33.50	33.23	2	3.000	1	5	6	24.77	1.2	0.632
SAND450	4	5	33.40	23.50	5	33.50	33.23	2	2.000	1	4	5	25.74	1.4	-0.004
SILT450	1	2	7.33	4.04	3	32.50	18.32	8	20.554	7	2	9	6.89	8.4	-3.655*
SILT450	1	3	7.33	4.04	3	21.67	16.33	6	16.327	5	2	7	7.06	6.1	-2.029
SILT450	1	4	7.33	4.04	3	35.00	20.00	5	24.490	4	2	6	9.24	4.5	-2.993*
SILT450	1	5	7.33	4.04	3	35.00	28.28	2	48.980*	1	2	3	20.14	1.0	-1.374
SILT450	2	3	32.50	18.32	8	21.67	16.33	6	1.259	7	5	12	9.30	11.5	1.165
SILT450	2	4	32.50	18.32	8	35.00	20.00	5	1.191	4	7	11	11.04	8.0	-0.226
SILT450	2	5	32.50	18.32	8	35.00	28.28	2	2.383	1	7	8	21.02	1.2	-0.119
SILT450	3	4	21.67	16.33	6	35.00	20.00	5	1.500	4	5	9	11.16	7.8	-1.195
SILT450	3	5	21.67	16.33	6	35.00	28.28	2	3.000	1	5	6	21.08	1.2	-0.632
SILT450	4	5	35.00	20.00	5	35.00	28.28	2	2.000	1	4	5	21.91	1.4	0.000
PF	1	2	5.33	2.31	3	4.75	1.49	8	2.409	2	7	9	1.43	2.7	0.407
PF	1	3	5.33	2.31	3	4.67	1.21	6	3.636	2	5	7	1.42	2.6	0.469
PF	1	4	5.33	2.31	3	4.80	2.49	5	1.162	4	2	6	1.74	4.6	0.307
PF	1	5	5.33	2.31	3	7.00	0.00	2	.	2	1	3	1.33	2.0	-1.250
PF	2	3	4.75	1.49	8	4.67	1.21	6	1.510	7	5	12	0.72	11.9	0.115

*Significant difference between groups at alpha=0.05.

Table A.1. (continued).

Variable	Groups 1st	Groups 2nd	Mean <---- 1st group ---->	S.D.	n	Mean <---- 2nd group ---->	S.D.	n	F (calc.)	df(n) <- for F ->	df(d)	df t	Pooled s	Approx. df for t	t (calc.)
PF	2	4	4.75	1.49	8	4.80	2.49	5	2.800	4	7	11	1.23	5.8	-0.041
PF	2	5	4.75	1.49	8	7.00	0.00	2	.	7	1	8	0.53	7.0	-4.277*
PF	3	4	4.67	1.21	6	4.80	2.49	5	4.227	4	5	9	1.22	5.6	-0.109
PF	3	5	4.67	1.21	6	7.00	0.00	2	.	5	1	6	0.49	5.0	-4.719*
PF	4	5	4.80	2.49	5	7.00	0.00	2	.	4	1	5	1.11	4.0	-1.976
MOTTDEP	1	2	430.00	121.24	3	223.37	187.78	8	2.399	7	2	9	96.48	5.9	2.142
MOTTDEP	1	3	430.00	121.24	3	132.67	188.17	6	2.409	5	2	7	103.93	6.2	2.861*
MOTTDEP	1	4	430.00	121.24	3	159.80	195.59	5	2.602	4	2	6	112.03	5.9	2.412
MOTTDEP	1	5	430.00	121.24	3	234.00	197.99	2	2.667	1	2	3	156.52	1.5	1.252
MOTTDEP	2	3	223.37	187.78	8	132.67	188.17	6	1.004	5	7	12	101.53	10.9	0.893
MOTTDEP	2	4	223.37	187.78	8	159.80	195.59	5	1.085	4	7	11	109.81	8.4	0.579
MOTTDEP	2	5	223.37	187.78	8	234.00	197.99	2	1.112	1	7	8	154.94	1.5	-0.069
MOTTDEP	3	4	132.67	188.17	6	159.80	195.59	5	1.080	4	5	9	116.42	8.5	-0.233
MOTTDEP	3	5	132.67	188.17	6	234.00	197.99	2	1.107	1	5	6	159.69	1.7	-0.635
MOTTDEP	4	5	159.80	195.59	5	234.00	197.99	2	1.025	1	4	5	165.08	1.9	-0.449
DRCLASS	1	2	2.00	1.00	3	2.87	1.36	8	1.839	7	2	9	0.75	5.0	-1.166
DRCLASS	1	3	2.00	1.00	3	3.67	0.52	6	3.750	2	5	7	0.61	2.6	-2.712*
DRCLASS	1	4	2.00	1.00	3	4.20	1.10	5	1.200	4	2	6	0.76	4.7	-2.905*
DRCLASS	1	5	2.00	1.00	3	3.50	0.71	2	2.000	2	1	3	0.76	2.9	-1.964
DRCLASS	2	3	2.87	1.36	8	3.67	0.52	6	6.897*	7	5	12	0.52	9.5	-1.511
DRCLASS	2	4	2.87	1.36	8	4.20	1.10	5	1.533	7	4	11	0.69	10.1	-1.933
DRCLASS	2	5	2.87	1.36	8	3.50	0.71	2	3.679	7	1	8	0.69	3.3	-0.902
DRCLASS	3	4	3.67	0.52	6	4.20	1.10	5	4.500	4	5	9	0.53	5.5	-1.000
DRCLASS	3	5	3.67	0.52	6	3.50	0.71	2	1.875	1	5	6	0.54	1.4	0.307
DRCLASS	4	5	4.20	1.10	5	3.50	0.71	2	2.400	4	1	5	0.70	3.1	1.000

*Significant difference between groups at alpha=0.05.

Table A.1. (continued).

Variable	Groups 1st	Groups 2nd	Mean (1st group)	S.D. (1st group)	n (1st group)	Mean (2nd group)	S.D. (2nd group)	n (2nd group)	F (calc.)	df(n) for F	df(d) for F	df t	Pooled s	Approx. df for t	t (calc.)
ROOTDEP	1	2	154.33	29.14	3	137.32	42.13	8	2.090	7	2	9	22.47	5.4	0.757
ROOTDEP	1	3	154.33	29.14	3	118.33	17.61	6	2.737	2	5	7	18.30	2.8	1.967
ROOTDEP	1	4	154.33	29.14	3	132.90	15.90	5	3.360	2	4	6	18.27	2.7	1.173
ROOTDEP	1	5	154.33	29.14	3	88.00	7.07	2	16.987	2	1	3	17.55	2.3	3.779*
ROOTDEP	2	3	137.32	42.13	8	118.33	17.61	6	5.720	7	5	12	16.54	9.9	1.148
ROOTDEP	2	4	137.32	42.13	8	132.90	15.90	5	7.021	7	4	11	16.50	9.7	0.268
ROOTDEP	2	5	137.32	42.13	8	88.00	7.07	2	35.496	7	1	8	15.71	8.0	3.139*
ROOTDEP	3	4	118.33	17.61	6	132.90	15.90	5	1.227	5	4	9	10.11	8.9	-1.440
ROOTDEP	3	5	118.33	17.61	6	88.00	7.07	2	6.205	5	1	6	8.76	5.1	3.463*
ROOTDEP	4	5	132.90	15.90	5	88.00	7.07	2	5.056	4	1	5	8.69	4.5	5.165*

*Significant difference between groups at alpha=0.05.

Table B.1. Soils data, site locations, and descriptions of site physiography. Data are ordered by site.

Site A. ECS No. 87. Burgis landform: Maltby Kames.
Location: T. 24 N., R. 3 E., Sec. 17, SE of SE.

General Description: South-facing 20% slope at edge of moraine, likely eroded. A till layer of varied thickness is present, usually beginning at a depth of about 65 cm and continuing for about 40 cm., with limestones. Surface soil is loamy sand, substratums contain layers of all textures.

Soil family classification: Typic Fragiboralfs, coarse-loamy, mixed.

Depositional environment/parent material: Port Bruce basal till.

Soil Pedon Data:

Horizon	Depth cm	Texture	Cs fr vol %	Est BD g/cc	pH H2O	pH CaCl2	TKN <—	TKP	Ca mg/kg	Mg	K	Bray's P —>
Subplot 1												
A	0- 8	l	3.4	0.772	5.32	6.19	5000.2	636.2	3100	178	107.4	28.64
B	8- 20	ls	13.2	1.408	5.67	5.64	462.2	252.2	760	28	19.3	14.54
Ex	20- 68	ls	4.6	1.800	6.24	5.34	160.0	113.1	433	15	14.3	2.21
BEx	68-108	grsl	31.7	1.800	6.96	6.96	372.2	185.0	1565	142	52.9	3.94
C1	108-150	s	1.0	1.595	7.44	6.85	147.4	84.7	320	27	12.0	5.26
C2	150-183	ls	11.9	1.747	7.14	7.06	308.0	170.0	1710	90	37.1	4.03
Subplot 2												
A	0- 10	sl	8.7	1.008	7.24	7.15	2726.2	546.1	4360	136	51.6	70.35
B	10- 28	lfs	4.0	1.458	6.52	6.42	319.0	171.4	490	25	17.8	23.74
Ex	28- 35	ls	6.2	1.800	6.98	6.71	152.6	108.6	400	13	16.0	10.11
BEx	35- 73	vstscl	49.2	1.800	7.06	7.27	874.2	459.7	3880	197	83.1	0.61
C	73-210	vgrs	49.8	1.536	8.01	7.66	51.0	149.6	1810	38	7.9	0.78
Subplot 3												
A	0- 9	ls	2.4	1.145	5.64	5.60	1733.6	378.6	1574	110	61.2	33.76
B	9- 32	ls	4.5	1.499	5.22	5.55	229.4	90.6	247	20	11.5	4.92
Ex	32- 50	ls	5.2	1.800	5.88	6.20	190.8	78.5	300	27	14.2	2.55
EBx	50- 64	grls	28.7	1.800	5.82	6.29	141.4	72.5	380	34	13.9	0.84
BEx	64-106	vgrsl	43.2	1.800	5.77	5.77	389.4	208.6	2080	120	27.2	0.11
C1	106-125	s	12.4	1.638	7.73	7.50	27.8	55.8	1700	38	6.2	0.09
C2	125-133	ls	1.2	1.580	8.10	7.57	83.6	112.4	2970	67	11.1	0.84
C3	133-150	grs	32.4	1.557	7.95	7.40	169.8	152.1	3480	65	11.5	0.00
C4	150-160	sl	6.9	1.740	8.38	7.69	53.0	74.7	2840	61	10.8	0.23
C5,6	160-213	s	0.1	1.757	7.02	7.38	4.2	31.6	1590	26	2.9	0.00
C7	213-229	ls	7.5	1.770	8.47	7.75	15.4	57.9	3420	94	10.6	2.65
C8	229-244	s	0.2	1.775	7.16	7.52	10.8	31.6	1530	32	3.9	0.00
C9	244-396	s	5.0	1.792	8.02	7.57	4.4	59.1	1830	39	3.6	0.16
C10,11	396-457	lfs	0.2	1.805	7.79	7.47	21.8	44.4	1880	34	4.2	0.00
Subplot 4												
A	0- 9	fsl	2.9	0.919	7.26	7.18	3494.6	37.5	3050	63	44.7	177.07
B	9- 28	lfs	2.4	1.425	7.35	6.95	409.6	254.7	1210	21	40.0	96.33
Ex	28- 64	lfs	3.2	1.800	6.96	7.03	263.8	139.2	813	15	22.7	10.42
BEx1	64-106	l	6.1	1.800	6.26	6.69	326.4	242.6	1530	42	57.9	7.90
BEx2	106-150	grl	25.4	1.800	7.52	7.43	427.4	320.1	2300	165	78.5	3.87

Site B ECS No. 88. Burgis landform: Maltby Kames.
Location: T. 24 N., R. 3 E., Sec. 17, NE of SE.

General Description: North-facing 16% slope above water-holding kettle feature. A thick till layer is present, usually beginning at a depth of about 30 cm and continuing past a depth of 150 cm., containing limestones and silty layers. Surface soil is loamy sand or sandy loam. Substratums were not sampled.

Soil family classification: Typic Fragiboralfs, fine loamy, mixed.

Depositional environment/parent material: Port Bruce basal till.

Soil Pedon Data:

Horizon	Depth cm	Texture	Cs fr vol %	Est BD g/cc	pH H2O	pH CaCl2	TKN <——	TKP	Ca	Mg mg/kg	K	Bray's P ——>
Subplot 1												
A,E	0- 4	fsl	1.5	0.570	5.45	4.81	7735.4	654.7	2970	282	158.0	43.41
Bs	4- 26	lfs	2.6	1.340	4.26	4.18	775.4	385.1	390	48	44.7	37.77
EBx	26- 42	lfs	4.0	1.800	4.86	4.55	261.6	168.0	254	39	23.2	4.99
B/Ex	42- 59	fsl	3.7	1.800	4.92	4.27	361.4	185.3	835	192	87.7	2.22
Bt	59- 94	sic	0.2	1.618	5.38	5.13	415.6	307.8	1797	490	123.6	13.35
BC1	94-105	scl	2.0	1.678	6.53	6.11	246.0	167.8	859	206	45.3	2.19
BC2	105-145	sil	1.4	1.501	5.24	5.07	306.4	236.7	1280	336	68.5	2.54
BC3	145-160	scl	2.7	1.739	5.92	5.82	246.2	173.0	933	217	50.2	2.49
Subplot 2												
A	0- 3	l	0.9	0.420	5.66	6.14	10562.4	930.6	9280	656	361.6	53.34
Bs	3- 14	sl	1.2	1.385	5.47	5.89	873.8	353.0	958	80	55.5	9.63
EBx	14- 26	sl	2.1	1.800	5.92	6.04	272.8	97.9	537	57	29.3	1.47
B/Ex1	26- 51	cl	0.7	1.800	5.32	4.74	510.8	184.2	1630	233	111.0	3.19
B/Ex1	51- 86	cl	1.3	1.800	5.37	5.72	375.6	175.6	1130	238	76.6	3.48
BC	86-155	sil	0.7	1.488	7.51	7.39	393.4	327.6	4180	370	79.0	2.60
Subplot 3												
A	0- 2	fsl	0.5	0.603	5.57	6.29	7215.4	995.7	4950	342	193.0	34.68
BE	2- 11	fsl	1.6	1.332	5.29	4.93	740.4	289.4	529	52	41.4	14.34
E/Bx	11- 31	l	0.4	1.800	4.37	4.05	314.8	104.1	690	149	78.1	2.29
B/Ex	31- 55	l	1.2	1.800	6.35	6.81	405.0	289.0	1570	236	103.0	5.38
Bt	55- 91	sicl	1.4	1.618	7.55	7.46	335.2	382.7	3980	408	94.3	2.50
BC	91-160	scl	2.4	1.674	7.67	7.38	335.2	352.5	7800	576	136.2	2.59
Subplot 4												
A	0- 4	sl	3.4	0.706	4.60	4.98	5797.2	586.5	2530	236	108.0	31.32
B	4- 15	fsl	2.2	1.324	4.74	4.57	771.0	434.6	479	63	44.0	63.18
E/Bx	15- 27	l	1.1	1.800	4.75	4.17	364.6	217.9	433	78	56.2	13.75
B/Ex	27- 60	l	1.0	1.800	5.18	4.27	405.6	249.9	990	265	102.5	13.09
Bt	60- 98	sicl	1.7	1.618	7.49	7.19	475.6	391.6	3340	560	121.7	2.12
BC	98-123	sl	0.6	1.705	7.56	7.11	335.6	246.3	1160	253	48.9	4.76
C1	123-140	s	0.6	1.574	5.92	5.84	100.0	124.2	223	53	17.1	9.87
C2	140-175	scl	0.6	1.742	7.20	7.33	357.8	281.0	2140	393	79.6	3.53

Site C ECS No. 90. Burgis landform: Maltby Kames.
Location: T. 24 N., R. 4 E., Sec. 6, NW of NE.

General Description: Nearly level surface topography. Site is located on a plateau, on a hilltop. Silty layers are present below 150 cm depths. Surface soil is loamy sand.

Soil family classification: Alfic Haplorthods, sandy, mixed, frigid.

Depositional environment/parent material: Lacustrine silts.

Soil Pedon Data:

Horizon	Depth cm	Texture	Cs fr vol %	Est BD g/cc	pH H2O	pH CaCl2	TKN <—	TKP	Ca mg/kg	Mg	K	Bray's P —>
Subplot 1												
A	0– 3	ls	0.0	0.423	5.42	6.00	10483.8	727.7	8040	532	372.4	38.96
E	3– 7	ls	0.1	1.602	5.96	5.84	84.6	94.8	330	38	38.8	13.13
Bs	7– 43	sl	0.1	1.605	7.05	7.15	359.2	347.5	460	35	48.8	56.17
Ex	43– 58	ls	0.0	1.800	6.26	6.29	473.0	133.4	479	37	22.6	13.43
B/Em	58– 96	scl	0.1	1.700	6.54	6.13	168.0	206.7	1010	197	90.6	22.70
BC	96–135	sicl	0.0	1.585	5.79	5.07	345.6	391.6	1530	267	122.0	24.45
C1	135–229	si	0.0	1.755	6.04	5.95	268.8	460.0	1950	324	125.5	12.56
C2	229–305	si	0.0	1.782	7.21	6.92	222.6	492.1	2270	868	140.8	14.79
Subplot 2												
A	0– 2	ls	0.0	0.802	5.91	5.52	4663.8	384.5	3560	240	238.0	22.58
AE	2– 6	ls	0.4	1.243	6.09	5.90	1162.0	223.2	780	64	37.2	13.11
Bs1	6– 25	ls	0.8	1.429	5.30	4.99	404.0	332.4	296	25	25.9	71.32
Bs2	25– 43	ls	1.4	1.507	5.67	4.96	283.0	287.6	151	15	19.4	92.43
B	43– 95	s	2.0	1.539	5.78	5.42	73.2	119.2	117	19	19.7	18.27
E/Bm	95–142	s	3.5	1.700	5.75	5.27	75.8	129.2	140	20	21.4	37.76
BC	142–152	sicl	0.7	1.582	5.37	5.14	240.0	228.5	1460	171	109.0	20.98
C	152–305	si	0.1	1.772	5.74	4.19	250.2	344.9	1770	229	138.0	21.68
Subplot 3												
A	0– 2	ls	1.8	0.744	5.66	6.05	5324.2	581.7	1750	106	89.8	44.44
AE	2– 7	ls	1.7	1.265	5.15	4.60	1048.4	265.8	680	42	27.6	18.86
Bs1	7– 25	ls	1.8	1.403	4.78	4.94	490.4	286.0	259	29	21.7	31.43
Bs2	25– 46	ls	2.8	1.511	5.20	4.84	282.2	153.0	120	8	13.8	29.48
E/Bm	46– 83	s	3.6	1.700	5.85	5.89	98.6	88.8	160	18	13.6	3.46
B/E	83–125	ls	3.9	1.629	7.11	6.57	93.4	120.6	506	113	17.9	0.38
BC	125–168	ls	3.5	1.512	7.63	7.36	65.0	108.4	1860	85	14.2	0.97
C1	168–198	s	7.0	1.755	7.60	7.60	41.6	97.3	2110	63	9.9	1.81
C2	198–274	ls	2.4	1.775	8.35	7.67	32.2	101.8	2725	77	16.6	2.36
C3	274–335	sil	0.3	1.790	7.49	7.44	50.6	141.3	2830	97	26.5	3.86
C4	335–351	scl	0.0	1.796	7.51	7.53	103.8	290.9	2830	187	59.5	6.48
C5	351–381	ls	6.0	1.799	7.80	7.20	17.6	61.9	2270	53	9.8	0.98

Site C, cont.
Subplot 4

Oa	0– 2	om	0.0	0.182	5.70	6.83	18489.3	1337.4	10640	347	670.0	104.79
AE	2– 6	ls	0.4	1.217	5.44	5.78	1301.6	312.8	829	66	52.0	18.54
Bs1	6– 37	s	1.2	1.456	6.17	5.77	272.0	508.6	409	23	35.0	80.95
Bs2	37– 57	s	1.9	1.538	6.83	6.80	186.8	213.1	230	10	22.2	69.34
Em	57– 98	s	1.6	1.700	6.24	5.81	127.8	132.8	150	7	12.0	42.52
B/Em	98–140	sl	0.3	1.700	6.22	5.84	75.6	140.9	538	92	46.0	10.56
C1	140–183	scl	0.0	1.744	6.76	6.34	96.4	159.3	700	142	64.8	23.04
C2	183–274	si	0.0	1.772	4.80	4.59	200.2	344.4	1410	283	117.5	31.71
C3	274–381	si	0.2	1.794	7.45	7.40	167.2	400.4	3920	574	91.6	21.42
C3sub	320–323	cemented	0.0	1.793	6.49	6.78	252.4	909.2	2272	792	65.4	29.60
C4	381–411	sl	3.5	1.802	7.65	7.56	62.0	158.8	2840	193	34.7	3.91

Site D ECS No. 91. Burgis landform: Maltby Kames.
Location: T. 24 N., R. 4 E., Sec. 8, center of N half.

General Description: Nearly level surface topography. Site is located on a plateau on a ridgetop. A till layer about 50 cm thick is present, beginning at variable depths between 40 and 90 cm, containing limestones. Surface soil is sandy loam. Substratums are sand with gravel stratification.

Soil family classification: Alfic Haplorthods, coarse-loamy, mixed, frigid.

Depositional environment/parent material: Port Bruce basal till.

Soil Pedon Data:

Horizon	Depth cm	Texture	Cs fr vol %	Est BD g/cc	pH H2O	pH CaCl2	TKN	TKP	Ca	Mg	K	Bray's P
							<—		mg/kg			—>
Subplot 1												
A	0- 4	sl	0.0	0.842	5.91	6.12	4246.6	541.5	3640	256	137.0	36.94
Bs	4- 32	sl	1.6	1.477	5.72	5.61	425.4	139.1	506	32	17.2	3.89
Em	32- 42	ls	1.9	1.700	7.21	6.54	106.4	63.3	360	9	18.4	0.38
Bt	42- 91	vgrsl	37.8	1.618	7.76	7.43	219.8	111.4	1530	108	27.5	2.84
C1	91-130	s	0.1	1.654	7.07	7.19	24.4	51.4	748	36	5.0	1.25
C2	130-183	s	14.6	1.741	7.80	7.52	33.2	437.6	1740	39	8.9	1.33
C3	183-442	s	3.1	1.791	7.77	7.45	15.6	33.9	1635	33	4.3	0.00
Subplot 2												
A	0- 3	l	0.2	0.815	7.11	6.75	4527.2	580.6	3940	334	146.2	62.43
AE	3- 10	l	1.7	1.166	4.96	5.42	1601.4	345.5	1128	92	30.2	6.14
Bs1	10- 26	sl	1.0	1.475	6.95	7.07	723.4	299.2	3140	96	33.7	17.31
Bs2	26- 44	sl	0.5	1.503	6.91	6.77	529.6	220.8	1090	28	22.7	23.00
E/Em	44- 60	ls	1.6	1.700	6.78	6.84	135.8	80.9	470	12	19.7	4.24
B/E	60- 97	s	0.8	1.601	6.72	6.92	35.4	43.7	259	10	9.8	3.19
Bt	97-130	grscl	20.6	1.618	7.35	6.85	222.0	126.7	1650	120	50.7	0.00
C	130-381	s	5.1	1.780	8.08	7.58	15.4	125.8	2010	39	4.4	0.00
Subplot 3												
A	0- 4	sl	1.2	0.757	5.75	6.53	5177.8	732.0	4160	172	104.7	79.27
E	4- 6	fsl	0.9	1.308	5.42	5.41	841.4	259.2	1130	34	22.2	39.89
Bs	4- 28	fsl	1.3	1.350	5.27	5.22	742.0	606.8	838	22	24.4	109.32
Ex	28- 59	fsl	0.8	1.800	5.40	5.15	120.6	78.9	630	49	37.3	5.87
B/Em	59- 74	ls	8.8	1.700	7.04	6.81	146.6	95.3	670	98	24.0	3.45
E/B	74- 91	s	0.4	1.608	6.24	5.75	43.4	45.4	170	10	9.7	2.30
Bt	91-155	vgrsl	36.3	1.618	7.36	7.14	304.2	224.4	2240	186	51.4	0.36
C	155-259	s	7.7	1.765	7.75	7.40	11.2	28.2	1340	25	3.0	0.31
Csub	205-210	si	3.3	1.765	7.80	7.32	165.2	150.0	3135	193	17.6	1.42
Subplot 4												
A	0- 8	sl	0.5	0.729	5.74	5.38	5511.6	694.8	4120	312	151.6	38.33
Bs1	8- 30	sl	4.3	1.393	5.21	5.69	731.4	342.0	565	51	26.3	18.90
Bs2	30- 41	sl	3.5	1.427	5.25	5.02	459.4	195.8	420	27	23.6	8.57
Ex	41- 54	sl	7.8	1.800	5.68	5.03	149.8	86.3	522	33	25.8	3.12
B/Em	54- 68	ls	3.8	1.700	5.26	5.31	72.0	57.9	486	31	20.9	1.84
Bt	68-130	vcbsl	42.3	1.618	6.99	7.16	222.0	150.6	1370	170	32.1	0.21
C	130-168	grs	22.8	1.505	7.58	7.54	47.4	94.2	2540	52	6.1	0.00

Site E ECS No. 94. Burgis landform: Maltby Kames.
Location: T. 24 N., R. 3 E., Sec. 9, NW of SW.

General Description: Generally west-facing site, average slope of 11%, located on undulating topography in a saddle between two ridges. A till layer of about 30 to 40 cm thick is present, beginning at a depth of about 90 cm, containing limestones. Surface soil is sandy loam. Substratums are gravelly sandy loam.

Soil family classification: Alfic Haplorthods, coarse-loamy, mixed, frigid.

Depositional environment/parent material: Port Bruce basal till.

Soil Pedon Data:

Horizon	Depth cm	Texture	Cs fr vol %	Est BD g/cc	pH H2O	pH CaCl2	TKN	TKP	Ca	Mg	K	Bray's P
							<———		mg/kg			———>
Subplot 1												
A	0- 4	sl	1.9	0.626	6.35	6.47	6873.6	503.2	5440	450	151.4	26.15
AE	4- 11	sl	2.6	1.246	4.32	4.35	1146.8	229.9	830	72	26.9	11.27
Bs	11- 39	sl	5.9	1.599	5.04	4.70	232.4	101.6	175	19	21.0	3.47
Em	39- 58	ls	5.6	1.700	5.10	4.50	373.4	146.2	279	31	23.5	4.29
E/Bm	58- 88	ls	12.5	1.700	5.64	5.45	112.2	60.3	275	28	20.4	0.65
Bt	88-124	scl	7.2	1.618	6.48	6.56	317.2	201.4	1285	209	69.2	3.64
C	124-274	sl	13.0	1.762	7.81	7.52	98.4	149.4	2950	103	33.5	0.00
Subplot 2												
A1	0- 2	sl	1.5	0.744	5.99	6.48	5327.8	569.6	3700	246	160.0	27.49
A2	2- 14	sl	1.6	1.163	5.31	6.10	1621.9	322.7	1080	92	44.3	7.94
Bs	14- 50	sl	0.9	1.437	5.83	5.31	475.2	228.6	529	45	19.2	15.55
Em	50- 76	ls	6.1	1.700	6.10	5.66	78.4	57.9	427	41	17.6	1.78
Bt	76-134	vstscl	43.7	1.618	6.67	7.42	326.0	199.5	2200	254	56.0	2.74
C1	134-165	s	7.3	1.510	7.46	7.32	37.2	88.0	1950	48	8.9	1.57
C2	165-231	ls	4.8	1.762	6.86	7.27	58.4	110.3	2960	84	19.4	1.21
Subplot 3												
A	0- 5	sl	2.3	0.751	6.14	6.30	5242.2	677.9	4680	260	169.4	35.06
AB	5- 15	sl	1.2	1.192	5.15	6.03	1448.8	440.0	659	60	40.2	7.69
Bw	15- 40	ls	1.3	1.447	5.58	6.08	349.2	182.9	503	26	22.2	8.46
BC1	40- 96	ls	7.5	1.560	5.80	5.80	181.0	124.0	460	17	18.4	6.83
BC2	96-140	ls	9.2	1.645	7.65	7.27	209.8	218.1	950	119	41.5	5.37
C1	140-183	sl	1.5	1.744	6.83	6.93	134.8	178.2	785	110	33.4	6.76
C2	183-229	sl	13.6	1.765	7.83	7.31	78.8	142.2	2970	94	48.4	0.00
Subplot 4												
A	0- 7	l	4.3	0.847	5.95	5.91	4188.0	392.2	3920	174	76.0	22.10
AE	7- 16	ls	4.2	1.395	5.61	5.91	503.0	110.2	820	30	0.0	8.76
Bhs	16- 23	sl	5.1	1.418	6.07	5.53	571.6	391.6	717	32	21.0	50.14
Bs	16- 42	sl	4.8	1.439	5.84	5.74	543.6	372.3	876	29	23.8	35.31
Em	42- 81	s	6.7	1.700	5.11	4.85	123.2	61.3	124	10	12.4	2.78
E/B	81-106	ls	10.0	1.653	6.20	5.14	185.2	77.4	480	66	38.8	0.51
Bt	106-132	scl	4.2	1.618	6.94	6.65	233.2	170.0	1330	211	53.9	2.22
C1	132-183	sl	14.1	1.742	7.51	7.46	99.2	154.6	3700	116	35.2	0.00
C2	183-307	sl	2.9	1.777	8.24	7.77	57.0	111.3	4000	106	25.5	0.00

Site F ECS No. 95. Burgis landform: Maltby Kames.
Location: T. 24 N., R. 3 E., Sec. 15, NW of NE.

General Description: Slopes average 8% on small undulating ridges on a generally level morainal area. A till layer 60 cm or more in thickness is present, beginning at depths of about 40 cm, containing limestones. Surface soil is sandy loam. Substratums are sand, loamy sand, or sandy loam, with gravel stratification.

Soil family classification: Alfic Haplorthods, fine-loamy, mixed, frigid.

Depositional environment/parent material: Port Bruce basal till.

Soil Pedon Data:

Horizon	Depth cm	Texture	Cs fr vol %	Est BD g/cc	pH H2O	pH CaCl2	TKN	TKP	Ca	Mg	K	Bray's P
							<——		mg/kg			——>
Subplot 1												
Oa	0– 3	om	1.4	0.498	7.25	7.48	8978.2	770.4	7440	436	275.4	79.82
A	3– 20	sl	2.6	1.052	6.18	6.11	2387.8	798.2	2000	121	63.0	26.48
AE	20– 28	sl	4.8	1.308	6.46	6.23	840.8	393.1	1010	68	34.8	20.34
Em	28– 47	ls	2.1	1.700	6.28	6.58	147.6	130.3	448	28	23.5	25.85
B/E	47– 72	scl	2.4	1.448	5.68	5.25	346.8	237.3	1480	174	97.8	17.21
Bt	72–145	scl	2.7	1.618	7.83	7.43	305.0	307.5	3820	244	73.2	2.71
C	145–183	scl	3.1	1.746	7.84	7.45	219.8	228.7	3980	201	63.3	0.00
Subplot 2												
A	0– 4	sl	2.0	0.908	4.90	5.71	3600.4	510.1	1518	138	113.4	28.34
Bs	4– 20	sl	2.2	1.343	4.81	4.78	715.8	348.0	360	40	38.5	61.74
Em	20– 31	ls	4.1	1.700	5.17	5.03	159.2	81.0	350	59	24.8	2.04
B/E	31– 50	scl	3.7	1.432	5.21	5.06	388.6	208.6	1265	245	85.2	2.22
Bt	50–103	cl	1.6	1.618	7.62	7.51	351.8	337.8	4480	352	81.6	0.65
C1	103–140	s	2.3	1.602	7.66	7.38	92.4	104.8	2870	118	17.9	0.00
C2	140–198	ls	3.2	1.748	7.75	7.53	81.9	80.3	2880	92	11.8	2.52
Subplot 3												
A	0– 5	fsl	4.0	0.780	5.24	5.75	4909.0	529.4	1300	93	40.6	22.00
Bs	5– 13	fsl	1.7	1.640	4.92	4.82	206.8	102.0	288	39	20.4	1.83
Em	13– 36	fsl	1.6	1.700	5.12	4.64	277.0	117.4	945	212	64.8	4.30
B/Em	36– 65	fscl	0.8	1.700	5.52	4.56	326.4	131.2	919	208	63.6	5.15
Bt	65– 95	cl	2.4	1.618	6.61	6.63	362.8	270.9	1660	384	88.8	7.68
C	95–168	fscl	1.7	1.595	7.98	7.63	172.0	235.2	4260	234	61.5	0.00
Subplot 4												
A	0– 2	sl	0.4	0.785	6.51	6.30	4850.6	454.1	4320	300	136.6	26.34
AE	2– 12	ls	0.6	1.302	4.27	3.67	870.2	188.9	234	22	32.4	23.55
Bs	12– 32	sl	0.7	1.391	5.09	4.72	507.0	306.5	320	27	28.0	45.84
Em	32– 53	ls	0.7	1.700	5.71	5.60	139.2	106.5	266	15	18.5	18.05
Bt	53–105	scl	1.4	1.618	7.19	6.81	266.4	232.3	2010	206	53.9	3.01
C1	105–152	s	0.7	1.592	7.61	7.22	36.8	57.1	707	73	12.9	2.71
C2	152–198	ls	3.5	1.751	8.06	7.74	43.8	65.8	1745	116	25.8	3.91
C3	198–290	sl	6.0	1.777	7.30	7.27	164.6	160.5	1250	162	36.1	2.14
C4	290–320	sl	0.3	1.790	7.38	7.37	103.4	92.8	918	154	37.6	1.80
C5	320–351	s	1.5	1.795	7.89	7.53	20.4	54.6	1980	73	11.5	1.44

Site G ECS No. 96. Burgis landform: Maltby Kames.
Location: T. 24 N., R. 3 E., Sec. 9, SW of NE.

General Description: Slopes average 7% on a bench on a northeast-facing morainal hillside. A till layer of varying thickness is present, usually about 40 cm thick and beginning at depths of about 70 cm, containing limestones. Surface soil is sandy loam. Substratums are sand, loamy sand, sandy loam, sandy clay loam, or silty clay loam, with some gravel stratification.

Soil family classification: Alfic Haplorthods, coarse-loamy, mixed, frigid.

Depositional environment/parent material: Port Bruce basal till.

Soil Pedon Data:

Horizon	Depth cm	Texture	Cs fr vol %	Est BD g/cc	pH H2O	pH CaCl2	TKN	TKP	Ca	Mg	K	Bray's P
							<—		mg/kg			—>
Subplot 1												
A	0- 4	sl	2.4	0.799	6.32	6.28	4697.2	565.2	3500	150	122.2	19.02
AB	4- 10	sl	0.8	1.260	6.08	6.01	1074.8	417.5	1050	58	33.7	32.11
Bs1	10- 38	ls	1.1	1.501	5.40	5.03	235.4	208.4	287	21	22.0	40.02
Bs2	38- 58	ls	6.3	1.559	4.67	4.42	216.6	221.3	189	13	21.2	55.00
E/Bm	58-114	ls	0.2	1.700	6.45	5.90	77.4	67.8	360	25	26.0	2.99
Bt	114-168	scl	1.6	1.618	6.89	6.30	145.2	145.0	1130	101	62.4	9.62
BC	168-213	sl	1.8	1.759	7.03	7.18	165.2	49.5	1100	171	38.2	4.06
C	213-231	l	2.3	1.770	7.21	7.46	156.8	188.5	3520	185	48.4	1.42
Subplot 2												
A	0- 6	sl	2.6	0.956	5.89	5.58	3160.4	561.2	2200	114	100.2	31.34
AB	6- 16	sl	1.2	1.348	5.83	5.05	674.0	321.2	667	32	21.2	46.75
Bw	16- 34	sl	2.5	1.490	5.58	5.47	247.8	216.2	341	28	24.2	48.44
E/Bm1	34- 48	ls	2.5	1.700	5.94	5.33	142.8	260.7	320	27	45.0	59.30
E/Bm2	48- 70	ls	4.2	1.700	5.54	5.13	125.4	219.0	575	65	57.4	22.00
Bt1	70- 98	scl	1.4	1.618	5.98	5.45	260.2	312.6	1540	322	98.6	9.93
Bt2	98-130	cl	0.3	1.618	7.78	7.53	329.8	419.4	4780	476	113.4	2.80
BC	130-155	sicl	0.3	1.583	7.47	7.50	251.4	401.2	4760	332	84.7	0.00
C	155-168	sl	4.9	1.744	7.63	7.55	130.4	181.5	2300	203	40.6	15.37
Subplot 3												
A	0- 7	sl	1.5	0.890	5.31	5.01	3766.0	424.1	2640	152	94.6	22.55
AB	7- 13	sl	1.2	1.227	4.86	4.62	1246.6	288.4	814	45	26.3	15.25
Bs	13- 52	fsl	3.6	1.393	5.48	4.89	489.8	635.5	355	46	31.6	224.05
E/Bx	52- 76	sl	0.8	1.800	5.23	4.63	168.8	198.8	330	57	42.9	69.30
B/E	76-102	scl	1.6	1.649	5.04	4.51	194.4	179.0	770	110	58.5	12.27
BC	102-145	ls	1.7	1.617	5.57	5.13	164.8	130.3	490	80	27.5	7.83
C1	145-183	scl	3.1	1.746	7.67	7.27	319.4	254.9	4280	436	85.2	3.94
C2	183-214	sicl	0.9	1.762	7.44	7.27	156.8	150.2	1465	243	44.3	3.69
Subplot 4												
A	0- 5	fsl	2.8	0.978	5.90	5.95	2973.0	387.3	2360	156	85.2	25.81
Bs	5- 35	fsl	2.6	1.358	4.83	4.51	528.8	527.2	296	28	35.1	70.00
E/Bm	35- 62	l	0.1	1.700	4.44	4.23	300.8	249.6	660	218	130.0	27.17
Bt	62- 83	cl	0.1	1.618	5.20	4.54	349.4	325.4	1040	350	169.0	26.62
BC	83-183	sl	1.4	1.571	7.91	7.65	107.8	164.5	3410	140	44.6	0.40

Site H ECS No. 98. Burgis landform: Maltby Kames.
Location: T. 24 N., R. 3 E., Sec. 5, center of N half of NE.

General Description: Slopes average 13% on a south-facing hillside in a rolling area of ice-disintegration topography. Soils are sandy to a depth of 450 cm.

Soil family classification: Entic Haplorthods, sandy, mixed, frigid.

Depositional environment/parent material: Outwash sand.

Soil Pedon Data:

Horizon	Depth cm	Texture	Cs fr vol %	Est BD g/cc	pH H2O	pH CaCl2	TKN	TKP	Ca	Mg	K	Bray's P
							<-		mg/kg			->
Subplot 1												
A	0- 7	ls	0.5	1.182	4.13	4.01	1503.2	127.5	460	48	65.8	8.34
EB	7- 15	s	2.8	1.482	3.84	3.86	263.6	45.3	13	5	8.4	2.69
Bs	15- 48	s	6.6	1.498	4.51	4.32	209.0	136.0	13	3	3.4	35.98
BC	48- 89	s	0.9	1.540	4.84	4.25	104.4	34.9	9	1	3.3	7.95
C1	89-244	s	0.4	1.747	5.42	5.64	28.6	48.5	70	12	3.5	2.73
C2	244-450	s	0.1	1.796	7.68	7.46	16.6	30.6	1630	24	3.8	0.00
Subplot 2												
AE	0- 6	ls	0.9	1.292	4.02	3.65	914.6	110.6	36	14	25.4	5.80
Bs1	6- 22	s	0.5	1.440	4.63	4.05	273.6	181.2	15	2	9.7	33.47
Bs2	22- 54	s	0.9	1.530	4.75	4.63	151.8	121.5	9	2	7.7	40.76
BC	54- 85	s	0.2	1.543	5.55	5.09	82.2	77.7	16	4	3.7	33.23
C1	85-120	s	0.3	1.643	6.35	5.20	33.2	31.0	26	8	4.2	16.89
C2	120-320	s	0.1	1.770	5.54	5.32	27.8	26.6	70	7	4.7	4.04
C3	320-335	fs	0.2	1.794	5.63	6.18	51.8	60.2	189	22	9.6	2.92
C4	335-366	cs	1.0	1.797	7.99	7.40	15.2	40.8	1690	39	8.6	3.16
C5	366-442	s	0.2	1.803	6.40	7.27	15.4	33.8	312	29	7.8	4.21
C6	442-457	s	2.1	1.807	7.68	7.01	21.0	58.2	1740	38	6.7	3.22
Subplot 3												
A	0- 4	ls	0.0	1.204	3.98	3.40	1373.8	128.0	162	40	49.6	13.37
E	4- 7	s	0.1	1.478	3.91	3.37	273.0	42.5	16	7	8.1	2.91
Bs1	7- 36	s	0.8	1.455	4.43	4.21	275.4	54.5	8	3	7.6	19.87
Bs2	36- 53	s	0.8	1.548	4.23	4.50	138.0	120.1	9	2	4.2	28.46
BC	53- 77	s	0.1	1.513	4.44	7.41	51.0	56.2	10	1	4.3	25.91
C1	77-213	s	0.1	1.644	6.89	7.42	11.0	24.3	11	3	5.1	12.08
C2	213-274	fs	0.0	1.777	4.60	5.01	117.2	28.9	15	5	5.5	8.72
C3	274-335	s	0.1	1.790	7.20	7.49	13.8	21.5	400	30	5.5	4.68
C4	335-366	cs	0.7	1.797	7.38	7.22	19.8	36.9	384	27	4.0	3.16
C5	366-381	cs	6.2	1.800	8.04	7.60	24.0	76.6	2190	46	5.4	0.56
C6	381-457	s	0.7	1.804	7.62	7.23	12.4	44.5	1740	33	2.9	0.83
Subplot 4												
AE	0- 5	ls	0.1	1.246	3.73	3.35	1143.4	122.6	122	24	51.0	10.18
Bs1	5- 26	s	0.1	1.410	4.15	4.26	378.6	166.3	9	3	13.0	34.91
Bs2	26- 63	s	0.6	1.534	4.54	4.42	182.4	182.2	7	2	8.1	61.31
BC	63- 94	s	0.6	1.593	4.96	4.42	106.6	95.5	7	1	3.9	38.94
C1	94-351	s	0.2	1.771	7.10	6.96	22.6	31.4	103	15	6.4	7.13
C2	351-366	fs	0.0	1.798	6.81	6.50	41.8	89.6	185	19	6.6	5.79
C3	366-457	s	0.4	1.804	7.67	7.41	17.4	41.5	1430	27	3.0	0.03

Site I. ECS No. 106. Burgis landform: Glennie moraine.
Location: T. 27 N., R. 5 E., Sec. 34, NE of SW.

General Description: Nearly level area at top of morainal hill. A till layer of varied thickness is present, beginning at depths between 14 and 115 cm and continuing for about 50 cm., with limestones. Surface soil is loamy sand or sandy loam; substratums are mostly loamy.

Soil family classification: Typic Eutroboralfs, fine-loamy, mixed.

Depositional environment/parent material: Port Huron basal till.

Soil Pedon Data:

Horizon	Depth cm	Texture	Cs fr vol %	Est BD g/cc	pH H2O	pH CaCl2	TKN	TKP	Ca	Mg	K	Bray's P
							<—	—	mg/kg	—	—	—>
Subplot 1												
A	0- 2	ls	0.0	0.552	6.19	6.17	8024.4	988.0	8840	560	444.0	62.72
Em	2- 14	l	1.5	1.700	5.80	5.24	940.4	443.1	1090	108	80.8	62.20
B/E	14- 54	cl	0.3	1.635	5.76	5.01	312.8	274.4	1232	212	142.0	30.01
Bt	54-137	cl	2.2	1.618	7.51	7.16	230.8	290.2	2180	530	94.8	14.30
BC	137-168	ls	1.1	1.739	7.48	6.82	209.8	268.6	888	241	45.5	16.93
C	168-213	s	0.3	1.759	7.27	6.33	26.6	83.8	150	31	8.9	7.65
Subplot 2												
A	0- 6	l	2.3	1.044	5.32	4.55	2448.2	642.6	1848	190	105.6	49.82
Bw	6- 26	l	0.5	1.394	5.72	4.72	507.6	504.4	440	46	73.9	104.20
E/Em	26- 49	sl	0.8	1.700	5.40	5.12	105.4	159.9	240	32	32.1	36.46
Bt	49- 86	cl	0.1	1.618	7.00	6.89	305.6	329.3	2359	776	139.6	12.61
C	86-168	sic	0.5	1.653	8.07	7.31	205.0	345.0	4310	292	102.0	1.58
Subplot 3												
A	0- 2	sl	0.5	0.637	5.51	4.84	6714.2	683.8	4260	432	368.0	54.71
Em	2- 18	l	0.8	1.700	5.79	5.71	317.0	317.4	560	86	65.4	65.28
B/Em	18- 57	sicl	3.7	1.700	5.65	5.07	856.2	861.9	1250	223	171.0	34.47
BC	57- 74	scl	3.6	1.550	5.86	5.47	203.6	233.6	1030	257	100.1	10.51
C1	74-110	sicl	6.1	1.604	7.00	6.95	329.0	316.9	1892	586	126.2	6.70
C2	110-152	grsl	19.3	1.574	8.01	7.51	92.0	211.5	2630	272	45.7	1.53
Subplot 4												
A	0- 3	ls	0.0	0.550	5.94	6.00	8053.2	697.8	3070	225	118.0	55.68
E	3- 10	ls	2.5	1.444	6.33	5.70	357.2	147.3	570	52	17.3	15.86
Bs1	10- 31	sl	2.2	1.466	6.45	5.63	451.8	573.1	990	87	34.5	131.30
Bs2	31- 64	sl	2.3	1.529	6.33	5.51	333.6	451.5	521	47	23.1	164.96
Em	64-115	ls	11.5	1.700	6.37	5.47	159.2	161.1	460	75	27.4	26.21
C1	115-198	sl	12.3	1.741	7.10	6.72	230.8	187.8	1685	390	63.0	3.62
C2	198-244	sl	12.0	1.770	8.02	7.43	89.6	166.8	3560	120	26.9	0.00

Site J. ECS No. 108. Burgis landform: Glennie moraine.
Location: T. 27 N., R. 5 E., Sec. 28, center of N half of SE.

General Description: East-facing 5% slope on morainal hillside. A till layer of varied thickness is present at three of the four subplots, beginning at about 30 cm where present. The till layer continues into the substratum in two of the subplots, and is about 30 cm thick at the other. The till contains limestones. Surface soil is loamy sand or sandy loam. Substratums where sampled are loamy sand and sand, with gravelly strata.

Soil family classification: Typic Eutroboralfs, fine-loamy, mixed.

Depositional environment/parent material: Port Huron basal till.

Soil Pedon Data:

Horizon	Depth cm	Texture	Cs fr vol %	Est BD g/cc	pH H2O	pH CaCl2	TKN	TKP	Ca	Mg	K	Bray's P
							<—	—	mg/kg	—	—	—>
Subplot 1												
A	0– 7	ls	6.9	0.744	6.55	5.98	5324.4	719.0	2720	214	69.0	34.76
Bs1	7– 26	ls	14.0	1.426	6.19	5.36	423.2	381.7	468	52	34.2	145.73
Bs2	26– 49	ls	9.8	1.491	5.93	5.14	359.8	146.1	283	32	18.1	9.38
BC	49– 91	ls	2.3	1.570	5.88	4.95	173.4	81.6	170	23	13.2	7.69
C1	91–183	s	1.8	1.552	7.59	7.10	58.4	60.0	525	118	11.9	1.98
C2	183–274	ls	8.8	1.772	8.10	7.29	45.4	79.8	2270	74	11.1	0.70
C3	274–320	ls	0.7	1.788	8.27	7.68	13.8	47.0	2410	63	6.7	0.00
Subplot 2												
A	0– 2	sl	0.0	0.874	5.71	5.76	3918.2	544.8	2160	290	276.0	47.28
AB	2– 14	sl	1.1	1.322	5.27	4.76	782.2	257.4	474	78	65.2	11.69
E/Bm	14– 27	sl	0.9	1.700	5.78	5.09	289.0	141.3	552	100	69.6	7.85
B/Em	27– 77	cl	0.2	1.700	5.44	4.85	296.0	225.9	1357	401	180.0	16.47
C	77–152	scl	2.5	1.659	7.61	7.28	229.0	262.4	1634	634	54.1	6.18
Subplot 3												
A	0– 3		0.3	1.782	5.70	4.85	0.0	211.6	1706	180	92.6	20.79
E	3– 8	ls	6.0	1.451	5.58	4.71	337.2	71.3	340	53	22.7	9.10
Bw	8– 22	sl	5.6	1.402	5.76	5.26	479.8	402.4	568	65	49.7	79.68
E/Bm	22– 43	sl	0.3	1.700	5.63	5.05	176.4	115.3	697	171	83.4	6.41
Bt	43– 95	sicl	0.0	1.618	6.57	6.30	376.0	316.2	2270	344	159.0	8.52
C1	95–135	sil	0.2	1.530	7.92	7.31	186.8	327.0	4140	366	74.8	0.69
C2	135–155	scl	13.7	1.519	7.75	7.26	69.4	66.4	2880	279	71.8	17.40
Subplot 4												
A	0– 4	l	0.0	0.978	5.33	4.72	2972.0	305.9	2220	166	143.0	33.12
Bw	4– 21	cbl	21.8	1.436	5.16	4.40	377.6	180.9	200	32	44.8	23.78
Bt1	21– 30	grscl	21.4	1.618	5.97	5.39	428.4	158.9	960	225	103.5	9.02
E/Bm	30– 46	sl	2.8	1.700	5.95	5.37	245.4	92.1	492	131	41.3	1.71
Bt2	46– 76	scl	7.5	1.618	7.46	7.13	386.4	311.0	2300	650	193.0	2.18
BC	76–110	ls	10.4	1.641	7.86	7.06	152.2	126.7	660	233	61.6	0.00
C1	110–168	sl	2.0	1.564	7.60	7.20	161.0	142.4	1210	362	61.6	0.00
C2	168–183	s	6.7	1.752	7.71	7.49	69.2	84.2	2090	144	19.6	1.68

Site K. ECS No. 109. Burgis landform: Glennie moraine.
Location: T. 26 N., R. 6 E., Sec. 14, SE of NW.

General Description: Dissected topography featuring rolling ridges; slopes average 8%. Soils are extremely variable. One subplot has a till layer near the surface; another has a till layer between depths of 137 and 187 cm. The other subplots have thin layers of loamy material in the substratum. Surface soil is loamy sand or sandy loam; substratums are stratified sands.

Soil family classification: Typic Eutroboralfs, fine-loamy, mixed.

Depositional environment/parent material: Outwash sand with ice-rafted till inclusions, reworked by fluvial action.

Soil Pedon Data:

Horizon	Depth cm	Texture	Cs fr vol %	Est BD g/cc	pH H2O	pH CaCl2	TKN	TKP	Ca	Mg	K	Bray's P
							<—		mg/kg			—>
Subplot 1												
A	0– 2	fsl	0.0	0.709	4.50	4.24	5758.2	523.7	2020	380	532.0	67.89
E	2– 8	lfs	0.6	1.455	4.54	3.64	327.0	67.8	68	23	20.7	7.53
Bs1	8– 25	sl	3.5	1.426	5.42	4.86	440.4	371.3	338	66	46.3	88.39
Bs2	25– 40	sl	4.2	1.602	5.47	4.99	241.6	184.9	180	27	49.3	60.92
E/Bm	40– 82	sl	2.2	1.700	6.52	5.57	134.2	50.5	292	62	24.9	3.55
C1	82–122	ls	0.7	1.630	6.88	5.05	98.6	69.4	423	92	27.7	2.70
C2	122–183	fs	0.0	1.739	7.46	6.40	24.6	53.9	127	33	8.2	0.70
C3	183–229	sil	0.0	1.765	8.22	7.48	90.6	223.0	3390	149	22.3	0.68
C4	229–290	s	1.3	1.781	8.21	7.12	3.0	30.4	2050	50	5.6	0.00
C5	290–335	sil	0.0	1.791	8.47	7.44	112.6	248.6	3700	192	26.5	0.00
C6	335–366	s	0.1	1.797	8.42	7.56	31.6	57.3	2280	63	6.1	0.00
Subplot 2												
A	0– 2	sl	0.0	0.644	4.36	4.17	6615.4	591.0	1696	260	386.0	60.00
E	2– 8	ls	0.2	1.407	4.46	3.78	463.2	87.2	113	31	40.1	9.47
Bs	8– 40	sl	0.9	1.461	5.01	4.60	353.8	242.1	220	38	48.8	62.63
Em	40–137	sl	0.6	1.700	6.07	5.40	100.8	100.2	350	74	45.5	9.05
B/E	137–183	scl	0.4	1.743	6.82	6.88	208.2	222.4	1607	478	133.0	2.31
Bt	183–244	scl	0.4	1.768	6.24	5.79	192.6	166.8	1120	318	109.5	7.77
Subplot 3												
A	0– 4	sl	0.0	0.482	5.90	5.37	9276.0	625.6	5444	523	615.0	104.48
Bw	4– 18	sl	2.9	1.492	5.48	4.73	243.6	127.4	320	40	19.6	42.01
Em	18– 28	sl	0.5	1.700	6.34	5.25	179.2	123.6	366	59	29.7	17.82
E/Bm	28– 38	scl	1.3	1.700	5.02	4.71	266.6	115.2	800	151	74.5	6.67
Bt	38– 68	scl	1.2	1.618	7.66	7.17	400.2	260.2	2780	708	175.0	2.97
BC	68–125	scl	0.4	1.683	8.02	7.49	262.4	257.1	4160	337	106.0	0.00
C	125–307	s	0.1	1.768	8.57	7.27	28.2	74.8	3392	89	9.1	1.38

Site K, cont.
Subplot 4

Oa	0- 5	om	0.0	0.384	4.97	4.60	11394.2	624.6	5288	486	568.0	71.60
E	5- 13	s	0.8	1.494	5.14	4.49	238.8	42.5	167	24	11.0	6.10
Bs	13- 52	ls	8.5	1.516	5.18	4.90	245.8	195.5	300	29	21.3	68.90
Bm	52- 76	ls	0.2	1.700	5.54	5.03	114.4	109.8	200	20	14.9	56.79
C1	76-135	s	0.2	1.626	6.17	5.04	61.0	65.5	108	13	8.3	15.63
C2	135-160	vfsl	0.0	1.546	6.11	5.24	210.4	221.6	560	74	35.8	9.04
C3	160-307	s	0.4	1.774	7.62	7.14	47.4	43.3	1530	95	12.7	2.46
C4	307-450	s	0.5	1.800	8.00	6.91	24.0	36.4	1679	41	7.1	0.65

Site L. ECS No. 110. Burgis landform: Glennie moraine.
Location: T. 26 N., R. 6 E., Sec. 28, center of E half.

General Description: Sloping area along side of hill at small head of outwash topographic feature. Soils are sandy throughout the sampled depth of 450 cm.

Soil family classification: Entic Haplorthods, sandy, mixed, frigid.

Depositional environment/parent material: Outwash sand.

Soil Pedon Data:

Horizon	Depth cm	Texture	Cs fr vol %	Est BD g/cc	pH H2O	pH CaCl2	TKN	TKP	Ca	Mg	K	Bray's P
							<—		mg/kg			—>
Subplot 1												
A	0– 4	s	0.0	1.170	4.19	3.38	1576.2	194.4	108	34	79.0	15.87
Bs1	4– 23	s	4.4	1.492	5.21	4.52	105.4	135.2	5	1	6.1	61.31
Bs2	23– 38	s	4.5	1.485	4.84	4.19	243.0	158.8	11	3	17.9	52.03
BC	38– 51	s	5.7	1.628	5.24	4.53	62.8	49.7	9	1	6.3	23.62
C1	51–259	s	0.0	1.740	7.13	6.90	29.0	42.9	331	41	6.8	4.36
C2	259–450	s	0.2	1.797	8.14	6.96	40.6	50.8	2070	53	7.7	0.80
C2-s	320–335	s	9.3	1.794	8.12	7.53	97.2	84.3	2640	66	12.9	2.02
Subplot 2												
A	0– 4	s	0.6	1.162	4.66	3.76	1630.2	190.3	200	36	41.8	0.00
Bs	4– 28	s	1.3	1.453	5.07	4.15	246.4	93.6	34	7	9.9	5.82
Bt	28– 58	ls	1.8	1.618	6.11	5.16	132.0	86.3	333	71	15.4	7.43
BC	58– 83	s	0.0	1.609	7.08	6.08	17.8	47.5	141	37	7.5	13.98
C	83–450	s	0.2	1.782	8.08	7.59	20.2	34.3	2210	43	5.3	0.00
Subplot 3												
A	0– 3	s	0.0	1.252	4.40	3.38	1112.8	127.9	260	40	45.6	12.18
AB	3– 8	s	0.0	1.391	4.08	3.33	517.4	70.5	52	12	19.5	5.99
Bs	8– 42	s	0.5	1.486	4.90	4.48	203.0	174.1	5	1	8.9	54.86
BC	42– 63	s	0.1	1.651	5.52	5.03	47.0	60.2	0	0	4.9	32.11
C	63–307	s	0.1	1.756	6.68	5.11	24.0	35.4	30	6	6.9	6.09
C	307–450	s	0.0	1.800	5.83	4.81	28.2	48.6	77	15	8.8	3.24
Subplot 4												
AE	0– 5	s	0.0	0.885	4.34	3.59	3810.6	452.4	207	27	67.1	9.76
Bs	5– 50	s	0.1	1.509	5.16	4.51	145.4	134.0	11	2	12.0	40.74
BC	50– 78	s	0.1	1.505	5.64	4.89	89.8	57.5	7	1	6.6	23.79
C1	78–168	s	0.1	1.619	6.63	5.86	28.8	27.3	51	17	9.7	6.82
C2	168–183	cos	8.0	1.752	8.33	7.55	76.2	75.9	1920	63	9.7	0.00
C3	183–307	s	0.1	1.777	7.66	7.06	33.8	45.9	490	39	7.1	2.19
C4	307–411	s	0.1	1.798	8.13	7.40	14.4	35.9	1870	43	5.7	0.00
C5	411–450	cos	4.0	1.805	8.13	7.26	100.6	59.3	2010	54	9.6	0.00

Site M. ECS No. 113. Burgis landform: Glennie moraine.
Location: T. 26 N., R. 5 E., Sec. 8, NW of NW.

General Description: Nearly level area on bench feature at the south side of morainal hill. A water table is present at a depth of about 145 cm. Surface soil is sand; substratums are stratified sands, silts, and clays. A clay layer in the substratum results in perched water.

Soil family classification: Typic Haplorthods, sandy, mixed, frigid.

Depositional environment/parent material: Outwash sand over lacustrine silt and clay.

Soil Pedon Data:

Horizon	Depth cm	Texture	Cs fr vol %	Est BD g/cc	pH H2O	pH CaCl2	TKN	TKP	Ca	Mg	K	Bray's P
							<-------		mg/kg			------->
Subplot 1												
A	0- 2		0.3	1.014	4.12	3.52	2684.0	196.7	546	110	81.2	15.44
EB	2- 7	s	1.2	1.434	4.31	3.75	383.6	108.9	38	16	12.0	5.48
Bs	7- 33	s	3.5	1.459	5.61	4.66	253.6	120.2	129	30	20.3	24.18
Ex	33- 52	sil	7.8	1.800	5.95	5.39	189.4	71.4	473	74	19.0	0.25
B/Ex	52- 86	sicl	0.2	1.800	6.66	6.00	374.4	129.1	2010	389	84.7	1.90
C	86-152	sic	0.0	1.615	7.95	7.49	443.6	334.1	5580	622	134.1	0.00
Subplot 2												
A	0- 6	s	0.0	1.152	4.31	3.42	1688.4	123.1	768	136	49.4	6.82
EB	6- 11	s	0.2	1.456	4.46	3.62	324.0	42.1	107	20	9.3	1.58
Bs1	11- 43	s	2.9	1.383	6.04	5.11	542.0	112.8	322	44	13.8	4.15
Bs2	43- 58	s	2.9	1.541	5.95	5.69	201.2	81.8	304	43	11.8	2.39
BC	58-137	s	1.4	1.626	6.91	6.25	68.8	43.4	206	38	8.7	0.84
Subplot 3												
A	0- 4		0.6	0.901	4.97	3.81	3664.0	331.7	182	58	46.8	11.29
AB	4- 12	s	1.5	1.322	4.20	3.60	781.2	82.8	41	9	15.2	11.05
Bs1	12- 41	s	4.2	1.476	5.79	5.72	243.4	167.2	75	18	15.2	115.00
Bs2	41- 54	s	1.5	1.552	6.25	5.11	145.6	129.1	40	10	10.6	66.75
BC	54- 68	s	2.6	1.477	6.03	5.22	71.2	98.6	42	6	6.9	62.94
C1	68-137	s	5.5	1.627	6.51	5.27	59.2	54.3	56	10	6.0	9.07
C2	137-213	s	4.3	1.751	7.55	6.96	95.2	77.1	380	83	12.5	1.68
Subplot 4												
A	0- 5	s	0.0	0.868	4.14	3.68	3978.4	216.7	640	84	72.4	41.64
EB	5- 9	s	0.3	1.455	4.34	3.50	327.2	55.0	58	17	10.7	3.68
Bs	9- 43	s	0.1	1.455	4.86	4.54	308.2	53.1	108	22	15.7	5.68
Em	43- 68	s	0.3	1.700	6.95	6.05	92.6	53.9	134	26	8.8	0.49
BC	68-112	grls	20.1	1.627	6.70	5.91	117.0	108.4	260	43	11.3	0.12
C1	112-140	si	0.0	1.469	7.79	7.54	251.6	267.7	3610	198	41.2	0.00
C2	140-175	cl	0.0	1.742	7.75	7.33	419.8	379.3	4440	464	156.0	0.00
C3	175-190	si	0.0	1.755	8.10	7.31	256.4	268.7	3560	170	39.1	0.00

Site N. ECS No. 114. Burgis landform: Glennie moraine.
Location: T. 26 N., R. 5 E., Sec. 10, center of SW quarter.

General Description: Slopes average 9% along sides of a small east-west trending drainage valley among undulating hills. A till layer with high silt content is present at a depth of about 30 cm. Surface soils are loamy sand, sandy loam, silt loam, or loam. Substratums contain varied textures.

Soil family classification: Typic Fragiboralfs, fine-loamy, mixed.

Depositional environment/parent material: Port Huron basal till.

Soil Pedon Data:

Horizon	Depth cm	Texture	Cs fr vol %	Est BD g/cc	pH H2O	pH CaCl2	TKN	TKP	Ca	Mg	K	Bray's P
							<——		mg/kg			——>
Subplot 1												
A	0- 4	l	0.0	0.621	6.28	5.98	6953.2	992.5	1446	266	99.6	11.15
Em	4- 20	l	0.0	1.700	6.41	5.81	517.0	123.0	780	120	54.2	2.28
E/Bx	20- 43	sl	0.1	1.800	6.17	5.89	284.6	77.2	935	178	81.5	0.66
Bt	43- 70	sil	0.5	1.618	7.21	6.75	306.8	168.3	1215	252	85.3	0.00
BC	70-125	sicl	0.0	1.587	7.25	6.65	401.0	304.8	1250	226	72.0	2.39
C1	125-198	sil	0.0	1.744	7.41	6.82	380.2	350.3	980	168	43.0	0.00
C1	198-259	si	0.0	1.772	7.21	6.73	315.6	316.8	1102	202	52.9	0.00
C2	259-366	lfs	0.0	1.791	7.37	6.53	153.4	200.5	489	86	24.0	2.75
Subplot 2												
A	0- 5	ls	0.2	0.877	4.61	3.87	3891.2	308.0	1866	268	151.6	19.27
Bw	5- 28	ls	4.0	1.435	6.14	5.49	379.4	135.8	530	68	20.1	9.90
E/Bx	28- 50	sl	0.8	1.800	6.22	5.48	148.2	60.9	540	117	35.0	0.97
Bt	50- 75	sicl	0.0	1.618	7.13	6.89	403.4	268.9	2010	616	100.3	1.28
BC	75-152	s	0.1	1.702	8.10	7.52	339.6	324.1	4220	371	69.8	0.00
Subplot 3												
A	0- 3	l	2.0	0.557	5.46	5.15	7952.6	528.9	5240	524	288.0	33.72
Bw	3- 22	grl	19.0	1.446	5.71	4.95	351.8	244.3	358	76	34.4	42.33
B/Ex	22- 38	sicl	0.2	1.800	6.34	6.23	468.6	193.6	1700	326	156.5	17.40
Bt	38- 63	cl	0.0	1.618	7.23	6.97	537.8	321.7	2440	606	206.0	10.53
BC	63- 152	sicl	0.1	1.600	8.12	7.57	290.6	340.4	4660	349	95.1	0.00
Subplot 4												
Oa	0- 5	om	0.0	0.702	6.22	5.93	5847.6	335.6	9480	1188	524.0	58.56
E	5- 21	sil	0.3	1.525	5.95	5.19	599.8	195.0	748	148	49.9	17.28
E/Bx	21- 49	l	0.3	1.800	6.39	5.98	277.8	88.5	700	182	75.4	1.48
Bt	49- 69	scl	0.3	1.618	5.76	5.19	248.0	132.5	931	275	69.1	4.83
BC	69-122	sil	0.0	1.487	5.79	5.22	495.0	272.0	1468	428	71.3	4.16
C	122-183	sicl	1.0	1.739	5.94	6.02	524.8	210.6	526	72	38.3	37.13

Site O. ECS No. 116. Burgis landform: West Branch moraine.
Location: T. 25 N., R. 4 E., Sec. 1, SW of SW.

General Description: Slopes average 7% with a mostly SE aspect in an area of rolling ridges. Surfaces may be eroded. A till layer of variable thickness is present at depths of about 30 cm, containing limestones. Surface textures are sandy loam; substratums where sampled are stratified sands and loamy sands.

Soil family classification: Typic Fragiboralfs, fine-loamy, mixed.

Depositional environment/parent material: Port Huron basal till.

Soil Pedon Data:

Horizon	Depth cm	Texture	Cs fr vol %	Est BD g/cc	pH H2O	pH CaCl2	TKN	TKP	Ca	Mg	K	Bray's P
							<——		mg/kg			——>
Subplot 1												
Oa,A	0- 7	om	0.1	0.792	5.96	5.64	4777.0	389.6	4540	500	174.0	43.52
E	7- 10	fsl	0.7	1.381	6.55	5.64	549.4	117.9	746	97	24.2	10.10
Bw	10- 20	fsl	0.3	1.394	5.22	4.37	506.4	482.7	434	62	35.9	99.13
Ex	20- 32	fsl	0.4	1.800	5.25	4.39	310.0	153.4	305	61	28.5	13.35
B/Ex	32- 64	scl	0.2	1.800	5.37	4.72	269.4	111.2	1075	281	82.5	4.33
Bt	64-110	scl	0.6	1.618	6.91	6.08	198.0	96.6	468	56	10.1	21.53
C	110-152	sicl	0.8	1.606	8.33	7.67	169.8	240.7	3740	273	43.9	0.00
Subplot 2												
A	0- 2	sl	0.0	0.830	5.94	5.68	4364.8	384.4	5000	424	232.0	46.14
Bw	2- 9	sl	1.1	1.362	6.00	5.36	618.6	308.9	494	76	44.4	37.24
Ex	9- 18	sl	1.1	1.800	7.48	6.92	39.2	56.0	250	58	8.5	3.20
B/Em	18- 39	scl	0.0	1.700	5.48	4.94	447.4	213.0	1410	311	78.0	15.78
Bt	39- 68	cl	1.0	1.618	8.06	7.64	364.8	285.3	3340	403	64.3	1.36
BC	68- 97	scl	2.4	1.649	7.85	7.38	236.2	147.2	1145	300	40.0	1.75
C	97-152	grcos	25.0	1.609	7.91	7.58	32.4	53.0	1840	48	6.2	0.94
Subplot 3												
Oa	0- 3	om	0.0	0.555	6.20	6.32	7984.8	483.1	10560	899	711.0	58.25
A	3- 7	sl	1.2	1.199	5.92	5.43	1402.4	223.5	2700	252	101.8	40.74
Bw	7- 26	sl	4.3	1.447	5.97	4.98	347.6	212.9	501	43	24.6	17.99
Ex	26- 47	sl	4.4	1.800	4.04	5.33	185.0	96.6	451	37	19.5	2.68
BC	47- 78	sl	3.6	1.543	6.40	5.64	249.6	143.7	442	35	15.1	9.03
C1	78-137	sl	3.0	1.625	8.11	7.58	87.8	82.5	823	134	18.9	6.27
C2	137-396	s	2.2	1.782	8.42	7.63	17.2	59.1	1686	56	6.3	0.00
C2-s	351-366	sl	2.3	1.798	7.72	6.96	80.6	58.4	1065	92	23.9	0.00
Subplot 4												
Oa	0- 5	om	0.0	0.595	6.39	6.13	7342.2	599.3	12560	1044	735.2	53.28
AE	5- 15	sl	0.9	1.361	5.96	5.29	625.0	186.7	601	101	26.5	21.76
Bw	15- 31	sl	0.3	1.433	5.79	4.93	386.0	265.5	568	85	31.8	38.71
B/Em	31- 61	scl	0.4	1.700	5.33	4.68	281.2	147.1	1065	235	72.1	5.51
Bt	61-105	scl	1.4	1.618	6.87	6.35	560.4	373.2	1500	413	83.9	5.39
C	105-183	ls	1.1	1.526	7.40	6.46	94.4	82.3	373	81	18.1	0.00

Site P. ECS No. 118. Burgis landform: West Branch moraine.
Location: T. 25 N., R. 5 E., Sec. 7, NW of NE.

General Description: Slopes average 15% in a lower slope position around the U-shaped end of a small valley filled with outwash sand. Aspect is mostly south, but the valley is narrow and shaded. A water table is present at about 194 cm, apparently due to perching above a clay layer. Surface soils are sandy, with well-developed loamy sand spodic B horizons. Substratums above the water table are sandy.

Soil family classification: Typic Haplorthods, sandy, mixed, frigid.

Depositional environment/parent material: Outwash sand over lacustrine clay or clayey till.

Soil Pedon Data:

Horizon	Depth cm	Texture	Cs fr vol %	Est BD g/cc	pH H2O	pH CaCl2	TKN <—	TKP	Ca mg/kg	Mg	K	Bray's P —>
Subplot 1												
Oa	0– 4	om	0.0	0.885	3.92	3.43	3813.2	150.0	1332	148	197.2	28.92
E	4– 20	s	0.3	1.571	4.55	3.70	117.8	4.6	22	6	6.3	0.03
Bhs	20– 25	ls	0.6	1.457	5.14	4.22	363.8	191.4	202	25	16.0	38.73
Bs	25– 52	s	0.7	1.471	5.82	4.82	342.4	81.6	132	16	11.4	10.34
BC	52– 82	s	1.7	1.543	5.90	4.97	149.8	51.3	87	7	8.2	11.55
C1	82–183	lfs	0.0	1.605	6.17	6.11	209.6	124.4	608	100	25.9	3.75
C2	183–244	s	0.0	1.768	7.68	7.04	34.2	104.4	246	45	8.6	3.95
Subplot 2												
A	0– 5	om	0.6	0.810	5.63	5.07	4581.2	281.0	3600	384	151.0	28.89
E	5– 15	s	0.9	1.495	5.08	3.91	236.6	34.3	89	18	6.0	0.87
Bs1	15– 27	ls	1.0	1.436	5.30	4.32	421.6	67.4	350	49	16.0	3.08
Bs2	27– 63	s	0.7	1.469	5.51	4.45	391.6	69.9	139	16	12.9	2.74
BC	63– 83	s	0.3	1.599	6.49	6.20	207.2	88.6	341	32	10.0	13.79
C	83–105	s	0.2	1.634	7.29	6.44	125.0	58.7	250	21	7.8	7.10
Subplot 3												
A	0– 3	om	0.0	0.720	5.24	4.97	5613.8	407.7	6320	630	564.0	62.65
E	3– 5	s	0.1	1.518	5.46	4.35	193.4	18.9	231	22	5.6	1.32
Bs	3– 69	ls	0.1	1.519	5.95	5.07	260.4	131.0	327	25	9.6	20.35
BC	69–125	s	0.0	1.628	6.59	6.30	92.0	80.1	332	63	18.4	5.12
C	125–229	fs	0.0	1.752	8.23	7.78	100.0	159.8	2490	147	21.4	0.09
Subplot 4												
A	0– 12	ls	0.4	1.001	5.60	5.00	2784.8	133.2	1814	140	42.8	12.12
E	12– 23	s	0.2	1.516	6.39	5.64	198.4	36.7	370	30	4.6	1.05
Bs1	23– 33	ls	0.4	1.476	6.89	6.93	340.6	99.6	867	51	9.1	9.98
Bs2	33– 57	ls	0.2	1.562	6.77	5.82	186.0	94.5	468	19	7.1	29.98
BC	57– 77	s	0.2	1.554	7.17	6.35	183.0	68.5	329	10	7.0	14.46
C1	77–152	s	0.6	1.615	6.82	6.06	81.8	37.9	192	7	6.5	10.08
C2	152–198	ls	0.0	1.751	7.81	7.14	78.4	87.2	361	57	14.3	0.47
C3	198–244	lfs	0.0	1.770	8.20	7.62	144.6	281.6	3500	173	32.7	0.00

Site Q. ECS No. 122. Burgis landform: West Branch moraine.
Location: T. 26 N., R. 3 E., Sec. 22, NE of NE.

General Description: Slopes average 15% along a SE facing bench on a hillside formed of outwash sand overlying flow till or ice-rafted till inclusions. Surface soils are sandy. Textural layers of loamy sand, sandy loam, silty loam, and clay loam are found at various depths in the subsoil and substratum.

Soil family classification: Alfic Haplorthods, coarse-loamy, mixed, frigid.

Depositional environment/parent material: Outwash sand with ice-rafted inclusions.

Soil Pedon Data:

Horizon	Depth cm	Texture	Cs fr vol %	Est BD g/cc	pH H2O	pH CaCl2	TKN	TKP	Ca	Mg	K	Bray's P
							<———		mg/kg			———>
Subplot 1												
A	0- 5	s	0.0	1.303	4.21	3.37	863.2	77.1	317	38	34.7	4.85
E	5- 11	s	0.3	1.548	4.30	3.50	146.8	23.9	22	6	10.4	1.83
Bs	11- 54	s	5.8	1.513	5.44	4.43	167.4	49.9	19	6	13.6	7.22
BC	54- 71	s	5.0	1.491	6.01	4.74	80.4	31.9	25	4	10.9	10.94
C1,C2	71-168	sl	0.0	1.622	7.01	6.47	149.8	118.2	1293	227	65.4	0.32
C3	168-198	s	0.0	1.755	7.18	6.39	38.2	37.4	155	34	8.8	0.00
C4	198-229	cl	0.0	1.768	6.90	6.49	322.4	316.2	3035	656	218.0	6.74
Subplot 2												
A/E	0- 10	s	0.1	1.490	4.98	4.00	247.0	31.1	116	18	14.9	1.61
Bs1	10- 25	s	0.7	1.469	5.63	4.67	204.2	49.2	89	13	18.3	7.12
Bs2	25- 64	s	5.5	1.563	5.83	4.93	90.2	58.9	49	8	21.0	7.77
C	64-213	sil	0.0	1.506	8.15	7.57	228.0	311.2	5000	459	74.2	0.00
Subplot 3												
A	0- 3	s	0.0	1.003	3.94	3.29	2769.4	185.1	302	84	143.6	30.80
Bs1	3- 28	s	7.4	1.464	4.85	4.27	208.2	70.2	8	4	13.5	9.75
Bs2	28- 54	s	7.9	1.550	5.26	4.47	108.0	85.9	17	6	14.4	36.03
BC	54- 87	s	3.5	1.548	5.20	4.47	70.8	53.3	39	19	19.3	22.20
C	87-411	ls	0.6	1.778	7.67	7.27	23.8	45.3	1263	40	9.0	1.13
Subplot 4												
A	0- 2	s	0.0	0.867	4.01	3.27	3988.0	248.4	722	146	216.0	23.57
E	2- 5	s	0.2	1.454	4.21	3.45	330.4	63.4	35	12	16.1	5.58
Bs1	5- 16	s	0.3	1.453	4.65	4.01	207.2	131.9	10	3	13.5	58.25
Bs2	16- 48	s	3.4	1.510	5.16	4.50	174.4	189.3	17	4	16.9	76.07
BC	48- 75	s	8.6	1.482	5.59	4.50	62.8	101.3	14	6	14.7	49.56
C	75-450	s	0.8	1.781	7.92	7.45	13.0	20.1	1600	37	8.5	2.41

Site R. ECS No. 124. Burgis landform: Glennie moraine.
Location: T. 27 N., R. 5 E., Sec. 31, center of W half of NE.

General Description: Slopes average 16% along a N-facing slope in a dendritic network of rolling ridges. Soils are sandy throughout the solum, containing gravel and cobbles. Substratums are stratified sands with some loamy textural layers.

Soil family classification: Entic Haplorthods, sandy, mixed, frigid.

Depositional environment/parent material: Outwash sand.

Soil Pedon Data:

Horizon	Depth cm	Texture	Cs fr vol %	Est BD g/cc	pH H2O	pH CaCl2	TKN	TKP	Ca	Mg	K	Bray's P
							<—		mg/kg			—>
Subplot 1												
AE	0- 6	s	0.0	1.314	4.26	3.54	818.2	92.2	125	20	12.8	5.79
EB	6- 19	s	0.3	1.500	4.97	4.26	226.8	108.1	25	4	8.8	27.30
Bs	19- 43	s	5.4	1.507	5.67	4.68	176.6	97.1	63	8	9.2	24.13
BC	43- 72	fs	0.1	1.593	5.33	4.81	93.2	67.2	29	5	8.0	27.51
C1	72-244	fs	0.0	1.742	6.35	5.30	14.2	68.1	53	12	7.5	14.65
C2	244-307	sil	0.0	1.784	8.55	6.83	138.8	240.2	3335	232	18.3	0.97
Subplot 2												
A	0- 5	s	0.0	1.233	4.22	3.51	1213.8	126.7	238	36	28.0	13.86
Bs1	5- 23	s	0.1	1.463	5.06	4.30	199.6	102.2	10	3	7.0	30.01
Bs2	23- 54	s	5.4	1.508	5.08	4.41	223.8	214.5	6	2	3.9	56.55
BC	54- 72	s	0.0	1.497	5.23	4.77	50.6	111.8	4	1	2.5	68.01
C	72-450	s	0.0	1.781	7.27	7.38	14.4	29.6	720	25	4.9	6.21
Subplot 3												
AE	0- 4	s	0.1	1.371	4.24	3.87	587.0	102.9	58	20	31.1	12.28
Bs	4- 43	s	3.4	1.479	5.31	4.55	212.4	110.2	37	13	12.7	35.30
BC	43- 75	s	5.9	1.601	5.35	4.59	85.2	69.5	17	5	7.4	25.97
C1	75-157	s	4.4	1.673	7.06	6.75	274.0	265.9	1756	530	85.7	0.52
C2	157-450	s	0.0	1.790	8.43	7.40	26.4	44.5	856	36	5.0	0.98
Subplot 4												
A	0- 5	s	0.3	1.247	5.17	4.25	1141.2	121.7	746	64	26.0	8.38
E	5- 15	s	0.9	1.549	5.13	6.07	145.6	74.6	176	22	18.9	19.19
Bs	15- 61	cbs	17.9	1.530	5.85	4.71	150.8	83.3	77	12	9.7	22.32
C	61-411	s	0.9	1.775	6.17	5.45	46.6	40.7	529	49	7.2	3.40

Site S. ECS No. 126. Burgis landform: Fletcher Pond channelled uplands.
Location: T. 26 N., R. 7 E., Sec. 15, SW of NE.

General Description: Nearly level area on top of morainal hill. A thick till layer is present at a depth of about 35 cm and continues through the solum, containing limestones. Surface soils are loamy sand and sandy loam. Substratums were not sampled.

Soil family classification: Two pedons, Typic Eutroboralfs, fine-loamy, mixed; two pedons, Typic Fragiboralfs, fine-loamy, mixed.

Depositional environment/parent material: Port Huron basal till, possibly eroded.

Soil Pedon Data:

Horizon	Depth cm	Texture	Cs fr vol %	Est BD g/cc	pH H2O	pH CaCl2	TKN	TKP	Ca	Mg	K	Bray's P
							<------		mg/kg			------>
Subplot 1												
A	0- 9	sl	0.4	1.055	4.84	4.36	2365.6	187.1	1354	120	59.1	13.83
BE	9- 15	sl	0.5	1.382	5.26	4.25	546.6	161.1	423	48	40.7	33.80
Ex	15- 24	fsl	0.4	1.800	5.88	4.77	176.4	81.9	252	46	66.9	10.10
B/Ex	24- 50	scl	0.2	1.800	5.67	4.66	253.4	90.8	867	218	114.5	1.41
Bt	50-107	scl	0.6	1.618	7.92	7.73	282.2	300.1	3420	490	97.2	4.75
C	107-152	sicl	0.3	1.606	8.06	7.40	180.2	258.1	4040	301	64.2	0.00
Subplot 2												
A	0- 10	lfs	1.1	1.036	6.04	5.34	2505.8	156.3	2100	198	67.2	7.45
Bw	10- 35	lfs	1.1	1.362	6.12	5.43	618.4	153.4	652	84	18.1	2.94
E'	35- 63	lfs	0.4	1.493	7.34	6.46	240.8	133.6	547	71	15.3	8.07
Bt	63- 91	scl	0.5	1.618	8.00	7.61	268.6	288.4	2370	367	85.3	1.55
C	91-152	sicl	1.6	1.618	8.37	7.63	142.4	228.4	3820	205	59.1	0.00
Subplot 3												
A	0- 10	s	0.9	1.176	6.05	5.24	1542.4	127.0	1366	102	33.0	10.75
E	10- 17	ls	1.6	1.484	5.75	4.91	260.6	50.3	280	31	12.5	6.15
Bw	17- 44	sl	2.6	1.453	5.55	4.59	331.6	131.5	362	48	30.3	3.64
Ex	44- 58	fsl	0.9	1.800	6.52	5.23	84.0	62.4	286	51	20.6	0.88
B/Ex	58- 80	scl	0.9	1.800	6.43	5.95	213.0	135.9	1183	271	78.0	1.07
Bt	80-122	scl	0.8	1.618	7.93	7.45	249.2	294.0	3900	375	87.8	0.00
C	122-152	sicl	1.5	1.601	8.42	7.78	177.4	279.2	3840	255	72.8	0.00
Subplot 4												
A	0- 14	sl	1.4	1.100	6.12	5.91	2038.6	352.4	1804	178	86.4	23.05
Bw	14- 21	ls	2.0	1.460	6.84	5.80	314.2	119.4	390	52	32.2	5.51
E	21- 26	sl	0.6	1.495	4.96	4.32	236.6	95.0	480	86	29.8	1.90
Bt	26- 98	scl	0.3	1.618	7.81	7.35	345.6	326.8	3840	414	111.0	0.04
C	98-152	sicl	0.6	1.621	8.24	7.40	115.2	256.7	4180	242	65.4	0.00

Site T. ECS No. 127. Burgis landform: West Branch moraine.
Location: T. 26 N., R. 4 E., Sec. 28, NE of NW.

General Description: Slopes average 10% on a ridgetop with mostly S aspect. Site adjoins the AuSable River Valley; sand textures may be a result of fluvial activity from glacial drainage through the valley. Soils are sandy throughout the sampled depth of 450 cm. Substratums contain gravel strata.

Soil family classification: Typic Udipsamments, mixed, frigid.

Depositional environment/parent material: Outwash sand.

Soil Pedon Data:

Horizon	Depth cm	Texture	Cs fr vol %	Est BD g/cc	pH H2O	pH CaCl2	TKN	TKP	Ca	Mg	K	Bray's P
							<—		mg/kg			—>
Subplot 1												
A	0- 4	s	0.0	1.243	4.22	3.46	1160.8	114.4	92	34	50.0	7.93
Bs1	4- 11	s	0.0	1.388	4.83	4.21	393.8	69.5	16	7	11.0	4.60
Bs2	11- 48	s	0.3	1.505	4.80	4.53	174.0	81.2	7	2	8.5	19.58
BC	48- 80	s	0.2	1.505	4.83	4.71	52.6	32.5	5	1	5.3	20.14
C	80-450	s	0.2	1.782	7.72	7.41	16.8	42.6	532	18	3.8	15.27
Subplot 2												
A	0- 5	s	0.0	1.053	4.19	3.54	2380.4	118.7	114	29	50.9	7.00
Bs1	5- 17	s	2.3	1.394	5.02	4.25	397.4	102.2	19	5	12.2	7.91
Bs2	17- 31	s	2.7	1.481	5.25	4.41	210.2	90.3	9	3	6.9	17.33
Bs3	31- 55	s	2.7	1.545	5.26	4.64	138.4	97.6	5	2	5.8	34.94
BC	55- 79	s	0.2	1.538	5.24	4.80	36.0	55.7	0	0	3.5	25.01
C	79-450	s	0.9	1.782	8.29	7.55	27.4	57.2	1252	39	5.1	4.03
Subplot 3												
A	0- 4	s	0.0	1.214	5.11	3.42	1316.8	89.2	52	32	65.2	10.35
Bs1	4- 12	s	5.0	1.411	4.80	4.12	324.8	69.0	16	5	14.7	24.47
Bs2	12- 46	s	5.8	1.498	5.12	4.58	191.2	141.0	14	2	8.4	50.52
BC	46- 60	s	0.5	1.599	5.73	4.85	87.0	99.8	11	1	4.5	44.62
C	60-450	s	0.5	1.780	7.74	7.49	16.8	25.3	573	25	3.6	3.48
Subplot 4												
A	0- 3	s	0.0	1.345	4.53	3.83	684.2	60.3	59	12	30.3	2.78
Bs1	3- 27	s	3.1	1.459	5.22	4.45	218.6	59.5	7	2	11.0	5.21
Bs2	27- 48	s	3.0	1.530	5.35	4.67	147.2	87.8	7	1	7.9	18.72
BC	48- 81	s	1.7	1.517	5.23	4.78	38.0	37.1	1	1	4.5	10.55
C1	81-274	s	0.1	1.753	6.07	5.25	34.6	30.6	20	6	4.2	9.38
C2	274-351	s	11.0	1.791	8.50	7.20	65.6	62.7	1254	72	5.2	0.00
C3	351-442	cos	3.1	1.802	8.75	7.57	18.8	37.9	1660	46	5.3	0.65

Site U. ECS No. 134. Burgis landform: West Branch moraine.
Location: T. 26 N., R. 2 E., Sec. 22, NE of NW.

General Description: Slopes average 5% on a planar area sloping gently to the north near the edge of the moraine at its border with the AuSable river valley. Soils have loam, silt loam, and loamy fine sand textures in the solum. Substratums are fine sand and loamy fine sand.

Soil family classification: Two pedons, Typic Fragiboralfs, fine-silty, mixed; two pedons, Typic Haplorthods, sandy, mixed, frigid.

Depositional environment/parent material: Lacustrine fine sands and silts.

Soil Pedon Data:

Horizon	Depth cm	Texture	Cs fr vol %	Est BD g/cc	pH H2O	pH CaCl2	TKN	TKP	Ca	Mg	K	Bray's P
							<—		mg/kg			—>
Subplot 1												
AE	0- 8	lfs	0.0	1.259	5.59	4.44	1075.6	110.6	756	66	38.4	9.18
E	8- 16	fs	0.2	1.511	6.15	4.97	207.4	43.1	236	25	9.6	7.06
Bs1	16- 25	lfs	0.6	1.484	5.88	5.00	355.2	101.1	424	40	16.8	3.50
Bs2	25- 66	fs	0.0	1.543	5.94	4.85	250.6	84.6	200	26	23.4	1.97
C1	66-198	fs	0.0	1.690	6.40	6.39	429.4	313.9	1494	380	65.1	0.94
C2	198-450	lfs	0.0	1.793	8.45	7.68	9.6	71.4	2360	45	8.0	0.00
Subplot 2												
A	0- 2	l	4.2	0.489	6.73	6.42	9143.6	691.5	8520	817	330.8	35.44
Bw	2- 12	l	13.9	1.330	5.42	4.83	747.6	311.3	608	105	54.6	11.05
B/Ex	12- 31	sl	10.0	1.800	5.14	4.48	366.2	121.5	1003	246	140.0	1.62
Bt	31- 60	sicl	0.0	1.618	5.08	4.55	360.6	211.5	1317	446	137.4	6.89
BC	60- 88	sil	10.0	1.526	6.80	6.23	365.2	293.1	1610	642	82.6	6.62
C1	88-168	vfs	0.3	1.618	8.73	7.67	204.8	341.7	3060	183	22.8	0.00
C2	168-450	fs	0.0	1.791	8.61	7.47	23.0	88.5	2550	67	7.9	0.00
Subplot 3												
A	0- 2	lfs	0.0	0.687	6.78	6.21	6036.0	381.1	4720	274	206.0	31.34
E	2- 20	fs	0.0	1.453	6.95	6.14	332.6	28.6	414	26	16.0	0.78
Bs	20- 37	lfs	0.4	1.401	5.49	4.58	673.8	189.2	360	48	29.9	2.72
BC	37- 59	fs	0.3	1.486	5.91	4.78	256.8	123.9	91	8	13.8	16.06
C1	59-168	fs	0.0	1.623	7.61	7.47	113.6	109.8	526	165	16.6	0.68
C2	168-290	lfs	0.0	1.773	8.37	7.70	35.8	92.5	2380	57	6.7	0.00
Subplot 4												
A	0- 2	sil	0.6	0.834	6.64	6.05	4330.0	459.9	7720	551	335.6	39.03
Ex	2- 10	cbsil	21.2	1.800	5.70	4.89	608.2	167.8	694	110	50.6	0.80
B/Ex	10- 27	sil	0.2	1.800	7.39	7.15	391.4	92.8	905	221	75.5	0.00
Btx	27- 59	sicl	0.0	1.800	5.36	5.06	409.0	176.3	1610	446	113.6	6.31
BC	59- 90	sil	0.0	1.522	7.16	6.83	381.4	276.1	1230	360	50.2	0.21
C1	90-107	sicl	0.5	1.626	8.54	7.92	183.6	231.2	4000	299	48.5	0.00
C2	107-450	fs	0.0	1.785	9.05	7.77	24.8	88.3	2490	52	6.8	0.23

Site V. ECS No. 136. Burgis landform: Eldorado Kamic Ridges.
Location: T. 25 N., R. 1 W., Sec. 1, NW of SE.

General Description: Slopes average 7% along a NE-facing hillside. Soils are sand with loamy or gravelly or cobbly strata occurring throughout the sampled depth.

Soil family classification: Entic and Alfic Haplorthods, sandy, mixed, frigid.

Depositional environment/parent material: Outwash sand with ice-rafted or flow till inclusions.

Soil Pedon Data:

Horizon	Depth cm	Texture	Cs fr vol %	Est BD g/cc	pH H2O	pH CaCl2	TKN	TKP	Ca	Mg	K	Bray's P
							<————		mg/kg			————>
Subplot 1												
A	0- 1	s	0.3	1.124	5.73	5.08	1874.8	194.9	948	98	142.4	22.64
E	1- 5	s	2.3	1.382	4.64	3.86	547.4	94.4	106	24	33.5	8.08
Bs1	5- 22	cbs	18.5	1.407	5.00	4.35	372.8	164.5	23	7	14.8	23.71
Bs2	22- 37	cbs	19.0	1.510	5.18	4.45	157.4	184.0	17	3	12.0	61.90
BC	37- 54	grs	17.3	1.626	5.69	4.66	64.4	76.8	18	6	9.5	29.46
C1	54-122	s	0.2	1.652	5.91	4.61	23.4	54.8	33	15	7.9	6.41
C2	122-290	s	0.7	1.765	7.12	6.96	60.4	56.4	304	60	9.5	0.79
C3	290-381	s	3.2	1.795	8.55	7.68	20.4	62.5	3060	69	13.5	0.77
Subplot 2												
A	0- 2	s	0.0	0.727	3.85	3.11	5530.4	347.9	502	140	302.0	81.66
E	2- 11	s	1.1	1.464	4.53	3.76	306.6	77.0	24	9	15.2	3.74
Bs	11- 30	ls	4.0	1.463	5.31	4.46	330.6	327.6	23	5	15.6	120.71
BC	30- 49	cbs	23.6	1.590	5.94	4.87	96.0	125.2	61	15	17.2	33.79
C1	49-183	s	5.8	1.615	6.40	5.45	48.0	33.0	182	45	19.6	3.90
C2	183-320	ls	0.3	1.779	6.19	5.56	43.6	68.8	300	84	30.4	6.33
C3	320-351	sl	0.2	1.795	6.20	5.62	84.8	118.5	953	257	58.1	6.65
C4	351-450	fs	0.2	1.803	9.20	7.95	14.8	78.2	2965	90	16.8	2.48
Subplot 3												
A	0- 3	s	2.2	1.116	3.81	3.19	1927.2	154.2	226	92	125.3	17.93
E	3- 6	s	1.0	1.477	3.82	3.36	275.0	55.1	23	8	11.1	2.60
Bs	6- 26	cbls	16.9	1.471	5.05	4.37	289.0	119.1	25	7	20.2	12.92
BC	26- 64	ls	11.2	1.595	5.87	5.00	91.2	54.3	97	25	16.1	14.41
C1	64-107	s	0.7	1.631	7.33	5.80	29.8	37.9	89	17	10.9	1.79
C2	107-152	ls	0.8	1.578	8.53	7.67	80.6	128.7	2340	152	33.8	2.81
C3	152-183	s	0.7	1.748	8.50	7.75	65.8	143.6	3240	102	19.9	0.00
C4	183-229	s	0.0	1.765	8.85	7.38	14.4	36.6	1493	36	5.3	0.00
C5	229-290	ls	0.0	1.781	7.38	6.93	101.4	146.7	662	115	29.0	5.29
C6	290-450	s	0.6	1.799	8.09	7.65	11.2	35.3	1429	42	5.5	0.00

Site V, cont.
Subplot 4

A	0– 1	s	0.0	1.126	3.87	3.23	1862.8	197.9	160	90	242.0	23.16
E	1– 2	s	1.4	1.490	4.09	3.46	246.6	50.3	14	8	14.7	6.19
Bs1	2– 6	s	1.8	1.389	4.68	3.92	365.2	144.0	16	8	16.8	18.53
Bs2	6– 66	s	9.8	1.498	5.88	4.88	237.8	180.7	67	19	21.7	43.11
BC	66–114	s	7.0	1.623	5.86	4.80	48.6	52.1	61	17	17.9	12.17
C1	114–259	s	5.1	1.757	6.04	5.04	32.8	18.6	96	23	14.1	2.75
C2	259–290	ls	2.3	1.784	7.91	7.57	16.8	55.9	560	100	17.2	2.71
C3	290–411	s	0.0	1.797	7.74	7.17	9.4	34.0	380	37	9.5	2.38
C4	411–450	s	2.1	1.805	8.09	7.67	26.4	57.2	1530	33	5.3	0.00

Site W. ECS No. 137. Burgis landform: Eldorado Kamic Ridges.
Location: T. 26 N., R. 1 W., Sec. 25, NE of SW.

General Description: Nearly level area within a pitted outwash feature; slight west-facing slope. Soils are sand or loamy sand, with gravelly strata occurring throughout the sampled depth.

Soil family classification: Entic Haplorthods, sandy, mixed, frigid.

Depositional environment/parent material: Outwash sand with ice-rafted or flow till inclusions.

Soil Pedon Data:

Horizon	Depth cm	Texture	Cs fr vol %	Est BD g/cc	pH H2O	pH CaCl2	TKN	TKP	Ca	Mg	K	Bray's P
							<—		mg/kg			—>
Subplot 1												
A	0- 2	s	0.0	0.976	3.92	3.23	2996.0	186.7	371	77	182.2	17.03
EB	2- 11	s	1.6	1.428	4.10	3.57	400.0	41.9	18	8	18.7	4.45
Bs1	11- 29	ls	11.6	1.459	4.78	4.31	341.0	107.6	23	7	18.1	13.43
Bs2	29- 56	ls	10.9	1.561	5.49	4.52	172.8	44.4	49	15	15.7	7.16
C1	56-137	s	5.5	1.633	5.65	4.93	43.0	37.7	103	26	10.6	4.76
C2	137-450	s	1.0	1.788	8.28	7.61	12.0	30.0	897	47	6.2	1.69
Subplot 2												
A,EB	0- 5	s	0.5	1.261	3.86	3.15	1069.0	66.0	106	32	28.6	8.32
Bs	5- 21	s	6.9	1.432	5.25	4.45	290.2	108.5	19	5	10.7	18.25
BC	21- 46	ls	6.3	1.531	5.81	5.07	172.4	99.4	97	24	16.7	37.86
C1	46- 75	ls	5.1	1.475	6.23	5.15	93.6	60.9	65	25	12.5	16.73
C2	75-137	s	0.2	1.654	6.24	5.10	26.0	21.3	32	10	5.2	8.25
C3	137-244	s	2.5	1.759	6.30	5.86	33.8	42.0	169	33	9.6	3.22
C4	244-450	s	0.8	1.796	8.11	7.54	2.4	39.6	1173	36	5.0	0.00
Subplot 3												
A,E	0- 4	ls	0.9	1.193	4.21	3.44	1441.8	111.7	440	76	54.2	15.71
Bs	4- 25	ls	10.5	1.457	5.19	4.34	308.6	101.8	68	13	15.9	8.91
BC	25- 41	ls	11.0	1.532	6.04	5.14	170.8	101.5	143	31	12.7	26.89
C1	41- 68	ls	4.4	1.624	5.94	4.96	66.0	70.1	220	45	14.2	5.44
C2	68-213	ls	9.8	1.608	7.94	7.12	16.2	37.6	367	58	10.8	4.64
C3	213-450	s	0.3	1.794	8.50	7.20	6.8	47.2	1040	34	5.9	0.00
Subplot 4												
A,E	0- 4	ls	0.0	0.985	4.11	3.39	2920.0	204.2	552	122	180.0	20.58
Bs	4- 28	ls	9.4	1.461	4.68	4.42	307.6	109.3	41	10	19.8	10.75
BC	28- 43	s	9.5	1.510	6.20	5.24	207.6	98.0	124	23	13.8	9.35
C1	43-122	s	10.4	1.604	6.41	5.38	92.2	65.5	127	26	13.5	6.79
C2	122-198	s	11.2	1.743	8.32	7.30	15.0	31.1	1406	33	5.9	0.00
C3	198-450	s	0.6	1.793	7.30	7.07	22.4	40.7	254	39	8.8	2.22

Site X. ECS No. 138. Burgis landform: Eldorado Kamic Ridges.
Location: T. 26 N., R. 1 W., Sec. 21, SE of NW.

General Description: Slopes average 5% on the top and sides of a morainal hill with a mostly south aspect. One pedon has a 30 cm thick till layer; other pedons are sand or loamy sand, with gravelly strata occurring throughout the sampled depth.

Soil family classification: Two pedons, Entic Haplorthods, sandy, mixed, frigid; one pedon, Alfic Fragiorthods, coarse-loamy, mixed, frigid; one pedon, Typic Fragiorthod, sandy, mixed, frigid.

Depositional environment/parent material: Outwash sand with ice-rafted inclusions.

Soil Pedon Data:

Horizon	Depth cm	Texture	Cs fr vol %	Est BD g/cc	pH H2O	pH CaCl2	TKN	TKP	Ca	Mg	K	Bray's P
							<—		mg/kg			—>
Subplot 1												
A	0- 2	s	0.7	1.071	4.26	3.36	2245.8	202.6	572	74	52.4	11.48
E	2- 4	s	2.3	1.449	4.25	3.40	343.6	57.0	85	15	14.1	12.03
Bs1	4- 14	ls	7.5	1.479	4.72	4.12	202.8	98.2	21	4	10.9	20.15
Bs2	14- 51	s	7.6	1.482	5.26	4.39	267.2	141.9	58	15	26.1	45.44
Em	51- 64	s	2.4	1.700	6.14	5.08	111.4	60.8	96	24	28.3	12.40
Ex	64- 87	s	9.7	1.800	6.40	5.32	155.8	124.1	130	25	57.8	12.28
C1	87-366	ls	0.9	1.772	7.89	7.71	32.2	52.8	725	50	25.1	7.63
C2	366-427	s	1.9	1.802	8.80	7.69	8.6	33.2	2690	74	13.0	2.79
Subplot 2												
A	0- 3	s	0.9	1.111	3.92	3.21	1964.0	153.8	178	48	86.8	7.99
E	3- 6	s	0.9	1.466	4.13	3.48	300.4	38.9	19	7	21.4	1.50
Bs1	6- 20	ls	6.7	1.438	4.54	3.97	358.6	121.3	14	6	20.6	19.50
Bs2	20- 48	s	10.1	1.507	5.03	4.39	197.6	90.8	13	4	10.5	15.81
C1	48-307	s	1.3	1.753	6.05	5.38	18.6	42.0	187	43	30.4	9.09
C2	307-450	ls	1.5	1.800	8.18	7.55	18.2	54.4	3510	102	23.9	1.32
Subplot 3												
A	0- 2	s	0.0	1.185	4.80	4.05	1485.2	179.6	685	88	71.4	11.76
E	2- 6	s	2.6	1.456	4.90	4.37	325.6	90.0	187	19	14.3	7.49
Bs1	6- 9	s	6.3	1.436	5.30	4.34	347.0	205.6	57	10	14.7	56.22
Bs2	6- 40	ls	5.5	1.482	5.48	4.72	288.6	163.5	105	13	19.7	35.77
BC	40- 60	s	3.0	1.580	5.33	4.69	107.0	82.1	47	7	13.2	28.17
C1	60- 89	s	0.6	1.572	5.82	4.91	53.0	51.1	39	5	9.4	19.38
C2	89-152	ls	6.9	1.604	6.71	5.95	53.2	37.5	173	34	21.7	5.03
C3	152-290	ls	0.9	1.770	6.53	5.75	23.0	34.6	219	45	22.5	5.23
C4	290-450	ls	0.8	1.799	8.51	7.65	25.0	65.3	1510	58	21.7	2.51
Subplot 4												
A	0- 2	s	0.0	0.967	3.56	3.08	3067.8	179.4	456	78	107.0	21.03
E	2- 7	s	4.2	1.461	4.18	4.01	312.6	37.4	35	10	16.6	9.06
Bs	7- 25	ls	8.2	1.449	4.38	3.80	345.4	152.5	32	8	17.7	45.32
Em	25- 37	ls	7.4	1.700	6.51	6.06	208.8	89.1	29	8	11.7	17.40
B/Ex	37- 65	scl	10.4	1.800	5.26	4.16	193.8	64.1	363	111	54.5	2.54
Bt	65-122	sl	9.3	1.618	7.23	7.38	66.0	60.7	1085	125	38.8	3.48
C1	122-351	ls	1.1	1.775	8.36	7.62	13.6	36.5	3020	86	20.9	1.56
C2	351-450	ls	1.3	1.803	8.17	7.59	29.2	52.6	2560	94	25.5	5.65