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Pre-European Settlement Forests of Northern Lower Michigan: The Role of Landform in Determining Composition Across The Landscape

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Jill Huckins Fisher

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PRE-EUROPEAN SETTLEMENT FORESTS OF NORTHERN LOWER MICHIGAN: THE ROLE OF LANDFORM IN DETERMINING COMPOSITION ACROSS THE LANDSCAPE

By

Jill Huckins Fisher

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ABSTRACT

PRE-EUROPEAN SETTLEMENT FORESTS OF NORTHERN LOWER MICHIGAN: THE ROLE OF LANDFORM IN DETERMINING COMPOSITION ACROSS THE LANDSCAPE

By

Jill Huckins Fisher

This study describes pre-European settlement forest composition at 101 sites across northern lower Michigan and assesses the role of landform in determining composition on eight landform types using data from the General Land Office Survey records.

Mapped profile plots of the 101 samples revealed distinct regionalization of forest composition with composition in each region determined by a different combination of climate, soils, and landform. Composition in the northwest corner of the study area appeared to be controlled primarily by climate. Composition in the southeast corner appeared to be controlled by a lacustrine soils laid down over landforms. Landform appeared most influential in the interior of the state were climate is not lake-modified and the soils are distinguished based on the mode in which the glacier deposited them.

Casey J,

to you, me and Gheodie

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The busy schedules of my committee members testify that their advice and wisdom is highly sought after. And so, Dr. Don Dickmann, Dr. Kay Gross and Dr. Patrick Webber, I thank you very much for your time, enthusiasm and comments on the text. I especially thank my advisor, Dr. Kurt S. Pregitzer for the accumulated consultation, prodding and words of advice and encouragement. I am looking forward to seeing in press his photographic history of the deforestation of Michigan and wish him well in this endeavor.

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These acknowledgements would not be complete without proper thanking of my family members, since I wouldn't be the me I am now without them. Thank you to my parents, Pat, Jeff and Sarah, and my brother Fred. The largest thanks goes to my best friend, Casey. Jessie and Jericho deserve their place here also, even if they can't read English.

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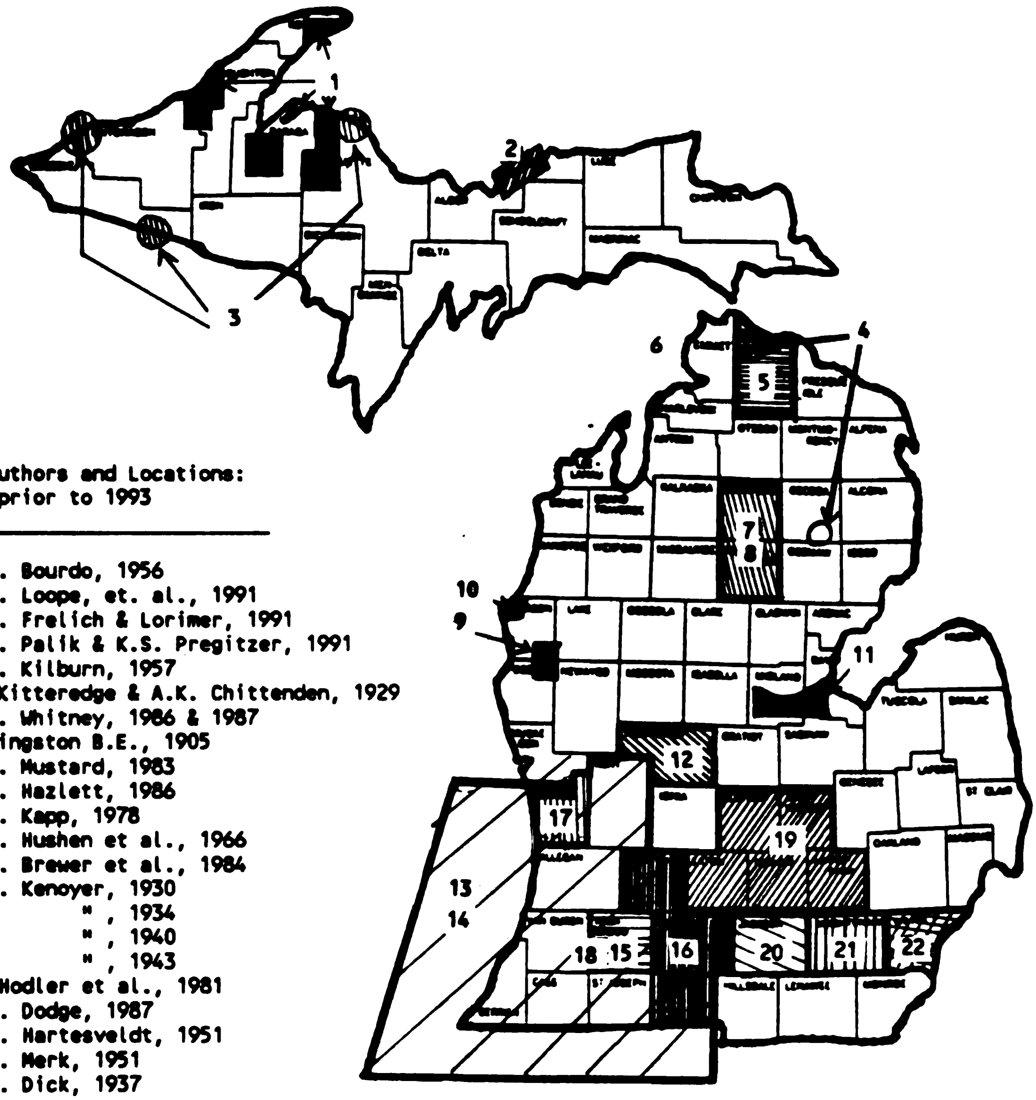
INTRODUCTION

Background

As European immigrants settled this country, a majority of our forests were logged before they were described from an ecological perspective. Ecological historians have subsequently tried to accurately depict the condition of these forests prior to European settlement (for example: Abrams & Nowacki 1992, Braun 1950, Curtis 1959, Lorimer 1977). Michigan's pre-European settlement vegetation history has been pieced together by many authors, however, these studies were conducted within limited geographic areas. Figure 1 lists authors and depicts the locations of areas that have been previously studied; the result is a patchwork of local studies across the state. Only two pre-European settlement vegetation maps have been produced for the entire state, but both lack critical information. Marschner's 1946 map, based solely on the notes from the General Land Office Survey, is so generalized that many forest types are lumped together as "hardwoods" and "pinelands". Veatch (1959) produced a more detailed map, grouping forest communities by soil type, climate, and geomorphological features. However, his



List of Authors and Locations:
prior to 1993

(1) E.A. Bourdo, 1956
(2) W.L. Loope, et. al., 1991
(3) L.E. Frelich & Lorimer, 1991
(4) B.J. Palik & K.S. Pregitzer, 1991
(5) P.D. Kilburn, 1957
(6) J. Kitteredge & A.K. Chittenden, 1929
(7) G.G. Whitney, 1986 & 1987
(8) Livingston B.E., 1905
(9) T.S. Mustard, 1983
(10) B.T. Hazlett, 1986
(11) R.O. Kapp, 1978
(12) T.W. Hushen et al., 1966
(13) L.G. Brewer et al., 1984
(14) L.A. Kenoyer, 1930
(15) " " , 1934
(16) " " , 1940
(17) " " , 1943
(18) T. Hodler et al., 1981
(19) S.L. Dodge, 1987
(20) R.J. Hartesveldt, 1951
(21) J.W. Merk, 1951
(22) W.B. Dick, 1937

General:
G.W. Parmelee, 1953
F.J. Marschner, 1946 (map of state)
J.O. Veatch, 1959 (map of state)

Figure 1. List and locations of previous work on pre-European settlement vegetation in Michigan prior to 1993. Appendix A lists full citations.

methodology for using these factors to characterize communities are not explicit and there are no data describing his communities (Dodge 1987, Veatch 1932). The accuracy of these maps has not been verified, and even if Veatch's map is accurate, the environmental determinants of pre-European settlement composition across the landscape are not well understood. To gain a better understanding of pre-European settlement forests and their determinants, this study examined the role of glacial landforms in influencing the composition of pre-European settlement forests across the upper half of the lower peninsula of Michigan.

Importance of Landforms

The incorporation of geomorphology (equivalent to glacial landforms in Michigan) in classifying land is increasing. Rowe (1984) and Hills (1952) emphasize the need to consider landforms in the classification process because of the modifying effects of landforms on local climate and soil formation processes. Other authors have documented the importance of landforms in influencing patterns of vegetation for both pre-European settlement (Grimm 1984, Hushen et al. 1966, Kapp 1978, Whitney 1986, 1987) and present-day communities (Host et al. 1987, Host and Pregitzer 1992, Padley 1989). This study is unique in that it examines the role of landforms in determining pre-European settlement composition over an area large enough to encompass potential regional differences.

Objectives

The primary objectives of this study were to:

1) examine the composition of the pre-European settlement forests of northern lower Michigan to understand the role landform had in determining composition across the landscape;

2) describe the variation in forest composition within a landform type;

3) describe upland forest types associated with the different landforms. Forest type is defined in this study as an assemblage of communities with the same overstory dominants, although proportions of dominants and auxiliary species may differ;

4) verify Veatch's pre-European settlement forest composition map;

5) document disturbance in the study area to ascertain any regional patterns of disturbance or patterns associated with landform.

METHODS

Background

Study Area Location and Climate

The position of Michigan's two peninsulas in the center of the Great Lakes subjects the state to a semi-marine climate even though it is located mid-continent (Eichenlaub et al. 1990). The average annual precipitation for the lower peninsula grades from 32" (81.3 cm) along the western shoreline to less than 28" (71.1 cm) along the eastern shoreline due to prevailing westerly winds. The average annual temperature varies from 46 degrees F (7.8 degrees C) along lake borders to less than 42 degrees F (5.5 degrees C) inland. Also noteworthy is the decrease in the average number of annual thunderstorms from south to north (Eichenlaub et al. 1990).

Braun described the present-day eastern forests of the United States in her 1950 book. The entire area for this study is included in Braun's Great Lake Section of the Hemlock-White Pine-Northern Hardwoods region. This region extends from northern Minnesota through northern Michigan towards the east across southern Canada and New England. The Great Lakes Section includes northern lower Michigan, eastern upper Michigan and part of Ontario between Lake Huron and Lake Ontario (Braun 1950). Braun describes the distinguishing forest community in this section as deciduous northern hardwoods dominated by sugar maple, beech and basswood with fewer yellow birch, white elm and red maple. Northern hardwoods occur on fine textured morainal ridges. Coniferous forests with white, red and jack pine occur on the dry, sandy outwash plains and mixed communities of hemlock and northern hardwoods dominate well drained morainal ridges and rolling ground moraines often with a fair amount of pine.

Albert et al.'s (1986) landscape ecosystem Region II, the northern half of the Lower Peninsula, was chosen as the study area. On Albert et al.'s map, regions and districts are delineated based on macroclimate and physiography, whereas the subdistricts are distinguished by finer differences in physiography and soils. The southern boundary represents the tension zone separating major temperature regimes (Kapp 1978, Hushen et al. 1966). Many differences in species distributions and soil types follow the tension zone, such as the southern limit of the range for jack and red pine and the shift of soil orders from southern Alfisols to northern Spodosols (Buol et al. 1973).

Glacial History

The last glacial lobes from the Laurentide Ice Sheet advanced over the entire state of Michigan and reached as far south as the middle of Indiana and the southern border of

Ohio. The first part of the study area to be uncovered by the retreating ice, approximately 14,000 years before present, was the central highlands region. The three ice lobes fully withdrew from lower Michigan 3,000 years later,and the area was left with a historical record of ice stagnations and retreats. Detailed descriptions of the glaciation of Michigan are given by Dorr and Eschman (1984) or Hough (1958).

Landforms in this study refer to those mapped by Farrand and Bell (1982). A listing of landforms and codes used for this study are found in the legend of Figure 2. Farrand and Bell's map has not been field tested for detailed accuracy; however, it remains the most complete source covering large regions (Grahame J. Larson, 1993 pers. comm.). An updated map with subsurface inclusions may account for more variation in forest composition for each landform (Host and Pregitzer 1992).

Sample Data

The study area was stratified by the landform designations on Farrand's map. Dunes, muck deposits and lacustrine silts and clays were not considered for this study due to the small area covered by these landforms. Quarter townships (nine square miles) were used as the sample unit instead of whole townships to gain more samples away from borders with other landforms and the shoreline of Lakes Michigan and Huron. All possible sample quarter townships were plotted and numbered on a mylar overlay. Fifteen quarter

Legend Figure 2: Codes Given to Farrand's Landforms in Quaternary Geology of Michigan Map (Department of Geological Sciences, The University of Michigan, Ann Arbor. 1982)

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1 = Outwash plains
2 = Ground Moraines of Fine Textured Till
3 = Lacustrine Sands and Gravels
4 = Ice Contact Features
5 = End Moraines of Coarse Textured Till
6 = Ground Moraines of Coarse Textured Till
7 = End Moraines of Medium Textured Till
8 = Ground Moraines of Medium Textured Till (not used)
9 = Lacustrine Silt and Clay (not used)
10 = End Moraines of Fine Textured Till

Note: Landforms that covered relatively little area were not used in this study. The numbering system was developed for a preliminary study and kept for continuity.

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townships were randomly selected for each landform type. Some samples were excluded from lacustrine sands and gravels and fine textured ground moraines because the area within those quarter townships contained more than fifty percent swamp or wetland. Medium textured till and end moraines of fine textured till were limited to 7 and 12 samples, respectively, due to limited area. The locations of all 101 final quarter township samples are shown in Figure 2. This scheme produced a 5.3% sampling of the entire study area.

From examination of Figure 2, two areas appear to be under-sampled. The area in the northwestern corner of the Lower Peninsula, including Antrim, Charlevoix and Emmet counties, was under-sampled due to the choppy pattern of the landforms in that area permitting few quarter townships away from borders with other landforms. The second under-represented area covers the counties of Wexford, Lake, Newaygo, Mason and Oceana. A few of the townships in this area were resurveyed, but those that were not most often did not differentiate between the three species of pine. A list of townships that were examined for intended use in this study but were subsequently found to not differentiate between pine species is shown in Table 1. Surveyor's common names and associated Latin names are listed in Table 2.

Three surveyors repeatedly reported only "pine" in the subdivision notes where exterior township lines or examinations run by other surveyors showed more than one pine species for the township: John Hodgson, Sye Sibley and John

Mullet. The latter surveyor recorded several species of pine in surveys of other areas. The notes from the General Land Office survey were then retrieved and recorded for each of the sample quarter townships to get count data and citation frequencies of trees.

Table 1. List of townships sampled for intended use in this study, but found to have no species differentiation between the pines in the surveyor's notes. The asterisks indicate townships that mention only pine in the subdivision notes but list more than one species of pine in the exterior township notes or in examinations of the surveyed work. This is not an inclusive list.

Township	Range
11 N	11 W
12 N	10 W, 11 W, 13 W
13 N	11 W, 13 W, 16 W*
14 N	9 W, 11 W
15 N	12 W
16 N	12 W
17 N	7 W, 9 W, 10 W, 12 W, 15 W*, 16 W
18 N	6 W, 7 W, 9 W*, 10 W, 11 W*, 12 W, 13 W, 16 W*, 18 W
19 N	9 W, 10 W, 11 W, 12 W, 13 W, 15 W, 16 W*, 18 W
20 N	11 W, 12 W, 13 W

Table 2. List of species designated by the surveyors with scientific names and modern common names in parentheses (modified from Bourdo (1954)).

Fir	(Balsam Fir)	Abies balsamea (L.) Mill.
Sugar	(Sugar Maple)	Acer saccharum Marsh.
Maple	(Red Maple)	Acer rubrum L.
Yellow birch		Betula alleghaniensis Britt.
White birch		Betula papyrifera L.
Birch @		
White Ash #		Fraxinus americana L.
Black Ash #		Fraxinus nigra Marsch.
Tamarack	(Eastern Larch)	Larix laricina (Du Roi) K. Koch
Ironwood		Ostrya virginiana (Mill.)K. Koch
Spruce	(White and Black)	Picea glauca (Moench.) Voss Picea mariana (Mill.) B.S.P.
Spruce Pine	(Jack Pine)	Pinus banksiana Lamb.
Scrub Pine		
Yellow Pine	(Red Pine)	Pinus resinosa Ait.
Norway Pine		
Pitch Pine @@		
White Pine		Pinus strobus L.
Pine *		
Aspen	(Quaking and Bigtooth)	Populus tremuloides Michx. Populus grandidentata Michx.
Black Cherry		Prunus serotina Ehrh.
White Oak		Quercus alba
Black Oak	(Northern Red Oak)	Quercus rubra L.
Red Oak ^^		
Willow		Salix spp.
Cedar	(Northern White Cedar)**	Thuja occidentalis L.
Lynn	(Basswood)	Tilia americana L.
Hemlock		Tsuga canadensis (L.) Carr.
Elm	(American Elm) (probably with Slippery Elm)	Ulmus americana L. Ulmus rubra Muhl.

@ Most of the townships used in this study listed birch separately from yellow birch, however; one case was found in the Upper Peninsula that listed white birch with birch mentioned in the low, wet spots, probably referring to yellow birch.

Often only ash was listed, the two have been combined for this study.

@@ Cases have been found (Mason Co.) where pitch pine was used to designate jack pine.

* Pine is cited as synonymous with white pine in Bourdo's list and kept separate in Whitney's list since all 3 pines did occur in the area. Whether it designates white pine or only pine depends on the surveyor and the area of the survey record.

^^ In only a few instances was red oak specifically mentioned. Following Whitney (1986), "black oak", "oak" and "red oak" are listed here as an oak complex that probably refers to northern red oak but may include black oak, scarlet oak and northern pin oak.

** Eastern red cedar (Juniperus virginiana L.) was not mentioned to be included with northern white cedar nor was it ever distinguished in the surveyor's notes examined for this study. Considering its present day range, cedar referred to northern white cedar.

Use of G.L.O. Records in Assessing Pre-European Settlement Vegetation

Many studies of pre-European settlement vegetation have relied upon General Land Office surveys conducted in the state of Michigan from 1815 to 1855 (see methods in references cited in Figure 1). Bourdo (1954, 1956) remains the best source for reviewing the use of the GLO records in pre-European settlement vegetation reconstruction. Instructions to the surveyors were frequently updated, cases of fraudulent and fabricated work exist, and detail of written information varies with each surveyor (Dodds et al. 1943). However, as Bourdo concludes, the GLO records continue to be the most consistent method for reconstruction of pre-European settlement vegetation.

A surveyor would walk a township or section line, set a post at each section corner and quarter mile mark, and record the species, diameter, direction and distance of the closest tree to the post in two of the four quadrants formed by the lines being laid. Bourdo (1954, 1956), following the instructions given to the surveyors in his area of study, resurveyed uncut tracts of forest in the Upper Peninsula of Michigan to determine if the surveyors showed bias in their witness tree selections. He concluded that no significant biases were evident for species selection, although bias for size was apparent. Many surveys in the Lower Peninsula were fraudulent, and a listing of resurveys was consulted in the final selection of townships (White 1984, Stewart 1935).

Delcourt and Delcourt's (1974) method of ANOVA with completely randomized design was used to evaluate a random 12% of the samples for bias of species selection (Table 3). This tests significant differences for the average distance to dominant tree species within a community type. Only one of the thirteen samples had a P value close to 0.05. This quarter townships had recorded evidence of recent disturbance which may explain biases in tree selection since few trees were left. Thus, I conclude that under normal conditions, there was no significant bias of species selection and the GLO records represent a reasonable approximation of original forest composition.

Line Descriptions

Trees that intersected the survey line between corners were recorded in addition to the corner witness trees. Some surveyors would record only those line trees that were approximately an even distance between the corner post and the

Table 3. Results from Delcourt and Delcourt's (1974) ANOVA tests for surveyor bias for species selection of witness trees. P values reflect the significant level for differences in average distances to dominant species. The dominant species are as follows: B=beech, H=hemlock, JP=jack pine, RM=red maple, RP=red pine, WO=white oak, WP=white pine.

County	Sample	Surveyor,Date	Dominant Species	F Ratio	P value
Alcona	10-1,10-3	J.Mullet, 1846	WO, WP, RP	1.63	0.162
Clare	1-10	F.Coleman, 1856	JP, WP, RP	2.745	0.105
Clare	2-9	F.Coleman, 1856	B, RP, WP	0.017	0.896
Clare	5-5	G.Aclair, 1857	B, RP, WP	2.225	0.119
Gladwin	3-13,3-14	J.Mullet, 1846	H, WP	6.610	0.150
Kalkaska	1-5	G.Cannon, 1852	JP, WP, RP	0.924	0.402
Mason	1-4	J.Brink, 1839	JP, RP, WO, WP	2.244	0.056
Mason	1-12	J.Brink, 1839	B,JP,RM,RP,WO,WP	0.518	0.598
Newaygo	1-13	M.Nye, 1856	RP, WO, WP	0.683	0.509
Ogemaw	4-13,4-14	B.Hall, 1846	RP, WO, WP	1.822	0.169

quarter mile post. These data are difficult to use in quantitative expressions such as species density due to the variability with which they were recorded. Since forest composition, not structure, was addressed in this study, line trees were included in count data. Because surveyors had more lee-way for selection of line trees, Kolmogorov-Smirnov tests were performed on the same samples tested above to assess surveyors bias of line trees. The K-S test measures the divergence between two sample cumulative distribution functions. Cumulative citation frequencies for dominant species recorded as corner trees were compared to cumulative citation frequencies for dominant species recorded as line trees. The test does not assume normal distributions, but does assume both samples came from the same distribution. The results in Table 4 show that no significant biases occurred in the selection of line trees for most quarter townships sampled. The one sample that did show a significant difference also had evidence of disturbance, which may explain the lack of a representative species in the line tree counts.

Table 4. Results from Kolmogorov-Smirnov tests for surveyor bias on line tree selection. Significant differences are marked with an asterisk.

County	Sample	Maximum difference
Alcona	10-1	0.25
	10-3	0.33
Clare	2-9	0.25
	1-10	0.5
	5-5	0.17
Gladwin	3-13	0.33
	3-14	0.67 *
Kalkaska	1-5	0.33
Mason	1-4	0.14
	1-12	0.2
Newaygo	1-13	0.2
Ogemaw	4-13	0.2
	4-14	0.2

Analysis

The Species/Landform Association

Strahler (1975, 1977) showed that binary (presence or absence) data produced comparable results with quantitative data (such as percent cover) in relating woody species with topographic position and underlying rock type. Strahler used contingency tables for each combination of species and environmental variable to generate G-statistics to convert to standardized residuals. The sign of these residuals show positive and negative correlations of species to environmental variables and the values show the strength of these relationships. Following this method, contingency tables were constructed for each species by each landform and standardized residuals were calculated to examine the first objective; are communities associated with landform type?

To explore the variation of the species/landform association all 101 samples were plotted using ordination techniques. Correspondence analysis is the best method for ordination of binary data (Digby and Kempton 1987, Pielou 1984) and is used as a graphical tool for exploratory data analysis by reducing dimensionality in the data, but provides no tests of significance. The analysis is based on the singular value decomposition (SVD) of a n * p data matrix where n rows indicate individual sites and p columns represent species counts at the sites. If most of the variation is captured in the first two dimensions, then the SVD values for the sites can be plotted and relationships examined in only two dimensions. The distances between plotted points reflect true distances of the counts for all species at one sample point compared to all the species at all other sample points.

Infrequent species can skew the outcome of the analysis because the x_{ij} values are weighted by the column and row totals,

$$x_{ij}/\text{sqrt } r_i c_j.$$

If a column sum for a species is small, the weighted value will overemphasize the importance of rare species. The original set of 17 species were reduced to eight species after a few preliminary runs revealed that the combination of the eight remaining species explained the most variation.

Correspondence analysis was run using SAS software (SAS

Institute Inc. 1985) and plotted with SYGRAPH software (Wilkinson 1988).

Variation of Composition within a Landform Type

SYGRAPH (Wilkinson 1988) software were used to generate profile plots with the citation frequency for the eight species used as the eight variables in the correspondence analysis. Based on current knowledge of species' habitats (Barnes and Wagner 1981), species were arranged along the gradient produced from the correspondence analysis. This gradient could be interpreted to reflect shade tolerance, soil moisture, soil nutrient, or rate of disturbance and is probably a combination of all four. Profiles are simplified histograms that connect the center point of the top of each variable's bar; the purpose of using profiles instead of histograms is for easy pattern recognition. Plots for all 101 samples were placed on the site location map to examine regional patterns in forest composition.

Forest Types

Distinctive groups were observed after plotting the profile plots on a map. Cluster analysis was run to describe natural groupings of species and relate these groups to environmental and geographic factors. Like correspondence analysis and most other multivariate procedures, cluster analysis is for exploratory data analysis and hypothesis development. If an underlying structure to a data set exists, then clustering by many different methods should consistently reveal real groups within the data.

Both hierarchical and non-hierarchical methods were used to cluster citation frequency data. Hierarchical structuring imposes a nested structure on the data set. Merging is permanent and therefore early decisions affect later groupings. Average linkage and Ward's method were tried.

Non-hierarchical structuring portions the data into "K" groups. Group membership may change as the grouping of data progresses. This method is more sensitive to outliers and also requires that the number of groups be provided, causing a problem if this is not known. The KMEANS method for non-hierarchical clustering was run using eight, five, and then four groups. All clustering was performed using Euclidean (root mean squared distance) as a metric for citation frequency data. Because citation frequencies were the data used, standardization was not necessary.

Forest types from Veatch's 1959 map where compared to the forest types suggested by the cluster analysis to assess the consistency of Veatch's forest types.

Disturbance

Line descriptions and township sketch maps are commonly used to study natural disturbance in pre-European settlement forests (Whitney 1986, Loope 1991, Lorimer 1980, Canham and Loucks 1984). If past windthrow or fire were evident to the surveyors, they would mark the areas on the township maps and/or record in their notes when they entered and left such disturbances. These line segments can be used to estimate the proportion of an area that was disturbed. Lorimer (1977) and Whitney (1986) used this method to determine disturbance frequencies in the hemlock-northern hardwood region from Wisconsin to Maine and for the pine communities of Crawford and Roscommon counties in northern Michigan, respectively.

Evidence of past disturbance could remain visible to the surveyors for only a window of time which has been estimated to vary from 15 to 30 years (Lorimer 1980, Canham and Loucks 1984, Whitney 1986). Therefore disturbance regimes for each landform type are represented by the possible range in return intervals. The return interval is defined as the time required for the total area of each landform type to be disturbed.

RESULTS AND DISCUSSION

Format of Species Counts and Citation Frequencies in Appendices

There are three summary tables for each landform type; one for species counts on upland sections of survey line (Appendix C), one for citation frequency (Appendix D) and one for swamp or wetland data (Appendix E). All tables are in the same format for comparison. The seventeen most common species appear as column headings. Species that occurred in samples but were infrequently cited appear at the bottom of the tables. Each table in Appendix C and D is in two halves. The upper half summarizes the species counts or citation frequencies for dominant species in the overstory, these were the species used in the correspondence analysis with the exception of black oak. The lower table represents species that were usually poorly represented in the overstory. Legal descriptions for the locations of each sample are given as well as the position of the quarter township sample within a township (see first page in Appendix C for the coding of quarter townships). The swamp data show the accumulated raw count data for species on all wetlands within a sample and the percentage of the sample area cited as wetland.

Description of Pre-European Settlement Forests and Species Trends

Although there was much variation in composition, it is clear when looking at the tables of citation frequencies in Appendix D that "typical" communities were associated with certain landforms. Table 5 summarizes the species percentages for all trees on each upland landform type from all 101 quarter townships.

The "typical" community for outwash plains was a jack pine dominated forest with red pine as a principal associate. Beech and sugar maple reached peak dominance on end moraines of coarse and medium textured till. Hemlock, though not a common overstory species today, accounted for approximately 20% of the total trees on all landforms except the dry outwash and ice contact features. Hemlock and white pine reached peak dominance on the ground moraines of fine till and the lacustrine sands and gravels associated with glacial lake beds. White pine, the most famous and sought after species in the pre-European settlement forest, was prevalent at both ends of the moisture spectrum and in addition to its mesic association with hemlock, it often dominated with the other pines on the dry sites.

The relatively minor contribution of the oaks, aspen and birch in the pre-European settlement forests (Table 5) contrasts with present-day forests where these species now dominate forest cover over much of northern lower Michigan.

Table 5. Comparison of species frequencies for all samples across all upland landforms. These data represent corner and line witness trees for a total sample of 2448 linear miles.

	Outwash plains	Ice contact	End fine	Ground coarse	End coarse	End med	Ground fine	Lacust-rine
Sugar maple	7.7	11.8	6.5	16.4	21.4	24.8	8.7	10.1
Hemlock	6.9	11.7	20.8	17.9	17.1	17.7	27.1	23.3
Beech	11.0	17.8	11.7	22.6	31.6	37.1	16.7	18.8
White pine	17.1	14.0	16.7	11.9	8.9	4.9	24.3	22.0
Red maple	2.3	2.0	1.8	1.3	3.0	0.7	8.3	4.9
White oak	6.5	1.7	0.7	0.2	1.6	1.2	0.3	1.3
Black oak	1.9	2.4	2.3	1.7	1.3	0.5	0.4	0.1
Red pine	15.5	20.5	21.4	14.9	5.3	5.2	3.7	5.5
Jack pine	20.8	11.7	8.1	3.2	1.5	0.8	0.0	1.4
Fir	0.1	0.0	0.3	0.3	0.0	0.0	0.6	0.9
Ash	0.4	0.0	1.0	0.1	0.6	0.6	2.2	2.2
Cedar	0.6	0.0	1.3	1.2	0.2	0.4	1.4	3.1
Elm	0.4	0.4	0.6	1.8	3.3	1.8	1.9	1.2
Basswood	0.2	1.0	0.5	1.8	2.1	1.2	1.7	0.3
Aspen	1.4	3.0	3.6	2.3	0.8	0.7	1.3	1.8
Birch	0.8	2.0	2.1	1.7	1.0	0.5	0.9	2.5
Yellow birch	0.8	0.0	0.5	0.6	0.1	1.9	0.3	0.5
Black cherry	5.6	0.0	0.1	0.1	0.1	0.0	0.2	0.0
	100	100	100	100	100	100	100	100

Aspen did not account for more than 15% of the species cited for any one site (see Appendix D) and was more common on the eastern side of the state. Apparently, birch, aspen and red maple grew on all landform types but were never dominant in pre-European settlement forests.

White oak was most common on outwash plains and dominated only one sample, 1-14 in Newaygo County, with white pine. Sample 1-14 is also unique in that 21% of the lines in that quarter township occurred in a dry prairie with scattered white and black oaks among prickly pear cactus noted by the surveyors.

The standardized residuals in Table 6 show the same relationships described above but lend statistical support to the relationships among species and landform. All species were found to be significantly associated with landform at an alpha level of 0.001.

Close examination of individual sites, however, reveals discrepancies in these trends (for example see sites 1-2, 1-11, and 1-15 in Table C1 in Appendix C) that required further examination.

Table 6. Haberman's standardized residuals for presence data of species by landforms for all 101 quarter townships. The sign reflects a positive or negative association and the value reflects the strength of the association.

		Landforms						
Species	G-Statistic	Outwash	Ice contact	Fine end moraine	coarse gr moraine	med end moraine	lacust-rine	fine gr moraine
Sugar maple	328.12**	-6.9	-2.1	-7.7	4.0	10.0	-3.3	-2.1
Hemlock	292.61**	-11.6	-6.4	3.8	1.1	0.7	5.9	9.6
Beech	132.62**	-8.3	-1.2	-6.9	4.4	14.1	0.0	-1.9
Red maple	62.84**	-0.1	-1.3	-1.6	-3.5	-3.4	5.5	3.1
White pine	283.07**	4.1	-1.1	1.8	-3.7	-8.5	6.9	9.4
White oak	224.34**	16.4	-1.0	-3.3	-5.5	-1.6	-1.5	-4.2
Red pine	518.94**	5.4	11.1	10.1	3.3	-6.6	-7.2	-9.3
Jack pine	935.44**	26.4	8.3	2.3	-6.8	-7.3	-7.6	-9.7

for alpha 0.01, critical value > 18.48 *
for alpha 0.001, critical value > 24.32 **

Community Variation Among Landforms

Correspondence analysis was used to ordinate samples along an indirect environmental gradient. The first two dimensions accounted for 67.8 % of the total variance in the spectral decomposition. Figures 3 and 4 show the plots of all samples and all species, respectively. The data resulted in an arch pattern. The arch results from the gradation of one Gaussian distribution of a species into another along the ordination, and thus truly represents the nonlinear relationships of species distributed along environmental gradients. The arch makes any interpretation of the second axis or any axis other than the first nonsensical (Digby and Kempton 1987, Noy-Mier and Austin 1969, Wartenberg et al. 1987).

In correspondence analysis, the proximity of variables (species) to observations (samples) represents an indirect measure of their association such that the samples to the extreme left of the ordination had the highest counts of sugar maple, hemlock and beech (Figure 5). The right end of the ordination represents dry samples with high species counts of jack and red pine. The ordination of the sites with more mesic communities in Figure 5 were less variable than sites on the landforms shown in Figure 6, which spanned the gradient in composition. Lacustrine sands and gravels, fine textured ground moraines, and end moraines of medium textured till had the least variation. The sample to the far right for end moraines of coarse textured till had cited evidence of fire, perhaps explaining its placement (Figure 5). Although samples from the dry end of the spectrum were predominantly associated with outwash plains or ice contact features, not all of the samples from these landforms were characterized by "dry" communities; rather these two particular landforms had samples across the gradient (Figure 6).

The correspondence analysis demonstrates the need for explanation of the variability in composition within many of the landform types such as outwash plains and ground moraines of coarse textured till.

Correspondence analysis coordinates for all samples (rows) and species (columns) produced by SYSTAT (Wilkinson 1989) are found in Appendix B.

Profile Plots

In landscape ecology, many facets must be considered when accounting for the regional distribution of communities. Albert et. al (1986) and Veatch (1932) list climate, geomorphology and soil as the three main factors controlling the broad distribution of current and pre-European settlement vegetation in Michigan. Although Veatch provided the list of factors used to determine his forest types on his 1959 pre-European settlement forest map, he synthesized all factors and depicted forest composition on his map without providing information on the role each factor played in regulating forest composition across the state. As Dodge (1987) mentioned, Veatch provided no quantitative information to describe the communities appearing on his map. Albert et al. (1986) discussed the influence of different factors for their climatic ecosystem regions. My results agree to some extent with both those of Veatch and Albert et al. and this correspondence is discussed below. Based on my results, I conclude that in northern lower Michigan pre-European

Legend Figure 3: Codes Given to Farrand's Landforms in Quaternary Geology of Michigan Map (Department of Geological Sciences, The University of Michigan, Ann Arbor. 1982)

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1 = Outwash plains
2 = Ground Moraines of Fine Textured Till
3 = Lacustrine Sands and Gravels
4 = Ice Contact Features
5 = End Moraines of Coarse Textured Till
6 = Ground Moraines of Coarse Textured Till
7 = End Moraines of Medium Textured Till
8 = Ground Moraines of Medium Textured Till (not used)
9 = Lacustrine Silt and Clay (not used)
10 = End Moraines of Fine Textured Till

Note: Landforms that covered relatively little area were not used in this study. The numbering system was developed for a preliminary study and kept for continuity.

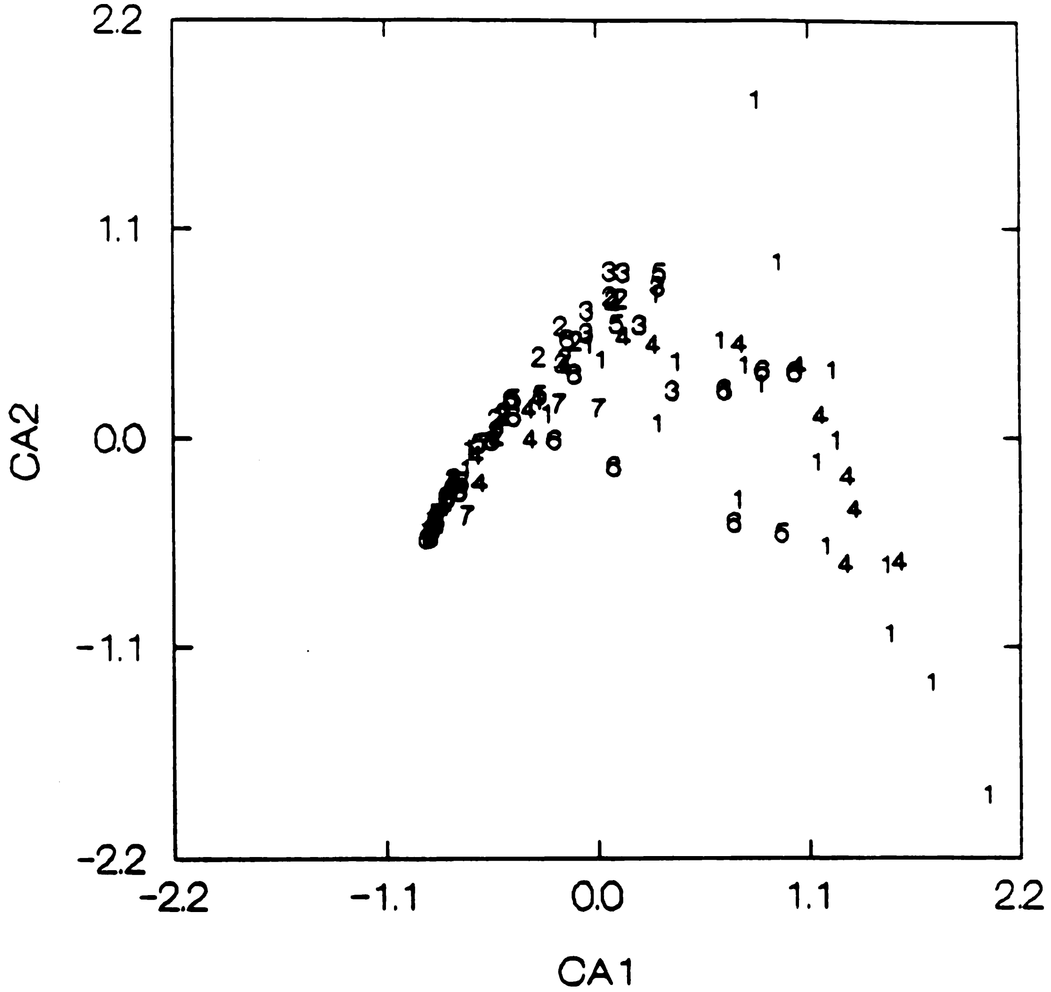

Figure 3. Correspondence analysis for all the upland samples on all landforms. The first two dimensions, axes 1 and 2, account for 67.8 % of the total variance for eight species: sugar maple, hemlock, beech, red maple, white pine, white oak, red pine and jack pine. The numbers refer to landform types in the legend. Refer to Figures 5 and 6 for clarity of numbers.

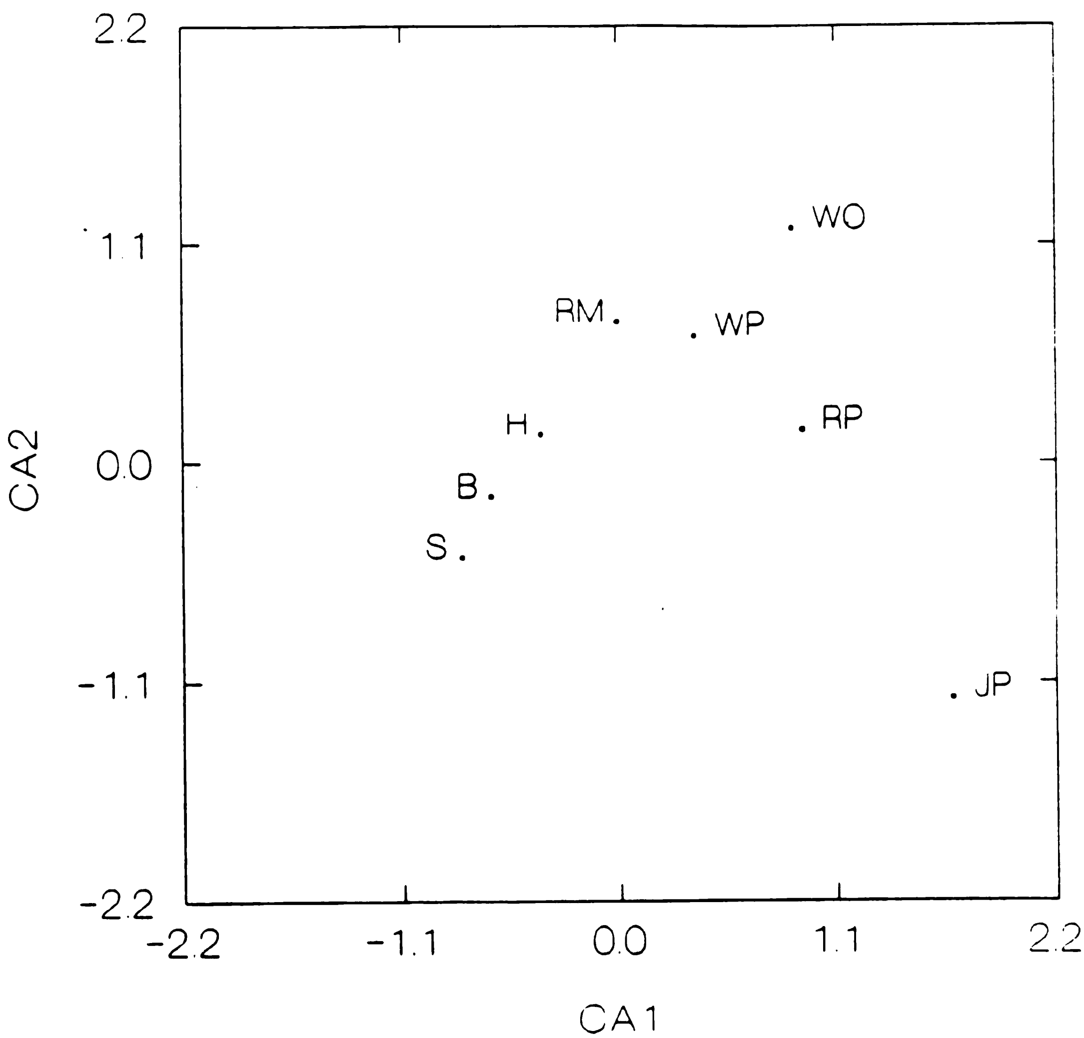

Figure 4. Correspondence analysis for the upland species on all eight landforms. The first two dimensions, represented by axes 1 and 2, account for 67.8 % of the total variance. Species codes refer to: S=sugar maple, H=hemlock, B=beech, RM=red maple, WP =white pine, WO= white oak, RP=red pine and JP=jack pine. The species appear to be arranged along a moisture, nutrient, shade intolerance gradient or a combined gradient based on knowledge of their present-day habitats.

Legend Figure 5: Codes Given to Farrand's Landforms in Quaternary Geology of Michigan Map (Department of Geological Sciences, The University of Michigan, Ann Arbor. 1982)

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1 = Outwash plains
2 = Ground Moraines of Fine Textured Till
3 = Lacustrine Sands and Gravels
4 = Ice Contact Features
5 = End Moraines of Coarse Textured Till
6 = Ground Moraines of Coarse Textured Till
7 = End Moraines of Medium Textured Till
8 = Ground Moraines of Medium Textured Till (not used)
9 = Lacustrine Silt and Clay (not used)
10 = End Moraines of Fine Textured Till

Note: Landforms that covered relatively little area were not used in this study. The numbering system was developed for a preliminary study and kept for continuity.

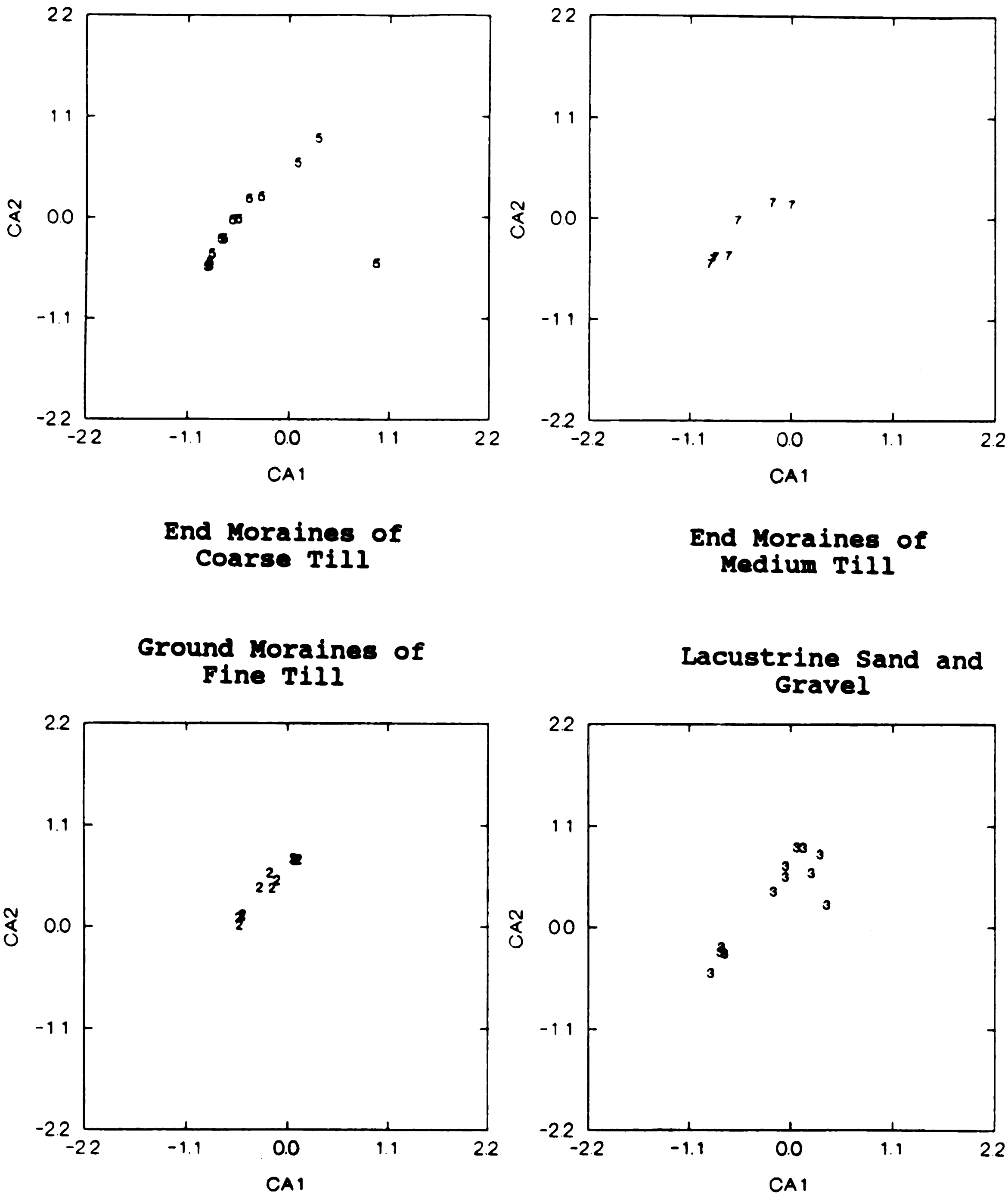

Figure 5. Correspondence analysis for quarter townships on individual landforms. The data used are the same as those plotted in Figure 3. The sites on these landforms appear to have been dominated by more mesic species than sites on the landforms in Figure 6.

Legend Figure 6: Codes Given to Farrand's Landforms in Quaternary Geology of Michigan Map (Department of Geological Sciences, The University of Michigan, Ann Arbor. 1982)

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1 = Outwash plains
2 = Ground Moraines of Fine Textured Till
3 = Lacustrine Sands and Gravels
4 = Ice Contact Features
5 = End Moraines of Coarse Textured Till
6 = Ground Moraines of Coarse Textured Till
7 = End Moraines of Medium Textured Till
8 = Ground Moraines of Medium Textured Till (not used)
9 = Lacustrine Silt and Clay (not used)
10 = End Moraines of Fine Textured Till

Note: Landforms that covered relatively little area were not used in this study. The numbering system was developed for a preliminary study and kept for continuity.

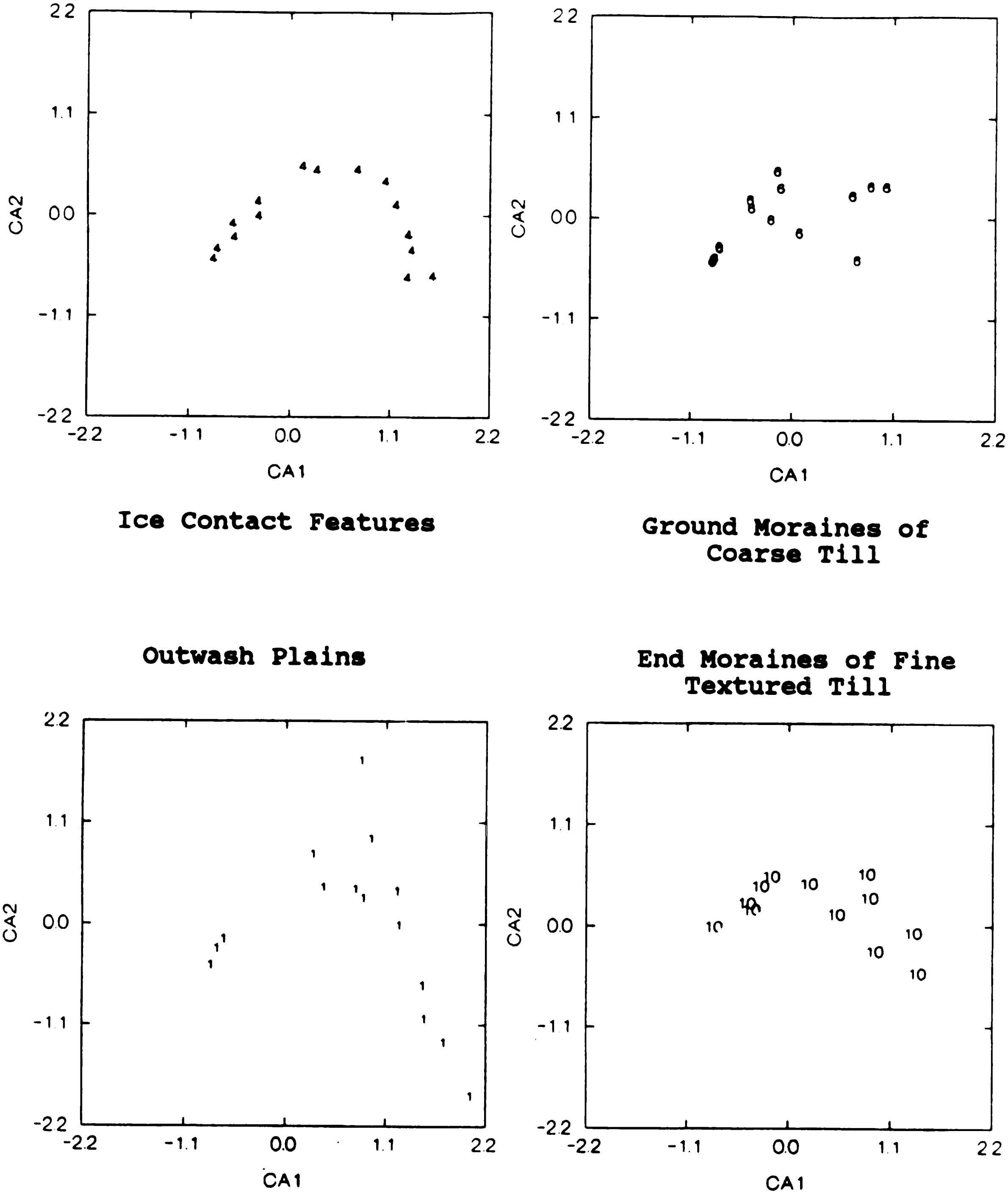

Figure 6. Correspondence analysis for quarter townships on individual landforms. The data used are the same as those plotted in Figure 3. The sites on these landforms appear to have been more variable in composition and dominated by more xeric species than sites on the landforms in Figure 5.

settlement forest composition was controlled by a combination of factors and that the relative importance of each factor changed with geographic location. The profile plots in Figure 7 show pockets of similar forest composition. The study area was divided into four regions for examination. Similar profiles in the first region where found on similar landform types. The communities in the other three regions seemed to be responding more strongly to factors other than landform since profiles were similar across landforms within regions (Figure 8). Figure 9 distinctly shows the regionalization for only the outwash plain samples.

Region 1

The profile plots in Region 1 and 3 were not all similar and appeared to be regulated by more "local" factors than in Regions 2 and 4. The major differences between Region 1 and 3 were the increase of oaks on dry landforms and the decrease of red pine on all landforms except ice contact features in Region 1. The importance of position in the landscape has been discussed by Kline and Cottam (1979), Leitner et. al (1991), Palik and Pregitzer (1992) and Grimm (1984), and may be the most important factor in distinguishing between these two regions. For example, ground moraines of coarse till in Region 1 were adjacent and mostly surrounded by landforms with mesic forests. These samples contained very little red pine, whereas in Region 3 samples from this landform were adjacent to outwash plains and ice contact features and had high counts

Legend Figure 7: Codes Given to Farrand's Landforms in Quaternary Geology of Michigan Map (Department of Geological Sciences, The University of Michigan, Ann Arbor. 1982)

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1 = Outwash plains
2 = Ground Moraines of Fine Textured Till
3 = Lacustrine Sands and Gravels
4 = Ice Contact Features
5 = End Moraines of Coarse Textured Till
6 = Ground Moraines of Coarse Textured Till
7 = End Moraines of Medium Textured Till
8 = Ground Moraines of Medium Textured Till (not used)
9 = Lacustrine Silt and Clay (not used)
10 = End Moraines of Fine Textured Till

Note: Landforms that covered relatively little area were not used in this study. The numbering system was developed for a preliminary study and kept for continuity.

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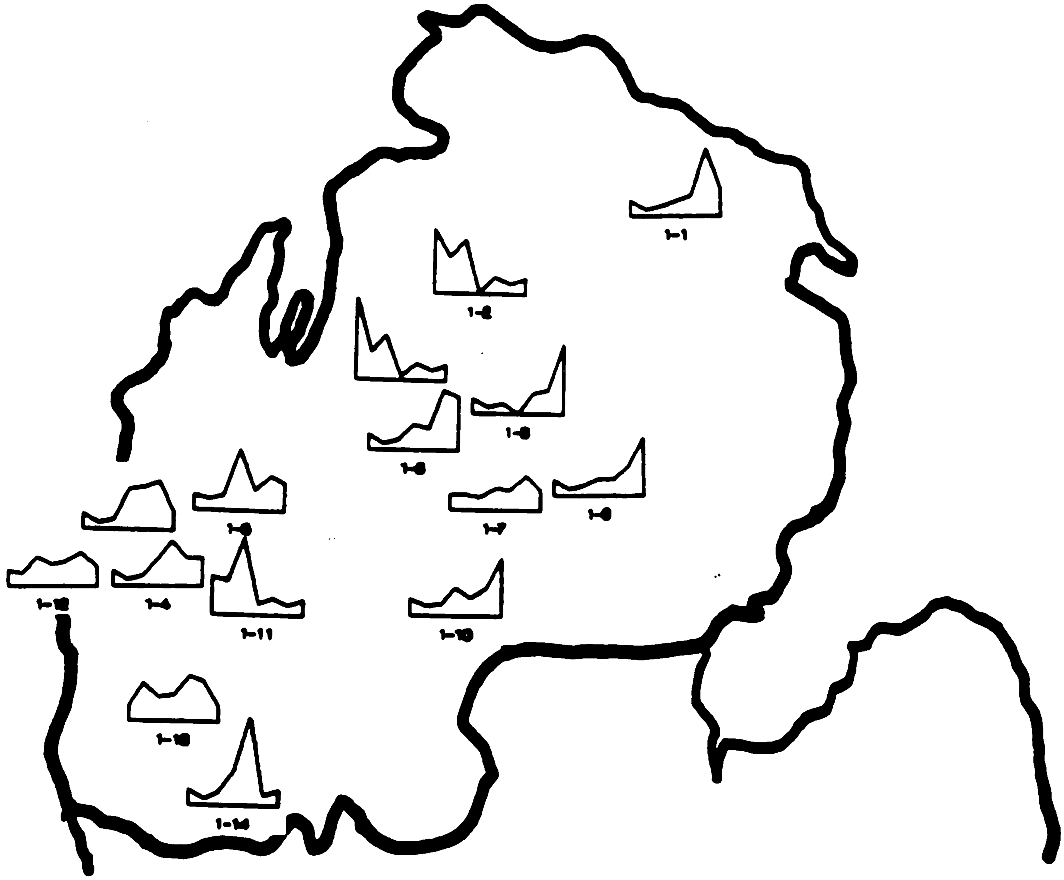


Figure 9. Profile plots for outwash plains only showing geographic variation in pre-European settlement composition within one landform type.

for red pine. Fires starting on the outwash plains could have easily swept up onto the moraines in Region 3, thus explaining the higher counts of red pine due to increased fire disturbance. The pattern of fire disturbance provides support for this theory.

Region 2

Samples from the northwestern third of the study area, (Region 2 in Figure 8) were consistently dominated by sugar maple and beech, often with a minor component of hemlock. Although Veatch did not include beech as a dominant species in his 1959 map, he listed it as a major species of the area in his book (Veatch, 1953). In this region, beech-maple forests dominated six of the eight landform types delineated by Farrand's map, including landforms (e.g. outwash) supporting drier communities in other geographic regions. A peculiarity of this region is that it is composed almost exclusively of sugar maple, beech and hemlock with few other species.

Weather would seem to have a great influence in this area since the predominant winds come off of Lake Michigan moisture-laden and sweep eastward across the land. An examination of weather conditions (Denton and Barnes 1988 and Eichenlaub 1979) shows that such a "lake-effect" has been well documented. However, most lake-effect designations are drawn closer to shore than the profiles in Figure 8 suggest. My results agree with the extent of Veatch's mesic forest community # 7 that extended further inland.

The area designated as Region 2 in Figure 8 does not contradict what Albert et al. (1986) described for moraines in each of the subdistricts within this area, but it does not support a need for divisions (districts and subdistricts) based on overstory composition alone.

Region 3

The northeastern area, Region 3, was characterized by "drier" communities. Here, some moraines were dominated by mesic hardwoods with differing proportions of hemlock, white pine, white oak and red maple, while other moraines are dominated by the pines.

Many fires were recorded by the surveyors in this region, likely contributing to pine dominance and suggesting that the soils on the moraines here may not be as mesic as they are in other regions. Samples from all moraines in this region had significantly more red pine than they did in Region 1.

A general difference in soils and therefore communities across the state may be attributable to composition of till. The Michigan lobe of the Laurentide Ice Sheet scraped over different bedrock than the Huron lobe did (see bedrock map in Hough 1958).

Region 4

The area in the southeastern corner of the study area, Region 4, also exhibited a similar forest composition across landform types (Figure 8). The pre-European settlement forests in this region were dominated primarily by white pine and hemlock, with a mixture of other mesic species, mostly red maple.

The soils are dominantly clays and silts with overlain sand (see map of Whiteside et al. 1968). These soils are the result of former glacial lake plains (Dorr and Eschman 1984). Topographical differences are not great until the high plains region which marks the boundary of the lake plain, this is shown as the western boundary for Region 4. Albert et al. (1986) stated that the climate changes slowly from the lake inland, and from south to north. The heavy clay soils deposited over the landforms and the equitable climate were apparently the dominant factors in determining forest composition. End and ground moraines of fine textured till and lacustrine sands and gravels showed little distinction in composition and are the only landforms in this region.

Generalized maps of the pre-European settlement forests of Michigan classify Region 2, and the lake plain area in Region 4 as northern hardwoods (Marschner 1946, Kuchler 1964). Beech-maple forests occurred on only 2 of the 23 samples in Region 4. My results distinguish Regions 2 and 4; northern hardwoods with very little white pine to the northwest (Region 2) and white pine-hemlock to the southeast (Region 4).

Tables similar to Table 6 but for each region are found in Tables 7 through 10. These tables support the previous descriptions of the community trends for the regions, based on correspondence analysis and the profile plots.

Table 7. Comparison of species percentages by landform for Region 1. Numbers in parentheses indicate the number of quarter township samples summarized for each landform in Region 1. Each quarter township represents 24 linear miles of corner and line witness tree data.

	Outwash plains (2)	Ice contact (3)	Grd.mor. coarse (3)	End mor. coarse (3)	End mor. medium (5)	Lacust-rine (4)
Sugar maple	39.4	30.3	28.9	39.7	30.6	25.0
Hemlock	16.4	22.6	21.8	18.3	13.2	25.8
Beech	29.1	37.1	26.2	28.1	42.9	35.1
White pine	2.1	3.9	3.3	1.8	2.3	1.4
Red maple	4.5	0.7	0.6	0.4	1.0	0.3
White oak	0.0	0.0	0.0	0.0	0.3	0.0
Black oak	0.0	0.0	0.0	0.0	0.3	0.3
Red pine	0.0	0.2	0.8	0.2	1.9	0.3
Jack pine	0.0	0.0	0.0	0.0	0.2	0.0
Fir	0.0	0.0	0.8	0.0	0.0	0.6
Ash	0.0	0.0	0.0	0.2	0.5	0.3
Cedar	0.0	0.0	4.1	0.0	0.2	3.9
Elm	1.0	0.9	1.4	6.3	2.1	0.6
Basswood	0.0	0.9	2.2	3.4	1.6	0.8
Aspen	0.0	0.0	5.0	0.4	0.6	1.4
Birch	2.1	3.4	3.3	0.7	0.0	3.1
Yellow birch	5.1	0.0	1.7	0.4	2.3	1.1
Black cherry	0.3	0.0	0.0	0.2	0.0	0.0
	100	100	100	100	100	100

Table 8. Comparison of species percentages by landform for Region 2. Numbers in parentheses indicate how many quarter township samples were summarized for each landform in Region 2. Each quarter township represents a sample of 24 linear miles of corner and line witness tree data.

	Ice Contact (2)	Fine End mor. (5)	Fine Gr.mor. (7)	Lacust-rine (7)
Sugar maple	24.0	8.2	6.3	2.4
Hemlock	19.0	34.1	22.1	22.8
Beech	26.9	17.2	12.9	6.1
White pine	9.5	16.9	32.1	34.7
Red maple	0.8	2.3	11.2	7.8
White oak	0.0	0.6	0.4	0.6
Black oak	5.0	0.6	0.7	0.0
Red pine	8.3	8.2	4.9	8.2
Jack pine	0.0	0.0	0.0	2.4
Fir	0.0	0.8	0.6	1.3
Ash	0.0	1.5	2.4	3.7
Cedar	0.0	2.7	1.5	3.1
Elm	0.8	1.3	2.2	1.8
Basswood	4.5	0.8	0.8	0.0
Aspen	0.8	1.5	0.7	2.3
Birch	0.4	2.9	1.0	2.6
Yellow birch	0.0	0.4	0.1	0.2
Black Cherry	0.0	0.0	0.0	0.0
	100	100	100	100

Table 9. Comparison of species percentages by landform for Region 3. Numbers in parentheses indicate how many quarter township samples were summarized for each landform in Region 3. Each quarter township represents 24 linear miles of corner and line witness tree data.

	Outwash (1)	Ice Contact (5)	End mor. Fine (7)	Grd.mor. Coarse (7)	End mor. Coarse (1)	End mor. Medium (2)
Sugar maple	0.0	2.3	5.5	10.7	6.0	8.2
Hemlock	0.0	6.7	12.7	11.8	6.0	30.5
Beech	0.0	8.5	8.4	11.4	10.0	20.9
White pine	15.2	15.6	16.6	12.8	5.0	12.3
Red maple	4.0	3.7	1.5	0.7	2.0	0.0
White oak	2.0	0.2	0.8	0.3	1.0	3.6
Black oak	1.0	0.4	3.3	3.6	2.0	0.9
Red pine	52.5	27.4	29.4	34.5	38.0	14.5
Jack pine	20.2	24.9	13.0	7.7	28.0	2.7
Fir	2.0	0.0	0.0	0.4	0.0	0.0
Ash	0.0	0.0	0.6	0.0	0.0	0.9
Cedar	0.0	0.0	0.4	0.7	0.0	0.9
Elm	0.0	0.2	0.3	0.6	0.0	0.9
Basswood	0.0	0.6	0.3	1.1	2.0	0.0
Aspen	1.0	6.7	4.3	2.4	0.0	0.9
Birch	2.0	2.9	2.3	1.0	0.0	1.8
Yellow birch	0.0	0.0	0.6	0.4	0.0	0.9
Black cherry	0.0	0.0	0.0	0.0	0.0	0.0
	100	100	100	100	100	100

Table 10. Comparison of species percentages by landform for Region 4. Numbers in parentheses indicate the number of quarter township samples summarized for each landform in Region 4. Quarter townships represent a sample of 24 linear miles of corner and line witness tree data.

	Outwash plains (12)	Ice contact (4)	Grd.mor. coarse (5)	End mor. coarse (9)	Grd.mor. fine (4)	Lacust-rine (1)
Sugar maple	1.9	0.5	15.7	14.2	12.9	4.1
Hemlock	5.8	1.7	22.1	17.6	35.9	17.5
Beech	8.7	3.9	32.6	35.1	23.5	40.2
White pine	21.7	22.1	15.7	12.5	10.6	16.5
Red maple	1.9	1.0	2.2	4.4	3.2	4.1
White oak	8.7	6.3	0.3	2.4	0.0	10.3
Black oak	2.5	5.1	0.6	1.9	0.0	0.0
Red pine	17.3	39.1	1.8	4.9	1.5	7.2
Jack pine	26.9	18.0	0.3	0.0	0.0	0.0
Fir	0.0	0.0	0.0	0.0	0.7	0.0
Ash	0.6	0.0	0.1	0.8	2.0	0.0
Cedar	0.8	0.0	0.1	0.3	1.2	0.0
Elm	0.3	0.0	3.4	2.2	1.2	0.0
Basswood	0.2	0.0	2.2	1.5	3.2	0.0
Aspen	1.9	2.4	0.7	1.1	2.2	0.0
Birch	0.5	0.0	1.5	1.2	0.7	0.0
Yellow birch	0.0	0.0	0.1	0.0	0.5	0.0
Black cherry	0.2	0.0	0.3	0.0	0.5	0.0
	100	100	100	100	100	100

Major Forest Types

Some samples changed groups during the different cluster analyses, however, many members grouped together regardless of clustering method. The non-hierarchical method compared exactly to the groups of the Ward's method with the exception that a fifth group was made up of only sample 1-14, the only sample dominated by white pine and white oak. Slight alterations of Ward's method provided the most consistent groups.

The first division using Ward's method split the sample locations into forests dominated by mesic species verses forests dominated by the conifers. These two groups were then further divided into two main groups each. The first group was composed primarily of sugar maple, hemlock and beech. The second group also was dominated by sugar maple, beech and/or hemlock but almost always included other species such as white and red pine, white oak or red maple. The third group was predominately dominated by white pine and hemlock with much red pine, red maple and white oak. The fourth group was dominated by one or a combination of the pines. Figure 10 compares the results from the cluster analysis to Veatch's forest communities and shows the consistency of forest types in Regions 2, 3 and 4.

Table 11 compares the total citation frequency of each species for each cluster. Table 12 compares the total relative dominance of each species for each cluster. Although sugar maple and beech dominated the forest type in cluster 1 numerically, sugar maple and hemlock accounted for larger basal areas than beech. The hemlock in this region were larger on average than the beech, which although numerous, had small diameters on average.

More and larger white pine occurred in the second forest type (cluster 2). White pine and hemlock dominated the basal area in this region with larger trees compared to the more frequent but smaller sugar maple and beech.

White pine accounted for almost 50 percent of the basal area in the third forest type (cluster 3), even though it accounted for only a third of the citation frequency. This forest type, that occurred almost exclusively in the Saginaw Bay area in Region 3, contained the most and the largest white pine in the study area along with a fair amount of hemlock and red pine.

The three pine species dominated the last forest type numerically (cluster 4), with the highest numbers for red pine and then jack pine and white pine. Red pine accounted for almost 50 percent of the basal area for this forest type, and white pine had the second largest basal area. Although many jack pine occurred in this forest type, they were usually small. Bourdo (1956) mentioned that the surveyors often selected large red pines over jack pine in areas of barrens due to their fire resistance.

Table 11. Comparison of species citation frequency among clusters.

	Cluster #1	Cluster #2	Cluster #3	Cluster #4
Sugar maple	36.0	14.6	4.1	2.2
Hemlock	16.6	24.4	18.6	4.8
Beech	33.8	35.5	11.7	2.5
White pine	1.7	8.9	29.8	16.1
Red maple	0.6	2.7	6.1	1.2
White oak	0.0	1.0	4.4	1.7
Black oak	0.3	0.8	2.1	2.7
Red pine	0.5	3.3	13.0	34.2
Jack pine	0.0	0.1	2.8	27.7
Fir	0.0	0.3	0.4	0.2
Ash	0.1	1.1	1.5	0.0
Cedar	0.9	1.1	1.3	0.3
Elm	3.7	1.5	0.7	0.2
Basswood	2.3	1.7	0.5	0.3
Aspen	0.6	1.2	1.5	4.3
White birch	1.3	1.4	1.4	1.5
Yellow birch	1.4	0.3	0.2	0.2
	100	100	100	100

Table 12. Comparison of species relative dominance among clusters.

	Cluster #1	Cluster #2	Cluster #3	Cluster #4
Sugar maple	39.0	13.1	3.3	2.0
Hemlock	23.3	26.3	15.2	6.3
Beech	20.7	18.8	5.4	1.4
White pine	3.5	23.2	49.5	27.4
Red maple	0.4	2.2	3.0	0.5
White oak	0.2	0.8	2.0	0.6
Black oak	0.0	1.8	2.1	2.6
Red pine	0.6	4.6	13.7	47.3
Jack pine	0.0	0.6	0.8	8.0
Fir	0.0	0.2	0.0	0.1
Ash	0.3	1.9	1.0	0.2
Cedar	0.6	1.1	0.6	0.6
Elm	5.7	2.1	1.2	0.5
Basswood	3.3	1.7	0.6	0.2
Aspen	0.0	0.0	0.6	1.4
White birch	1.3	1.4	0.6	0.6
Yellow birch	0.0	0.0	0.3	0.2
	100	100	100	100

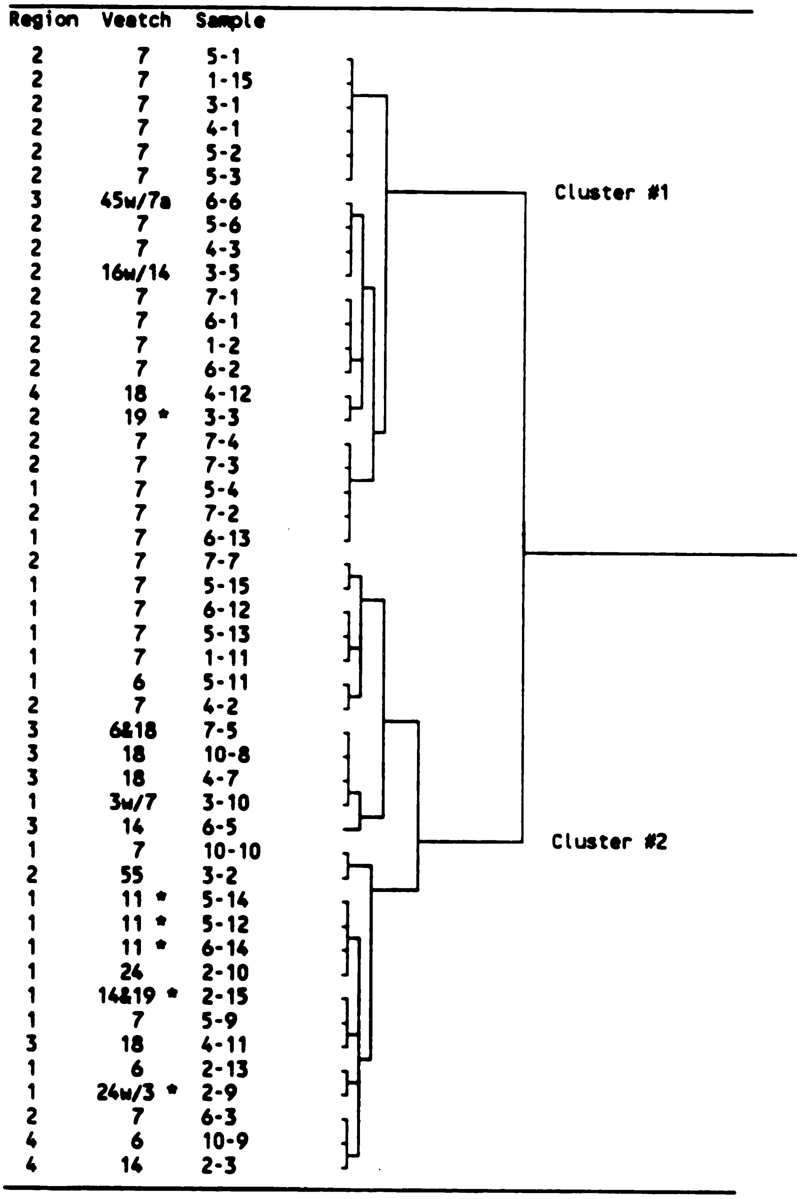
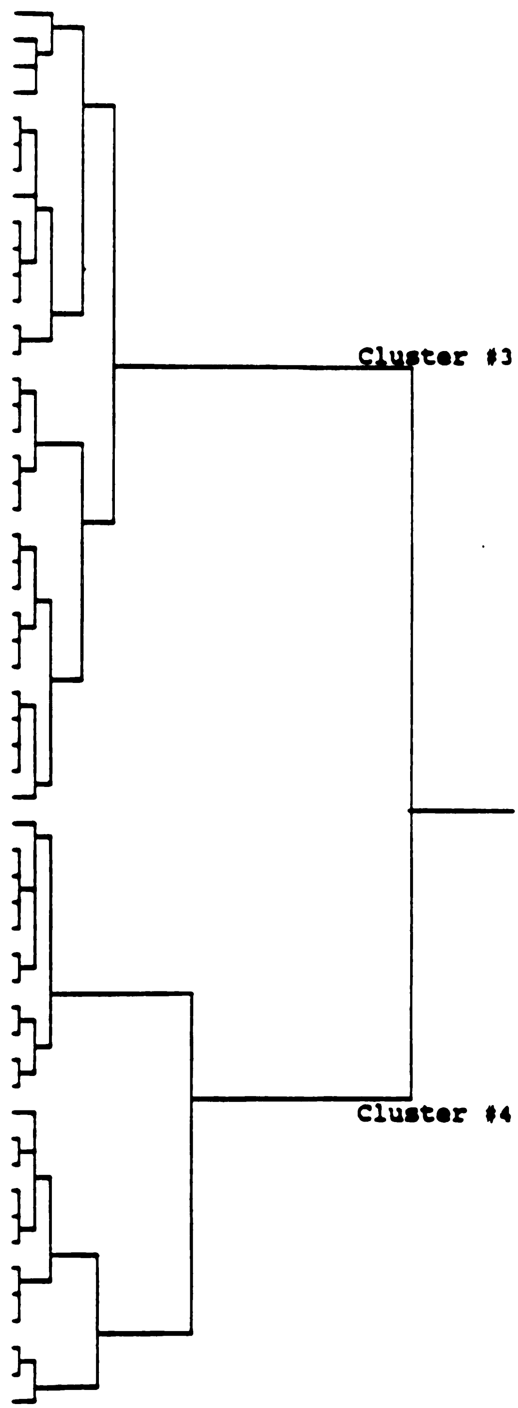


Figure 10. Comparison of cluster analysis with regions from this study and with forest community designations from Veatch's 1959 map. The cluster analysis was done using Euclidean distance for the Ward minimum variance method.

Figure 10. (cont'd)

Region	Veatch	
1	2	1-14
1	3	1-9
1	17	1-4
1	3	1-8
1	16	1-13
4	24	10-12
4	3w/24	3-7
1	3	5-5
1	3	5-10
3	18	4-6
4	18	4-15
1	3	1-12
3	3w/6	10-7
3	7&3	6-7
3	6w/18	7-6
1	18w/6	10-13
2	3w/18	6-11
1	3	3-11
1	17 *	3-13
1	14 *	2-6
1	3	3-12
1	6&18	2-5
1	17 *	3-14
1	14w/6	2-7
1	17 *	3-8
1	17 *	3-15
1	24	10-11
1	14 *	2-4
1	14 *	2-8
1	6w/18	2-12
2	11	6-15
3	18	6-8
3	3	6-10
3	3	6-9
1	3	4-13
1	3	4-8
3	3	4-4
3	3	1-1
1	3	4-14
1	19w/3	1-7
3	3	10-1
3	3	10-3
3	3	10-4
3	3	10-5
3	3	4-5
3	7w/3	5-8
3	3	10-6
3	18w/3	6-4
1	3	4-9
1	3	1-5
3	3	4-10
1	3	1-10
1	3	1-6
1	3	1-3



Comparison with Veatch and Albert et al.

Veatch's map compared favorably with the results from the cluster analysis. The numbers for Veatch's forest communities match those in the legend to his 1959 map. Veatch's map in many cases successfully provides a more detailed description of the pre-European settlement forests than Marschner's map (1946). Note that many of Veatch's communities are consistent with the finer subdivisions in the cluster analysis and are more defined than the forest types of this study. The samples where Veatch's designation does not correspond with the cluster analysis are marked with an asterisk (Figure 10).

Albert et al. (1986) note that boundaries on their map reflect hypotheses that need testing. This study agrees with most of the ecosystem districts delineated in Albert et al.'s Region II. Figure 11 compares the regions from this study based on pre-European settlement forest composition with the districts of Albert et al.

The many subdivisions reflecting minor climatic and physiographic differences of Albert et. al's map are not distinguishable in Region 2 based on overstory composition of the pre-European settlement forest. Region 4 closely reflects the Albert et al. District 7 but appears to extend inland and cover more of Ogemaw and Clare Counties. The area covering Subdistrict 12.3 was avoided for this study because of the abundance of lowland wet areas, which supports this subdistrict designation. The evidence of much drier communities on moraines in Region 3 than on the same landform

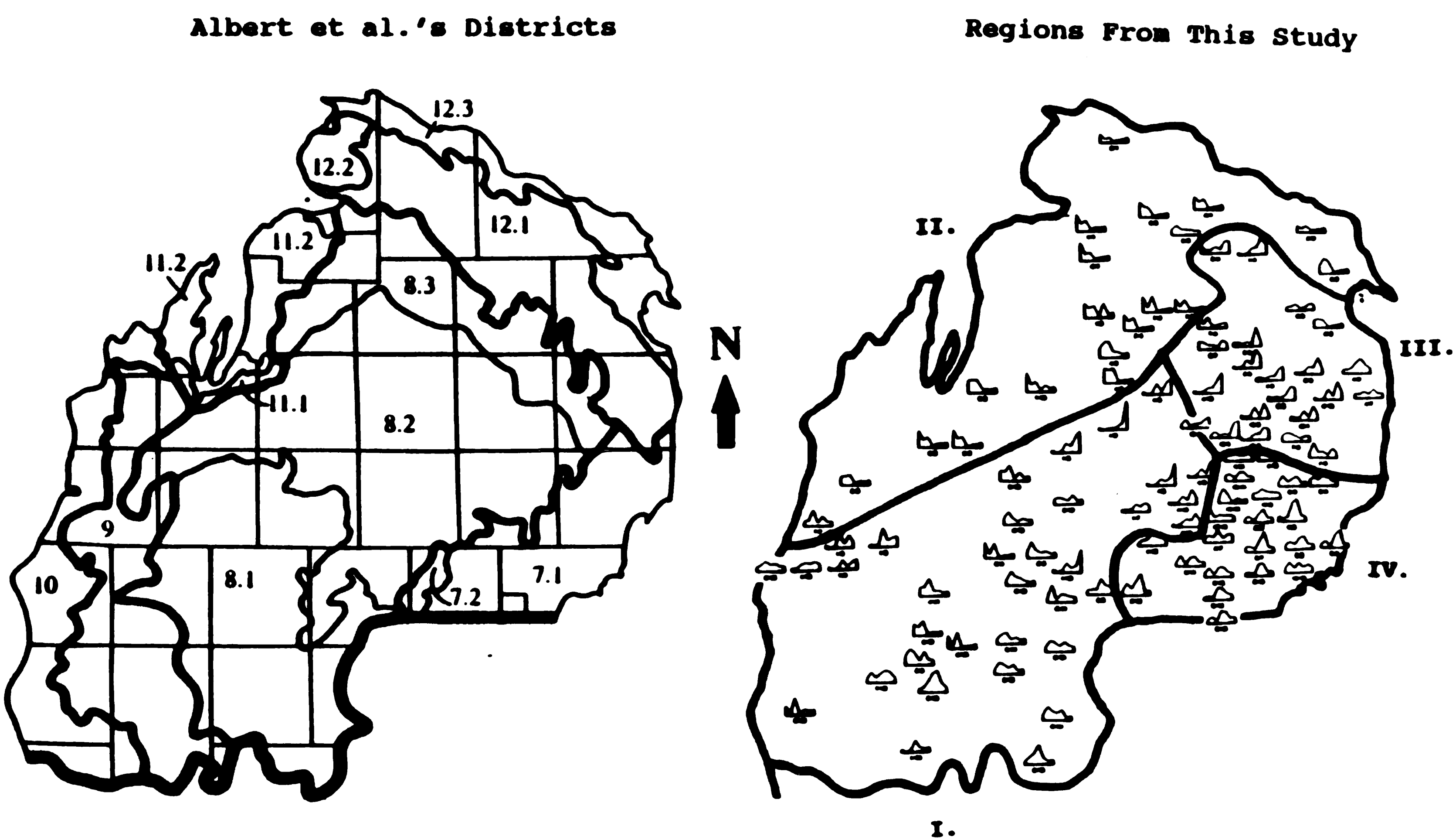


Figure 11. Comparison of regions from this study to Albert et al.'s districts from Regional Ecosystems of Michigan (1986).

types in Region 2, leads to a disagreement with District 12.1 as one regional ecosystem.

Finally, Districts 10, 9, and 8 seem to be an accurate gradient of diminishing lake affect which was reflected in the data used for this study. One very important conclusion is that the hierarchical regionalization used by Albert et al, is supported by the composition of the pre-European settlement forest. Their method is ecologically relevant. Climate is the most important, overriding factor affecting forest composition. Second, I believe major soil groups can have more of an affect on composition than landform and finally, all of the factors mentioned affect disturbance regimes.

Disturbance

Padley (1989) found that although two moraines from subsequent stages of the Huron ice lobe in Michigan differed in only a few soil properties, the present-day forests on the two moraines were very different. This was attributed to differences in disturbance histories, affecting the successional patterns of vegetation.

The importance of the role of disturbance in controlling pre-European settlement forests has been documented for many areas: Roscommon and Crawford counties (Whitney 1986), a segment of shoreline on Lake Superior (Loope 1991), upper Wisconsin (Canham and Loucks 1984), and the "Big Woods" of Minnesota (Grimm 1984). The disturbance regime in a given area is strongly related to soil, vegetation and position in the landscape. Grimm (1984) found that the pre-European settlement vegetation communities on the windward side of the Cannon River were subjected to fires more frequently than the communities on the east side. Grimm also stated that the mesic communities surrounding the dry communities acted as fire breaks because of the nonflammability of the vegetation.

In this study, 22% of the total samples covering 17.9% of the total sample mileage had some kind of disturbance recorded by the surveyors. Table 13 summarizes these disturbances by type (windfall or fire) for each landform. More area was affected by fire than by windfall (14.9% and 3.1%, respectively). Fire was most frequent on outwash plains and ice contact features. The greatest disturbance by windfall occurred on ground moraines of fine-textured till. End moraines of medium and fine-textured till had the least disturbance.

The return intervals in Table 13 can be compared to Whitney's disturbance regime table (1986). Whitney's jack pine community showed a shorter return time (83-167 yr) than that determined for outwash samples (163-326) in this study. All of Whitney's return times for his forest types were shorter than my calculations. Although the total number of lines examined for each study are comparable (2448 for this study and 2270 for Whitney's) the area covered by Whitney's study was continuous and in only one region. Secondly, Whitney's study area occurred in the middle of a band of disturbances that covers the center of the study area (Figure

Table 13. Disturbance regime summarized by landform type.

	outwash plains	ice contact	fine end moraine	course gr moraine	course end moraine	med end moraine	lacust-rine	fine gr moraine	total
Mileage sampled by landform type									
	317.2	329.7	250.0	216.6	316.1	156.6	221.1	208.8	2016.1
% of total mileage	(15.0)	(16.3)	(12.4)	(10.7)	(15.7)	(7.8)	(11.0)	(10.3)	(100)
Number of disturbances for each landform type									
fire	5	2	1	1	1	1	1	0	12
windfall	1	1	1	1	2	0	2	3	11
% tot. distance affected by fire	9.0	2.4	0.8	1	0.3	1.3	0.9	0	14.89
Est. return time (in years) based on interval surveyor could record *									
15 yr	167	625	172	1428	5000	1149	16670	-	
30 yr	333	1250	345	3030	10000	2325	37037	-	
% tot. distance affected by windfall	0.2	0.1	0.1	0.1	1.1	0	0	1.45	3.05
Est. return time (in years) based on interval surveyor could record									
15 yr	7692	16667	16667	16667	1370	-	-	1000	
30 yr	14286	37037	37037	37037	2727	-	-	2000	
% tot. distance affected by fire and/or windfall	9.2	2.5	0.9	1.1	1.4	1.3	0.9	1.45	17.94
Est. return time (in years) based on interval surveyor could record									
15 yr	163	600	1666	1370	1071	1154	1666	1034	
30 yr	326	1200	3333	2727	2143	2308	3333	2069	

* Estimated return time is roughly the time required for disturbances to occur to cover an area equal total area sampled for each landform type. Note that the windfalls recorded by the surveyors would probably not include individual treefall gaps, but were larger wind disturbances such as those described by Lorimer (1977).

12). Roscommon and Crawford Counties are very dry (dominated by sandy soils) and not only have the greatest proportion of outwash and ice contact features (Farrand's map), but are also situated in the middle of dry areas with few mesic communities for fire breaks. Kalkaska and Crawford Counties contained the largest disturbances (Table 14). The percentage of area effected by windfall was comparable in Whitney's (0.1 to 1.2% for different forest types) and in this study (0.1 to 1.45% for different landforms).

Table 14. Size of individual disturbances. Values indicate the total number of linear miles a disturbance covered according to the surveyors' notes.

FIRE		WINDFALL	
Sample	Size	Sample	Size
1-10	12.0	5-6	2.5 (burnt)
1-5	7.75, 0.5	5-1	1.25
3-3	7.3	2-9	0.8
4-9	6.25	1-9	0.8
1-3	5.9	10-3	0.6
1-12	2.8	3-12	0.55, 0.35 (burnt)
10-3	2.75	2-10	0.55,0.15,0.05,0.05
7-5	2.0	4-13	0.3
6-4	1.5	2-6	0.2
5-8	1.0	3-10	0.2
1-7	0.75		

Canham and Loucks (1984) calculated an estimated return interval for the pre-European settlement hemlock-white-pine-northern hardwood forests of northern Wisconsin to be 1210 years. The average return time according to my calculations for the 15 year estimate was 1259 years for all ground and end moraines. Apparently windthrow in this area was a more consistent mode of disturbance, whereas fire was highly variable in extent.

Figure 12 shows regionalization of disturbance across the study area. Percentages of fire and wind disturbances by region is listed in Table 15. Region 1 contained 73% of recorded occurrences of fire and 51% of recorded windfall. The northern hardwood forests in Region 1 had more moderately shade tolerant species such as white pine, red maple and oaks than the northern hardwoods in Region 2. The northern hardwood forests in Region 2 were distinctive in that they were dominated almost exclusively by sugar maple, beech and hemlock, usually in that order frequency. Larger treefall gaps in Region 1 may have allowed for more shade intolerant species to exist compared to Region 2 (S.T.A. Pickett pers. com. 1993).

Fire disturbances dominated in Region 3, accounting for 12% of all fire occurrences in the study area. The surveyors recorded only blowdowns for Region 4. The heavy clay soils may have promoted shallow root systems making trees more susceptible to blowdown.

As Whitney (1986) stated, climate, disturbance, soils,

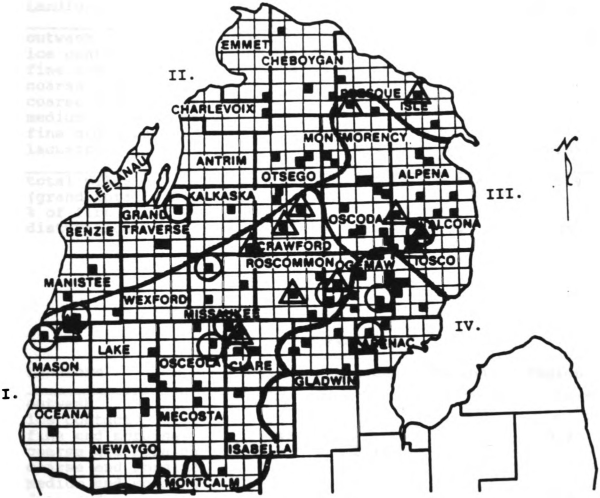


Figure 12. Regional distribution of disturbances; △ = fire, ○ = windthrow. Cited disturbances covered an estimated 17.9 % of the total area sampled. Region 1 contained the highest percentage of both types of disturbance; 73% of all cited fires and 51% of cited windthrow occurred in Region 1.

Table 15. Percentage of each type of disturbance by region. Distances are in total linear miles of survey line affected. Entries in parentheses are sites of windfall that were burnt.

FIRE

Landform	Region 1	Region 2	Region 3	Region 4
outwash	29.28			
ice contact	8.25			
fine end moraine				
coarse grd moraine		(2.15)	1.5	
coarse end moraine			1.0	
medium end moraine			2.0	
fine grd moraine			2.1	
lacustrine		4.5		(0.9)
total miles	37.53	6.65	6.6	0.9
(grand total = 51.68 miles)				
% of fire disturbance	73%	13%	12%	2%

WINDFALL

Landform	Region 1	Region 2	Region 3	Region 4
outwash	0.75			
ice contact	0.3			
fine end moraine	1.48			0.2
coarse grd moraine	0.2	2.15		
coarse end moraine	1.25			
medium end moraine				
fine grd moraine				0.63
lacustrine	0.13			0.9
total miles	4.11	2.15	0.0	1.73
(grand total = 7.99 miles)				
% of windfall disturbance	51%	27%	0%	22%

and topography all influence one another and these factors cannot be addressed independently. This study clearly shows that the influence of disturbance also changes from region to region.

CONCLUSIONS

Whereas in some regions of northern lower Michigan local differences in pre-European settlement composition can be predicted from landform, landform alone cannot be used to predict the pre-European settlement composition anywhere in the state. Some generalizations can be made, such as mesic forests tended to occur on the moraines of all textural classes and did not usually occur on ice contact features or on outwash plains; however, regional differences in composition within a community-landform association must also be considered. Once a region is delineated, then predictions of community composition based on landform may be useful. This strong regional pattern has not been evident in previous pre-European settlement studies. This may be attributed to the small size or the mid-continental climate of the areas previously examined.

Composition in the northwest corner of the study area appeared to be controlled primarily by climate. Composition in the southeast corner appeared to be controlled by a lacustrine soils laid down over landforms. Landform appeared most influential in distinguishing local ecosystems in the interior of the state where the climate is not lake-modified and the soils are distinguished based on the mode in which the glacier deposited them. Regional trends may not be as evident in the southern half of Michigan's Lower Peninsula since the lake effect is not as predominant (Albert et al. 1986).

Patterns and rates of disturbance were different for the four regions. Slight differences in dominant species for a community type within regions may be due to the successional stage achieved since the last disturbance at the time that area was surveyed, assuming the areas covered by the regions were large enough to produce a quasi-equilibrium landscape where the proportion of the area in each successional stage remains constant over time (Frelich and Lorimer 1991). Of course other factors such as early competition, seed predation, differences in seed sources and attacks by pathogens must also be considered in influencing the successional pathways of the pre-European settlement forests (Abrams et al. 1985). Although these factors certainly played a part in succession of pre-European settlement forests, their role may be emphasized in present-day forests due to human influences such as exotic pest introductions (i.e. the gypsy moth), forest fragmentation and the resulting decrease in seed sources.

The properties of landforms as well as their relative positions to each other did seem to influence disturbance regimes. Region 2, for example, had the least amount of disturbance and the most shade tolerant species while the mesic forests in Region 1 may have been disturbed on a more regular basis so that more shade intolerant species occurred and a different steady-state with a shorter return time was attained.

This study provided a fair testing of Veatch's 1959 map and found it to be mostly accurate though not fool proof. This study also provides quantitative data on the pre-European settlement communities in northern lower Michigan, information that was missing from Veatch's map.

The results of this study compared well to the districts in Albert et al.'s map. Overstory composition may be affected by factors on a different scale than those for the understory and ground flora. Areas of Albert et al.'s regional ecosystem districts and subdistricts that conflict with the results from this study may reflect differences in factors important to vegetation in structural layers other than the overstory.

The composition and extent of Michigan's present-day forest types is vastly different than that of the pre-European settlement forest. This study has provided information on the minor role species such as aspen, red maple and the oaks played in the pre-European settlement forests of northern lower Michigan. The explosion of these species since the turn of the century serves as a measure of how much humans have disturbed the landscape of the state.

USE OF THE PRE-EUROPEAN SETTLEMENT RECORDS FOR CURRENT LAND MANAGEMENT

Previously, knowledge of pre-European settlement forests was sought mostly by historians and scientists, but now natural resource managers are seeking this information. Organizations such as the Michigan Chapter of the Nature Conservancy are using pre-European settlement information to provide target communities for management goals of natural areas (1992). The Michigan Natural Features Inventory is in the process of producing a pre-European settlement map for the entire state of Michigan using the GLO records (1993). However, the survey records are only a snapshot in time. For this reason, some ecologists argue the validity of using such information to manage our current forests towards a historical model that may have existed under different circumstances. Have past logging, settlement, and resulting populations of species such as white-tailed deer, altered the soil, disturbance regimes, local climate and regeneration processes enough that pre-European settlement targets are now irrelevant? If an organization decrees a pre-European settlement community a management goal, a few issues should be recognized.

As mentioned above, time since last disturbance significantly altered the species composition in an area. Use of the GLO surveys to predict the pre-European settlement vegetation that occurred on a particular piece of ground may be misleading if only the notes containing the local area are examined. I suggest an examination of a particular region will give a general picture of the disturbance regimes of the area, as well as an overall forest composition, and the patterning of forest types across the region. This information combined with the MNFI pre-European settlement map should provide adequate pre-European settlement information for managers of natural land. Return intervals should also provide a baseline for management of natural stands. These should be constructed for the region in question to gain better accuracy, and would be most useful if calculated for forest types, not landforms (Whitney 1986).

Tree density was not considered in this study but would be useful to the forest manager (see methods in Cottam and Curtis 1956). Again, the scale with which the surveyor's recorded this data should be kept in mind and the densities calculated should be used to compare areas or forest types and not taken as an absolute for a given area.

Examination of pre-European settlement forests provides valuable information on the successional dynamics of our country's forests. Further studies to answer the following questions would be of value in understanding our pre-European settlement forests. How was the variability in rate of disturbance influenced by the patch size within and among vegetation types? Today's forests are highly fragmented, but the original forests covered most of the land area of Michigan. Did the continuous forested landscape ameliorate differences between sites within a region? And finally, in addition to the factors controlling forest composition already described, can we predict the effect of the position in the landscape on the type of forest found there?

Appendix A

APPENDIX A

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Appendix B

Appendix B

SAS Output for Correspondence Analysis

Raw Data

OBS	LF	S	H	B	WP	WO	M	RP	JP
1	1	0	0	0	15	2	4	52	20
2	1	48	28	47	2	0	10	0	0
3	1	0	0	0	1	2	0	12	93
4	1	0	0	0	25	18	0	16	21
5	1	0	0	0	24	3	3	45	65
6	1	0	0	0	16	0	1	17	71
7	1	0	8	2	20	2	2	22	7
8	1	0	5	5	55	2	3	22	22
9	1	0	0	0	37	17	1	34	4
10	1	2	3	1	26	1	1	16	73
11	1	23	26	72	11	0	2	0	0
12	1	0	6	20	20	6	3	21	5
13	1	1	30	15	25	19	8	27	0
14	1	0	0	2	32	47	1	0	0
15	1	67	20	38	4	0	3	0	0
16	2	5	31	11	18	0	6	0	0
17	2	11	25	21	35	0	7	6	0
18	2	9	8	13	53	0	17	10	0
19	2	2	18	1	20	0	9	5	0
20	2	7	16	6	32	2	15	8	0
21	2	8	24	16	31	1	9	6	0
22	2	12	46	25	11	0	3	2	0
23	2	12	41	31	18	0	1	0	0
24	2	3	36	24	39	0	17	0	0
25	2	16	38	21	6	0	3	4	0
26	2	12	20	18	8	0	6	0	0
27	3	26	11	16	0	0	0	0	0
28	3	23	45	48	0	0	0	0	0
29	3	16	11	22	3	0	0	1	0
30	3	24	25	39	2	0	1	0	0
31	3	1	21	16	32	2	1	20	11
32	3	2	20	2	36	0	13	1	0
33	3	4	17	39	16	10	4	7	0
34	3	2	32	3	23	2	6	3	0
35	3	3	11	2	33	0	8	2	0
36	3	6	27	5	26	0	6	6	0
37	3	1	11	4	34	0	7	13	0
38	3	0	19	6	31	0	7	6	4
39	4	60	21	43	2	0	1	0	0
40	4	25	43	64	13	0	2	1	0
41	4	48	35	56	2	0	0	0	0
42	4	0	1	0	21	0	1	55	29
43	4	0	10	1	10	0	1	28	36
44	4	4	10	19	30	0	10	19	0
45	4	8	12	24	9	1	5	5	0
46	4	0	0	3	21	6	0	45	18
47	4	0	0	2	29	3	0	32	40
48	4	0	2	0	11	15	2	35	64
49	4	24	28	29	13	0	2	15	0

Raw Count Data (continued)

51	4	0	4	0	21	6	1	44	10
52	4	2	3	11	20	11	3	40	6
53	4	0	16	21	32	0	7	33	1
54	5	65	20	30	2	0	0	0	0
55	5	56	21	38	0	0	1	0	0
56	5	60	24	40	0	0	0	0	0
57	5	55	11	60	0	0	0	0	0
58	5	6	15	14	45	20	5	17	0
59	5	38	36	47	8	0	0	1	0
60	5	6	6	10	5	1	2	38	28
61	5	26	45	47	9	0	9	6	0
62	5	2	13	40	52	4	16	23	0
63	5	11	28	46	9	0	3	0	0
64	5	6	34	37	15	1	6	2	0
65	5	30	26	66	4	0	5	0	0
66	5	6	32	36	14	2	6	10	0
67	5	26	4	70	0	1	2	0	0
68	6	42	21	41	0	0	0	0	0
69	6	51	30	35	0	0	0	0	0
70	6	12	28	19	12	0	2	3	0
71	6	19	8	8	17	1	1	32	30
72	6	3	11	21	2	0	0	12	0
73	6	24	26	26	0	0	0	0	0
74	6	21	21	14	11	0	0	25	8
75	6	5	14	6	11	0	0	61	2
76	6	1	3	5	20	0	3	53	5
77	6	2	0	0	29	1	1	60	9
78	6	8	53	10	24	0	4	12	2
79	6	37	25	62	4	0	1	0	0
80	6	45	9	69	2	0	0	0	0
81	6	14	41	35	19	2	7	0	0
82	6	1	20	42	56	0	3	0	0
83	7	52	26	51	0	0	0	0	0
84	7	52	14	65	0	0	0	0	0
85	7	41	14	45	4	0	0	0	0
86	7	37	12	40	3	0	0	6	1
87	7	12	24	29	12	8	0	9	2
88	7	6	43	17	15	0	0	23	4
89	7	8	16	65	7	2	6	3	0
90	10	7	9	3	26	0	0	40	7
91	10	6	6	4	33	0	0	49	0
92	10	3	25	2	10	1	1	19	23
93	10	0	19	4	10	3	0	44	48
94	10	2	1	3	16	4	3	36	23
95	10	11	16	12	16	0	5	29	8
96	10	14	18	38	19	1	3	14	0
97	10	10	31	16	14	1	0	6	0
98	10	11	45	35	1	0	2	0	0
99	10	13	20	8	24	0	5	5	0
100	10	0	36	9	16	2	2	10	0
101	10	5	31	14	26	0	2	18	0

The Correspondence Analysis Procedure

Inertia and Chi-Square Decomposition

```
Singular  Principal  Chi-
Values    Inertias   Squares  Percents    9   18   27   36   45
                                      ----+----+----+----+----+---
0.77734   0.60426    6176.13   46.80% **************************
0.52015   0.27056    2765.36   20.95% *************
0.40468   0.16377    1673.89   12.68% ********
0.35288   0.12453    1272.79    9.64% *****
0.24581   0.06042     617.56    4.68% ***
0.21923   0.04806     491.22    3.72% **
0.14000   0.01960     200.32    1.52% *
          -------    -------
          1.29119    13197.3  (Degrees of Freedom = 700)
```

Row Coordinates

Landform	Dim1	Dim2	Dim3	Dim4
1	1.23689	-0.01278	-0.28700	-0.64936
1	-0.75829	-0.26534	0.05779	0.00487
1	2.02170	-1.86940	0.30390	0.94650
1	1.21585	0.35442	1.15781	0.12325
1	1.49729	-0.66938	-0.02846	0.12646
1	1.73167	-1.28778	0.04032	0.69822
1	0.75804	0.38053	-0.21732	-0.20897
1	0.84623	0.28223	-0.17890	0.23470
1	0.93291	0.92762	0.68519	-0.42752
1	1.51691	-1.03224	0.06063	0.68746
1	-0.68660	-0.16128	0.05904	0.05651
1	0.40354	0.39688	0.17292	-0.19229
1	0.29617	0.75760	0.52498	-0.05208
1	0.82086	1.77871	3.22497	0.19369
1	-0.82756	-0.44990	0.18348	-0.21385
2	-0.30243	0.42489	-0.32233	0.55413
2	-0.16600	0.41674	-0.24960	0.28125
2	0.12349	0.73136	-0.35937	0.33886
2	0.06533	0.74153	-0.49376	0.51745
2	0.08098	0.72399	-0.27063	0.38979
2	-0.11048	0.50486	-0.24004	0.33708
2	-0.49635	0.11283	-0.20079	0.32192
2	-0.49051	0.12702	-0.14825	0.31535
2	-0.19041	0.58482	-0.34939	0.61727
2	-0.52136	0.01386	-0.16627	0.18591
2	-0.52881	0.09917	-0.14289	0.30574
3	-0.86516	-0.49187	0.18462	-0.21421
3	-0.75018	-0.21384	-0.00851	0.12247
3	-0.71515	-0.28195	0.09325	-0.09244
3	-0.76130	-0.26685	0.06102	0.01905
3	0.38955	0.24519	-0.16523	0.09377
3	0.06466	0.87440	-0.47116	0.72392
3	-0.18565	0.38898	0.48123	0.08431
3	-0.05454	0.66680	-0.26232	0.55917
3	0.13805	0.86891	-0.41901	0.58159
3	-0.05672	0.54965	-0.37937	0.38084
3	0.31686	0.79551	-0.45790	0.18461
3	0.22253	0.59128	-0.39508	0.50658
4	-0.84794	-0.46872	0.19234	-0.21442
4	-0.63442	-0.09147	-0.01892	0.12775
4	-0.80414	-0.35800	0.11449	-0.07536
4	1.29258	-0.20290	-0.34939	-0.50891
4	1.28271	-0.66616	-0.19701	0.09820
4	0.13249	0.53027	-0.35191	-0.00557
4	-0.35995	0.14937	-0.03959	0.07696
4	1.15437	0.11982	0.03649	-0.56716
4	1.32838	-0.37295	-0.01416	0.07163
4	1.56340	-0.65209	0.60330	0.21083
4	-0.35224	-0.00720	-0.12073	-0.15029
4	-0.61702	-0.23632	0.07205	-0.16704
4	1.03840	0.37697	-0.02438	-0.65933
4	0.73169	0.49321	0.32380	-0.57417
4	0.28614	0.48897	-0.39723	-0.20971
5	-0.86683	-0.52513	0.21495	-0.27477
5	-0.86517	-0.48856	0.19167	-0.21707
5	-0.86843	-0.49629	0.19326	-0.22168
5	-0.89392	-0.53180	0.25955	-0.28059
5	0.32351	0.86879	0.68355	0.04253

5	-0.70687	-0.23457	0.04847	-0.00383
5	0.95761	-0.50021	-0.13449	-0.32794
5	-0.54773	-0.01536	-0.11265	0.14059
5	0.10124	0.59834	-0.15300	0.10562
5	-0.61712	-0.02746	-0.04725	0.20657
5	-0.43361	0.20513	-0.12261	0.32799
5	-0.74560	-0.23286	0.07074	0.02829
5	-0.29934	0.22657	-0.10230	0.14385
5	-0.83910	-0.39526	0.28625	-0.17205
6	-0.85031	-0.44455	0.16992	-0.16385
6	-0.83873	-0.43176	0.13682	-0.13911
6	-0.43658	0.11220	-0.16391	0.20604
6	0.70917	-0.44657	-0.06217	-0.16442
6	-0.22472	-0.01183	-0.16755	-0.36367
6	-0.78771	-0.30975	0.04990	0.00947
6	0.08458	-0.15243	-0.16319	-0.31987
6	0.65946	0.25102	-0.48783	-1.05344
6	0.85797	0.35196	-0.49606	-0.88739
6	1.02478	0.34514	-0.41958	-0.87100
6	-0.11821	0.33071	-0.35745	0.29598
6	-0.78276	-0.31993	0.12287	-0.06278
6	-0.86288	-0.47142	0.24459	-0.23418
6	-0.45128	0.20181	-0.06698	0.34497
6	-0.15526	0.51648	-0.18860	0.40200
7	-0.85028	-0.44434	0.17003	-0.16369
7	-0.87993	-0.49705	0.23690	-0.23908
7	-0.81918	-0.41938	0.19364	-0.18853
7	-0.67690	-0.40907	0.14938	-0.29246
7	-0.19719	0.17529	0.38907	-0.01249
7	0.00972	0.15436	-0.31930	-0.03615
7	-0.57678	-0.02146	0.11073	0.08496
10	0.66757	0.25173	-0.38183	-0.56919
10	0.63473	0.51189	-0.45688	-0.78627
10	0.72545	-0.32550	-0.17710	0.21118
10	1.18502	-0.56880	-0.07163	-0.01660
10	1.13729	-0.12613	-0.01536	-0.30595
10	0.31124	0.07553	-0.29035	-0.26283
10	-0.26475	0.12467	-0.06959	-0.10155
10	-0.31301	0.19292	-0.13395	0.14856
10	-0.67323	-0.06006	-0.12332	0.29269
10	-0.16828	0.37907	-0.25616	0.23474
10	-0.05236	0.48599	-0.24622	0.25915
10	0.01576	0.40691	-0.34888	0.02099

CA OF THES1 DATA
Column Coordinates

	Dim1	Dim2	Dim3	Dim4
S	-0.80126	-0.47485	0.17979	-0.25109
H	-0.39855	0.13835	-0.19922	0.26854
B	-0.65169	-0.17097	0.09229	-0.02700
WP	0.38299	0.63478	-0.14645	0.20778
WO	0.88043	1.17425	2.38114	-0.03302
M	-0.00926	0.70530	-0.39392	0.56186
RP	0.92900	0.16018	-0.27631	-0.69479
JP	1.68210	-1.18195	0.12884	0.47600

Appendix C

Quarter Township Codes for Appendices C-E

The codes for the QT (quarter township) columns for all tables in Appendices C-E refer to the direction of that quarter township within the township; SW=southwest corner, NE=northeast corner and so on.

For example, Table C2. species counts for ground moraines of fine textured till shows sample 2-10 in Osceola County was located in the northwest corner of T19N R7W. Sample 2-12 crossed a county line between Clare and Gladwin counties. For instances such as this, the first location given (SE corner of T19N R2W in Clare County) contains six of the nine square miles, the second (SW corner of T19N R3W of Gladwin County) contains the last three square miles. The last example is for sample 2-13 where the code SWcn refers to the southwest corner that has been corrected north by one square mile, in most cases to avoid a boundary with another landform type.

Legend for Appedices C-E: Codes Given to Farrand's Landforms in Quaternary Geology of Michigan Map (Department of Geological Sciences, The University of Michigan, Ann Arbor. 1982)

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1 = Outwash plains
2 = Ground Moraines of Fine Textured Till
3 = Lacustrine Sands and Gravels
4 = Ice Contact Features
5 = End Moraines of Coarse Textured Till
6 = Ground Moraines of Coarse Textured Till
7 = End Moraines of Medium Textured Till
8 = Ground Moraines of Medium Textured Till (not used)
9 = Lacustrine Silt and Clay (not used)
10 = End Moraines of Fine Textured Till
11 = Dunes (not used)
12 = Peat and Muck (not used)

Note: Landforms that covered relatively little area were not used in this study. The numbering system was developed for a preliminary study and kept for continuity.

Table C1. Species counts on non-swampland for outwash plains. Data in these tables are the tallies of all witness and line trees surveyed on the uplands of each quarter township. The total number of individuals counted for each sample was dependent upon the number of trees each surveyor recorded, the availability of bearing and line trees, and the exclusion of data points that occurred in wetlands.

MAJOR SPECIES

SAMPLE	COUNTY	LOCATION	QT	Sugar maple	Hem-lock	Beech	White Pine	Red Maple	White Oak	Black Oak	Red Pine	Jack Pine
1-1	P. Isle	T33N R4E	SW	0	0	0	15	4	2	1	52	20
1-2	Otsego	T30N R3W	NW	48	28	47	2	10	0	0	0	0
1-3	Crawford	T26N R3W	NE	0	0	0	1	0	2	1	12	93
1-4	Mason	T20N R15W	NW	0	0	0	25	0	18	2	16	21
1-5	Kalkaska	T25N R5W	SE	0	0	0	24	3	3	3	45	65
1-6	Roscommon	T23N R1W	NE	0	0	0	16	1	0	0	17	71
1-7	Roscommon	T22N R2W	NE	0	8	2	20	2	2	0	22	7
1-8	Manistee	T21N R13W	NE	0	5	5	55	3	2	2	22	22
1-9	Manistee	T21N R15W	SW	0	0	0	37	1	17	4	34	4
1-10	Clare	T20N R6W	SE	2	3	1	26	1	1	0	16	73
1-11	Lake	T19N R11W	SE	23	26	72	11	2	0	3	0	0
1-12	Mason	T20N R16W	NE	0	6	20	20	3	6	0	21	5
1-13	Newaygo	T15N R13W	SE	1	30	15	25	8	19	1	27	0
1-14	Newaygo	T12N R12W	NE	0	0	2	32	1	47	18	0	0
1-15	Kalkaska	T27N R6W	NE	67	20	38	4	3	0	0	0	0
	total			141	126	202	313	42	119	35	284	381

MINOR SPECIES

SITE	COUNTY	LOCATION	QT	Fir	Ash	Cedar	Elm	Bas-wood	Aspen	Birch	Yellow birch
1-1	P. Isle	T33N R4E	SW	2	0	0	0	0	1	2	0
1-2	Otsego	T30N R3W	NW	0	0	0	2	0	0	5	10
1-3	Crawford	T26N R3W	NE	0	0	0	0	0	0	0	0
1-4	Mason	T20N R15W	NW	0	0	0	0	0	2	0	0
1-5	Kalkaska	T25N R5W	SE	0	0	0	0	0	2	0	0
1-6	Roscommon	T23N R1W	NE	0	0	0	0	0	4	0	0
1-7	Roscommon	T22N R2W	NE	0	0	3	0	0	8	0	0
1-8	Manistee	T21N R13W	NE	0	0	0	0	0	3	0	0
1-9	Manistee	T21N R15W	SW	0	0	0	0	0	0	0	0
1-10	Clare	T20N R6W	SE	0	0	0	2	0	4	0	0
1-11	Lake	T19N R11W	SE	0	6	8	1	1	0	0	0
1-12	Mason	T20N R16W	NE	0	0	0	1	1	0	0	0
1-13	Newaygo	T15N R13W	NE	0	2	0	0	0	2	0	0
1-14	Newaygo	T12N R12W	NE	0	0	0	0	1	0	0	0
1-15	Kalkaska	T27N R6W	NE	0	0	0	1	0	0	0	0
	total			2	8	11	7	3	26	7	10

Table C2. Species Counts for Non-swampland on Ground Moraines Composed of Fine Till

MAJOR SPECIES

SAMPLE	COUNTY	LOCATION	QT	Sugar maple	Hem-lock	Beech	White pine	Red maple	White oak	Black oak	Red pine	Jack pine
2-3	Iosco	T23N R5E	SW	5	31	11	18	6	0	1	0	0
2-4	Iosco	T23N R5E	SE	11	25	21	35	7	0	0	6	0
2-5	Iosco	T22N R5E	NW	9	8	13	53	17	0	0	10	0
2-6	Ogemaw	T22N R4E	SW	2	18	1	20	9	0	0	5	0
2-7	Ogemaw	T21N R4E	NW	7	16	6	32	15	2	1	8	0
2-8	Ogemaw	T21N R4E	NE	8	24	16	32	9	1	1	6	0
2-9	Clare	T20N R6W	NW	12	46	25	11	3	0	0	2	0
2-10	Osceola	T19N R7W	NW	12	41	31	18	1	0	0	0	0
2-12	Clar/Glad	T19N R2&3	SE/SW	3	36	24	39	17	0	2	0	0
2-13	Missaukee	T22N R7W	SWcn	16	38	21	6	3	0	0	4	0
2-15	Missaukee	T23N R5W	SW	12	20	18	8	6	0	0	0	0
	total			97	303	187	272	93	3	5	41	0

MINOR SPECIES *

SAMPLE	COUNTY	LOCATION	QT	Fir	Ash	Cedar	Elm	Bas-wood	Aspen	Birch	Yellow birch
2-3	Iosco	T23N R5E	SW	3	4	3	2	0	5	2	0
2-4	Iosco	T23N R5E	SE	1	4	0	0	0	0	0	0
2-5	Iosco	T22N R5E	NW	0	0	1	1	1	0	2	0
2-6	Ogemaw	T22N R4E	SW	0	4	3	2	1	0	2	0
2-7	Ogemaw	T21N R4E	NW	0	2	0	2	2	0	0	0
2-8	Ogemaw	T21N R4E	NE	0	1	3	1	0	0	1	0
2-9	Clare	T20N R6W	NW	2	3	2	2	4	0	0	2
2-10	Osceola	T19N R7W	NW	0	4	2	2	6	6	0	0
2-12	Clar/Glad	T19N R2&3	SE/SW	0	2	1	8	2	0	0	1
2-13	Missaukee	T22N R7W	SWcn	0	1	0	0	3	1	2	0
2-15	Missaukee	T23N R5W	SW	1	0	1	1	0	2	1	0
	total			7	25	16	21	19	14	10	3

* Uncommon species cited for

sample 2-10 : 2 black cherry, 3 ironwood

Table C3. Species Counts on Non-swampland for Lacustrine Sand and Gravel

MAJOR SPECIES

SAMPLE	COUNTY	LOCATION	QT	Sugar maple	Hem-lock	Beech	White pine	Red maple	White oak	Black oak	Red pine	Jack pine
3-1	Cheboygan	T38N R3W	SE	26	11	16	0	0	0	0	0	0
3-2	Alpena	T32N R7E	SE	23	45	48	0	0	0	0	0	0
3-3	P. Isle	T34N R6E	SE	16	11	22	3	0	0	1	1	0
3-5	Manistee	T24N R14W	SW	24	25	39	2	1	0	0	0	0
3-7	Ogemaw	T21N R2E	NE	1	21	16	32	1	2	0	20	11
3-8	Iosco	T21N R6E	NE	2	20	2	36	13	0	0	1	0
3-10	Mason	T20N R17W	SW	4	17	39	16	4	10	0	7	0
3-11	Gladwin	T20N R1E	SEcn	2	32	3	23	6	2	0	3	0
3-12	Arenac	T20N R3E	SW	3	11	2	33	8	0	0	2	0
3-13	Gladwin	T19N R2E	NE	6	27	5	26	6	0	0	6	0
3-14	Gladwin	T19N R2E	SE	1	11	4	34	7	0	0	13	0
3-15	Gladwin	T18N R2E	SW	0	19	6	31	7	0	0	6	4
	total			108	250	202	236	53	14	1	59	15

MINOR SPECIES

SAMPLE	COUNTY	LOCATION	QT	Fir	Ash	Cedar	Elm	Bas-wood	Aspen	Birch	Yellow birch
3-1	Cheboygan	T38N R3W	SE	0	0	0	1	1	0	0	1
3-2	Alpena	T32N R7E	SE	2	1	7	1	1	0	2	0
3-3	P. Isle	T34N R6E	SE	0	0	7	0	0	5	7	4
3-5	Manistee	T24N R14W	SW	0	0	0	0	1	0	0	0
3-7	Ogemaw	T21N R2E	NE	0	0	0	0	0	3	0	0
3-8	Iosco	T21N R6E	NE	1	13	4	8	0	1	2	1
3-10	Mason	T20N R17W	SW	0	0	0	0	0	0	0	0
3-11	Gladwin	T20N R1E	SEcn	5	5	4	1	0	1	2	0
3-12	Arenac	T20N R3E	SW	0	3	4	0	0	2	1	0
3-13	Gladwin	T19N R2E	NE	1	1	1	2	0	1	3	0
3-14	Gladwin	T19N R2E	SE	1	1	3	0	0	5	3	0
3-15	Gladwin	T18N R2E	SW	0	0	3	0	0	1	5	0
	total			10	24	33	13	3	19	25	6

Table C4. Species Counts on Non-swampland for Ice Contact Features

MAJOR SPECIES

SAMPLE	COUNTY	LOCATION	QT	Sugar maple	Hem-lock	Beech	White pine	Red maple	White oak	Black oak	Red pine	Jack pine
4-1	Emmet	T34N R4W	SE	60	21	43	2	1	0	0	0	0
4-2	Crawford	T28N R3W	NEce	25	43	64	13	2	0	0	1	0
4-3	Crawford	T28N R3W	SW	48	35	56	2	0	0	0	0	0
4-4	Oscoda	T28N R4E	NW	0	1	0	21	1	0	1	55	29
4-5	Oscoda	T28N R4E	SEcn	0	10	1	10	1	0	0	28	36
4-6	Alcona	T28N R8E	SW	4	10	19	30	10	0	1	19	0
4-7	Alcona	T27N R8E	SE	8	12	24	9	5	1	0	5	0
4-8	Ogemaw	T23N R1E	SE	0	0	3	21	0	6	4	45	18
4-9	Crawford	T27N R2W	NE	0	0	2	29	0	3	1	32	40
4-10	Oscoda	T27N R2E	NW	0	2	0	11	2	0	0	35	64
4-11	Ogemaw	T24N R3E	NE	24	28	29	13	2	0	5	15	0
4-12	Ogemaw	T24N R4E	NW	34	18	36	10	0	0	7	5	0
4-13	Ogemaw	T22N R1E	NW	0	4	0	21	1	6	8	44	10
4-14	Ogemaw	T22N R1E	SW	2	3	11	20	3	11	8	40	6
4-15	Roscommon	T21N R1W	NWcs	0	16	21	32	7	2	6	33	1
	total			205	203	309	244	35	29	41	357	204

MINOR SPECIES

SAMPLE	COUNTY	LOCATION	QT	Fir	Ash	Cedar	Elm	Bas-wood	Aspen	Birch	Yellow birch
4-1	Emmet	T34N R4W	SE	0	0	0	2	3	0	0	0
4-2	Crawford	T28N R3W	NEce	0	0	0	0	1	0	5	0
4-3	Crawford	T28N R3W	SW	0	0	0	2	0	0	10	0
4-4	Oscoda	T28N R4E	NW	0	0	0	0	0	11	1	0
4-5	Oscoda	T28N R4E	SEcn	0	0	0	0	0	14	1	0
4-6	Alcona	T28N R8E	SW	0	0	0	0	0	1	2	0
4-7	Alcona	T28N R8E	SE	0	0	0	1	3	1	0	0
4-8	Ogemaw	T23N R1E	SE	0	0	0	0	0	0	0	0
4-9	Crawford	T27N R2W	NE	0	0	0	0	0	5	0	0
4-10	Oscoda	T27N R2E	NW	0	0	0	0	0	8	11	0
4-11	Ogemaw	T24N R3E	NE	0	0	0	1	4	1	1	0
4-12	Ogemaw	T24N R4E	NW	0	0	0	1	7	1	0	0
4-13	Ogemaw	T22N R1E	NW	0	0	0	0	0	3	0	0
4-14	Ogemaw	T22N R1E	SW	0	0	0	0	0	2	0	0
4-15	Roscommon	T21N R1W	NWcs	0	0	0	0	0	5	4	0
	total			0	0	0	7	18	52	35	0

Table C5. Species Counts on Non-swampland for End Moraines of Coarse-textured Till

MAJOR SPECIES

SAMPLE	COUNTY	LOCATION	QT	Sugar maple	Hem-lock	Beech	White pine	Red maple	White oak	Black oak	Red pine	Jack pine
5-1	Cheboygan	T33N R4W	SE	65	20	30	2	0	0	1	0	0
5-2	G.Traverse	T25N R10W	NW	56	21	38	0	1	0	0	0	0
5-3	G.Traverse	T25N R10W	NE	60	24	40	0	1	0	0	0	0
5-4	Osceola	T20N R8W	NW	55	11	60	0	0	0	0	0	0
5-5	Clare	T19N R5W	SE	6	15	14	45	5	20	13	17	0
5-6	G.Traverse	T27N R9W	NEcw	38	36	47	8	0	0	0	1	0
5-8	Alcona	T27N R5E	SW	6	6	10	5	2	1	2	38	28
5-9	Newaygo	T16N R11W	SW	26	45	47	9	9	0	3	6	0
5-10	Newaygo	T15N R11W	NW	2	13	40	52	16	4	2	23	0
5-11	Osceola	T17N R8W	SW	11	28	46	9	3	0	0	0	0
5-12	Mecosta	T16N R8W	SW	6	34	37	15	6	1	2	2	0
5-13	Missaukee	T24N R7W	SW	30	26	66	4	5	0	0	0	0
5-14	Isabella	T16N R6W	NE	6	32	36	14	6	2	0	10	0
5-15	Oceana	T14N R17W	NE	26	4	70	0	2	1	2	0	0
	total			393	315	581	163	56	29	25	97	28

MINOR SPECIES *

SAMPLE	COUNTY	LOCATION	QT	Fir	Ash	Cedar	Elm	Bas-wood	Aspen	Birch	Yellow birch
5-1	Cheboygan	T33N R4W	SE	0	0	0	18	6	0	0	0
5-2	G.Traverse	T25N R10W	NW	0	1	0	5	3	0	3	1
5-3	G.Traverse	T25N R10W	NE	0	0	0	10	9	0	1	1
5-4	Osceola	T20N R8W	NW	0	2	0	10	4	0	0	0
5-5	Clare	T19N R5W	SE	0	0	1	0	0	7	2	0
5-6	G.Traverse	T27N R9W	NEcw	0	0	0	2	1	2	0	0
5-8	Alcona	T27N R5E	SW	0	0	0	0	2	0	0	0
5-9	Newaygo	T16N R11W	SW	0	3	1	1	0	5	3	0
5-10	Newaygo	T15N R11W	NW	0	2	2	0	0	0	2	0
5-11	Osceola	T17N R8W	SW	0	0	0	1	4	1	2	0
5-12	Mecosta	T16N R8W	SW	0	1	0	4	0	0	1	0
5-13	Missaukee	T24N R7W	SW	0	0	0	4	1	0	1	0
5-14	Isabella	T16N R6W	NE	0	1	0	0	1	0	2	0
5-15	Oceana	T14N R17W	NE	0	1	0	6	8	0	1	0
	total			0	11	4	61	39	15	18	2

* Additional Species seldom recorded

5-1 3 ironwood
5-2 1 ironwood
5-6 1 ironwood
5-9 2 ironwood
5-10 2 ironwood
5-11 1 butternut
5-13 2 ironwood
5-15 4 ironwood

Table C6. Species Counts on Non-swampland for Ground Moraines of Coarse-textured Till

MAJOR SPECIES

SAMPLE	COUNTY	LOCATION	QT	Sugar maple	Hem-lock	Beech	White pine	Red maple	White oak	Black oak	Red pine	Jack pine
6-1	P. Isle	T35N R2E	SW	42	21	41	0	0	0	0	0	0
6-2	Cheboygan	T34N R1W	NW	51	30	35	0	0	0	0	0	0
6-3	Cheboygan	T34N R1E	SE	12	28	19	12	2	0	0	3	0
6-4	P. Isle	T33N R2E	NE	19	8	8	17	1	1	4	32	30
6-5	Alpena	T30N R6E	NE	3	11	21	2	0	0	1	12	0
6-6	P. Isle	T34N R5E	SW	24	26	26	0	0	0	0	0	0
6-7	Montmorency	T29N R3E	SW	21	21	14	11	0	0	4	25	8
6-8	Montmorency	T29N R3E	SE	5	14	6	11	0	0	3	61	2
6-9	Alcona	T28N R6E	SE	1	3	5	20	3	0	7	53	5
6-10	Alcona	T27N R7E	SE	2	0	0	29	1	1	6	60	9
6-11	Clare	T19N R6W	SE	8	53	10	24	4	0	0	12	2
6-12	Lake	T17N R11W	NE	37	25	62	4	1	0	0	0	0
6-13	Osceola	T17N R10W	SW	45	9	69	2	0	0	0	0	0
6-14	Isabella	T14N R6W	SW	14	41	35	19	7	2	1	0	0
6-15	Montcalm	T12N R7W	NE	1	20	42	56	3	0	3	0	0
	total			285	310	393	207	22	4	29	258	56

MINOR SPECIES *

SAMPLE	COUNTY	LOCATION	QT	Fir	Ash	Cedar	Elm	Bas-wood	Aspen	Birch	Yellow birch
6-1	P. Isle	T35N R2E	SW	1	0	6	3	3	2	0	4
6-2	Cheboygan	T34N R1W	NW	0	0	6	2	4	1	9	0
6-3	Cheboygan	T34N R1E	SE	2	0	3	0	1	15	3	2
6-4	P. Isle	T33N R2E	NE	0	0	0	1	1	4	3	0
6-5	Alpena	T30N R6E	NE	0	0	0	0	0	0	0	0
6-6	P. Isle	T34N R5E	SW	0	0	4	3	2	0	0	1
6-7	Montmorency	T29N R3E	SW	0	0	0	0	3	1	1	0
6-8	Montmorency	T29N R3E	SE	1	0	1	0	0	3	0	0
6-9	Alcona	T28N R6E	SE	2	0	0	0	2	6	2	1
6-10	Alcona	T27N R7E	SE	0	0	0	0	0	3	1	1
6-11	Clare	T19N R6W	SE	0	1	1	1	3	5	2	1
6-12	Lake	T17N R11W	NE	0	0	0	0	2	0	4	0
6-13	Osceola	T17N R10W	SW	0	0	0	22	6	0	0	0
6-14	Isabella	T14N R6W	SW	0	0	0	0	3	0	3	0
6-15	Montcalm	T12N R7W	NE	0	0	0	0	1	0	1	0
	total			6	1	21	32	31	40	29	10

* Additional Species seldom recorded

6-12 3 ironwood
6-13 6 ironwood
6-14 3 ironwood

Table C7. Species Counts on Non-swampland for End Moraines of Medium-textured Till

MAJOR SPECIES

SAMPLE	COUNTY	LOCATION	QT	Sugar maple	Hem-lock	Beech	White pine	Red maple	White oak	Black oak	Red pine	Jack pine
7-1	Otsego	T30N R2W	NE	52	26	51	0	0	0	0	0	0
7-2	Otsego	T30N R1W	NW	52	14	65	0	0	0	0	0	0
7-3	Montmorency	T30N R1E	NW	41	14	45	4	0	0	0	0	0
7-4	Montmorency	T30N R1E	SE	37	12	40	3	0	0	0	6	1
7-5	Alcona	T25N R6E	SW	12	24	29	12	0	8	2	9	2
7-6	Alcona	T25N R6E	NE	6	43	17	15	0	0	0	23	4
7-7	Manistee	T22N R16W	NE	8	16	65	7	6	2	2	6	0
	total			208	149	312	41	6	10	4	44	7

MINOR SPECIES

SAMPLE	COUNTY	LOCATION	QT	Fir	Ash	Cedar	Elm	Bas-wood	Aspen	Birch	Yellow birch
7-1	Otsego	T30N R2W	NE	0	0	0	5	1	0	0	3
7-2	Otsego	T30N R1W	NW	0	0	0	4	2	0	0	4
7-3	Montmorency	T30N R1E	NW	0	0	1	4	4	3	0	5
7-4	Montmorency	T30N R1E	SE	0	0	0	0	3	1	0	2
7-5	Alcona	T25N R6E	SW	0	0	1	2	0	2	2	2
7-6	Alcona	T25N R6E	NE	0	2	1	0	0	0	2	0
7-7	Manistee	T22N R16W	NE	0	3	0	0	0	0	0	0
	total			0	5	3	15	10	6	4	16

Table C8. Species Counts on Non-swampland for End Moraines of Fine-textured Till

MAJOR SPECIES

SAMPLE	COUNTY	LOCATION	QT	Sugar maple	Hem-lock	Beech	White pine	Red maple	White oak	Black oak	Red pine	Jack pine
10-1	Alcona	T26N R6E	NW	7	9	3	26	0	0	3	40	7
10-3	Alcona	T26N R6E	SE	6	6	4	33	0	0	7	49	0
10-4	Oscoda	T26N R2E	SE	3	25	2	10	1	1	0	19	23
10-5	Oscoda	T26N R3E	SWcn	0	19	4	10	0	0	4	44	48
10-6	Oscoda	T26N R4E	SEcw	2	1	3	16	3	4	6	36	23
10-7	Oscoda	T25N R4E	NE	11	16	12	16	5	0	3	29	8
10-8	Oscoda	T25N R4E	SW/E	14	24	38	19	3	1	4	14	0
10-9	Ogemaw	T23N R2E	NE/W	10	31	16	14	0	1	0	6	0
10-10	Ogemaw	T22N R2E	NEcs	11	45	35	1	2	0	0	0	0
10-11	Ogemaw	T23N R4E	NE	13	20	8	24	5	0	2	5	0
10-12	Ogemaw	T23N R4E	SEcw	0	36	9	16	2	2	2	10	0
10-13	Arenac	T20N R4E	NWcs	5	31	14	26	2	0	0	18	0
	total			82	263	148	211	23	9	31	270	109

MINOR SPECIES *

SAMPLE	COUNTY	LOCATION	QT	Fir	Ash	Cedar	Elm	Bas-wood	Aspen	Birch	Yellow birch
10-1	Alcona	T26N R6E	NW	0	0	0	0	1	3	1	0
10-3	Alcona	T26N R6E	SE	0	0	0	0	0	2	1	3
10-4	Oscoda	T26N R2E	SE	0	0	1	1	1	16	9	0
10-5	Oscoda	T26N R3E	SWcn	0	0	2	1	0	4	5	0
10-6	Oscoda	T26N R4E	SEcw	0	0	0	0	0	6	1	0
10-7	Oscoda	T25N R4E	NE	0	1	0	0	0	3	0	1
10-8	Oscoda	T25N R4E	SW/E	0	4	0	0	0	0	1	1
10-9	Ogemaw	T23N R2E	NE/W	0	0	3	3	1	2	6	1
10-10	Ogemaw	T22N R2E	NEcs	0	1	1	1	1	0	1	0
10-11	Ogemaw	T23N R4E	NE	1	1	3	1	1	1	4	1
10-12	Ogemaw	T23N R4E	SEcw	3	1	3	0	0	0	3	0
10-13	Arenac	T20N R4E	NWcs	0	4	3	1	1	4	0	0
	total			4	12	16	8	6	41	32	7

* Additional species seldom cited

10-5 3 "dead" oak

Appendix D

Table D1. Citation frequency for non-swampland on outwash plains. Citation frequency is the count for a species at a site divided by the total count for all species at that site, then multiplied by 100 so that the sum of all citation frequencies for all sites equal 100.

MAJOR SPECIES

SAMPLE	COUNTY	LOCATION	QT	Sugar maple	Hem-lock	Beech	White pine	Red maple	White oak	Black oak	Red pine	Jack pine
1-1	P. Isle	T33N R4E	SW	0.0	0.0	0.0	15.2	4.0	2.0	1.0	52.5	20.2
1-2	Otsego	T30N R3W	NW	31.6	18.4	30.9	1.3	6.6	0.0	0.0	0.0	0.0
1-3	Crawford	T26N R3W	NE	0.0	0.0	0.0	0.9	0.0	1.8	0.9	11.0	85.3
1-4	Mason	T20N R15W	NW	0.0	0.0	0.0	29.1	0.0	20.9	2.3	18.6	24.4
1-5	Kalkaska	T25N R5W	SE	0.0	0.0	0.0	16.6	2.1	2.1	2.1	31.0	44.8
1-6	Roscommon	T23N R1W	NE	0.0	0.0	0.0	14.7	0.9	0.0	0.0	15.6	65.1
1-7	Roscommon	T22N R2W	NE	0.0	10.7	2.7	26.7	2.7	2.7	0.0	29.3	9.3
1-8	Manistee	T21N R13W	NE	0.0	4.2	4.2	46.2	2.5	1.7	1.7	18.5	18.5
1-9	Manistee	T21N R15W	SW	0.0	0.0	0.0	38.1	1.0	17.5	4.1	35.1	4.1
1-10	Clare	T20N R6W	SE	1.6	2.3	0.8	20.2	0.8	0.8	0.0	12.4	56.6
1-11	Lake	T19N R11W	SE	14.7	16.7	46.2	7.1	1.3	0.0	1.9	0.0	0.0
1-12	Mason	T20N R16W	NE	0.0	7.1	23.8	23.8	3.6	7.1	0.0	25.0	6.0
1-13	Newaygo	T15N R13W	NW	0.8	23.1	11.5	19.2	6.2	14.6	0.8	20.8	0.0
1-14	Newaygo	T12N R12W	NE	0.0	0.0	2.0	31.7	1.0	46.5	17.8	0.0	0.0
1-15	Kalkaska	T27N R6W	NE	48.2	14.4	27.3	2.9	2.2	0.0	0.0	0.0	0.0
	average			6.5	6.5	10.0	19.6	2.3	7.9	2.2	18.0	22.3
	standard deviation			13.9	7.8	14.3	13.0	2.0	12.3	4.3	14.7	26.8

MINOR SPECIES

SAMPLE	COUNTY	LOCATION	QT	Fir	Ash	Cedar	Elm	Bas-wood	Aspen	Birch	Yellow birch
1-1	P. Isle	T33N R4E	SW	2.0	0.0	0.0	0.0	0.0	1.0	2.0	0.0
1-2	Otsego	T30N R3W	NW	0.0	0.0	0.0	1.3	0.0	0.0	3.3	6.0
1-3	Crawford	T26N R3W	NE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1-4	Mason	T20N R15W	NW	0.0	0.0	0.0	0.0	0.0	2.3	2.3	0.0
1-5	Kalkaska	T25N R5W	SE	0.0	0.0	0.0	0.0	0.0	1.4	0.0	0.0
1-6	Roscommon	T23N R1W	NE	0.0	0.0	0.0	0.0	0.0	3.7	0.0	0.0
1-7	Roscommon	T22N R2W	NE	0.0	0.0	4.0	0.0	0.0	10.7	1.3	0.0
1-8	Manistee	T21N R13W	NE	0.0	0.0	0.0	0.0	0.0	2.5	0.0	0.0
1-9	Manistee	T21N R15W	SW	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1-10	Clare	T20N R6W	SE	0.0	0.0	0.0	1.6	0.0	3.1	0.0	0.0
1-11	Lake	T19N R11W	SE	0.0	3.8	5.1	0.6	0.6	0.0	1.9	0.0
1-12	Mason	T20N R16W	NE	0.0	0.0	0.0	1.2	1.2	0.0	1.2	0.0
1-13	Newaygo	T15N R13W	NW	0.0	1.5	0.0	0.0	0.0	1.5	0.0	0.0
1-14	Newaygo	T12N R12W	NE	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0
1-15	Kalkaska	T27N R6W	NE	0.0	0.0	0.0	0.7	0.0	0.0	0.7	3.6
	average			0.1	0.4	0.6	0.4	0.2	1.7	0.9	0.7
	standard deviation			0.5	1.0	1.6	0.5	0.4	2.7	1.1	1.8

Table D2. Citation Frequency for Non-swampland for Ground Moraines of Fine-textured Till

MAJOR SPECIES

SAMPLE	COUNTY	LOCATION	QT	Sugar maple	Hem-lock	Beech	White Pine	Red maple	White oak	Black oak	Red pine	Jack pine
2-3	Iosco	T23N R5E	SW	5.5	34.1	12.1	19.8	6.6	0.0	1.1	0.0	0.0
2-4	Iosco	T23N R5E	SE	10.0	22.7	19.1	31.8	6.4	0.0	0.0	5.5	0.0
2-5	Iosco	T22N R5E	NW	7.8	7.0	11.3	46.1	14.8	0.0	0.0	8.7	0.0
2-6	Ogemaw	T22N R4E	SW	3.0	26.9	1.5	29.9	13.4	0.0	0.0	7.5	0.0
2-7	Ogemaw	T21N R4E	NW	7.5	17.2	6.5	34.4	16.1	2.2	1.1	8.6	0.0
2-8	Ogemaw	T21N R4E	NE	7.8	23.3	15.5	31.1	8.7	1.0	1.0	5.8	0.0
2-9	Clare	T20N R6W	NW	10.5	40.4	21.9	9.6	2.6	0.0	0.0	1.8	0.0
2-10	Osceola	T19N R7W	NW	9.8	33.3	25.2	14.6	0.8	0.0	0.0	0.0	0.0
2-12	Clar/Glad	T19N R2&3W	SE/W	2.2	26.7	17.8	28.9	12.6	0.0	1.5	0.0	0.0
2-13	Missaukee	T22N R7W	SWcn	16.8	40.0	22.1	6.3	3.2	0.0	0.0	4.2	0.0
2-15	Missaukee	T23N R5W	SW	17.1	28.6	25.7	1.4	8.6	0.0	0.0	0.0	0.0
	average			8.9	27.3	16.2	24.0	8.5	0.3	0.4	3.8	0.0
	standard deviation			4.6	9.4	7.4	11.9	4.9	0.7	0.6	3.4	0.0

MINOR SPECIES

SAMPLE	COUNTY	LOCATION	QT	Fir	Ash	Cedar	Elm	Bas-wood	Aspen	Birch	Yellow birch
2-3	Iosco	T23N R5E	SW	3.0	4.0	3.0	2.0	0.0	5.0	2.0	0.0
2-4	Iosco	T23N R5E	SE	1.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0
2-5	Iosco	T22N R5E	NW	0.0	0.0	1.0	1.0	1.0	0.0	2.0	0.0
2-6	Ogemaw	T22N R4E	SW	0.0	4.0	3.0	2.0	1.0	0.0	2.0	0.0
2-7	Ogemaw	T21N R4E	NW	0.0	2.0	0.0	2.0	2.0	0.0	0.0	0.0
2-8	Ogemaw	T21N R4E	NE	0.0	1.0	3.0	1.0	0.0	0.0	1.0	0.0
2-9	Clare	T20N R6W	NW	2.0	3.0	2.0	2.0	4.0	0.0	0.0	2.0
2-10	Osceola	T19N R7W	NW	0.0	4.0	2.0	2.0	6.0	6.0	0.0	0.0
2-12	Clare/Glad	T19N R2&3W	SE/W	0.0	2.0	1.0	8.0	2.0	0.0	0.0	1.0
2-13	Missaukee	T22N R7W	SWcn	0.0	1.0	0.0	0.0	3.0	1.0	2.0	0.0
2-15	Missaukee	T23N R5W	SW	1.0	0.0	1.0	1.0	0.0	2.0	1.0	0.0
	average			0.6	2.3	1.5	1.9	1.7	1.3	0.9	0.3
	standard deviation			1.0	1.5	1.2	2.1	1.9	2.1	0.9	0.0

Table D3. Citation Frequencies on Non-swampland for Lacustrine Sand and Gravel

MAJOR SPECIES

SAMPLE	COUNTY	LOCATION	QT	Sugar maple	Hem-lock	Beech	White pine	Red maple	White oak	Black oak	Red pine	Jack pine
3-1	Cheboygan	T38N R3W	SE	46.4	19.6	28.6	0.0	0.0	0.0	0.0	0.0	0.0
3-2	Alpena	T32N R7E	SE	17.7	34.6	36.9	0.0	0.0	0.0	0.0	0.0	0.0
3-3	P. Isle	T34N R6E	SE	20.8	14.3	28.6	3.9	0.0	0.0	1.3	1.3	0.0
3-5	Manistee	T24N R14W	SW	26.1	27.2	42.4	2.2	1.1	0.0	0.0	0.0	0.0
3-7	Ogemaw	T21N R2E	NE	0.9	19.6	15.0	29.9	0.9	1.9	0.0	18.7	10.3
3-8	Iosco	T21N R6E	NE	1.9	19.2	1.9	34.6	12.5	0.0	0.0	1.0	0.0
3-10	Mason	T20N R17W	SW	4.1	17.5	40.2	16.5	4.1	10.3	0.0	7.2	0.0
3-11	Gladwin	T20N R1E	SE	2.2	36.0	3.4	25.8	6.7	2.2	0.0	3.4	0.0
3-12	Arenac	T20N R3E	SE	4.3	15.9	2.9	47.8	11.6	0.0	0.0	2.9	0.0
3-13	Gladwin	T19N R2E	NE	7.1	31.8	5.9	30.6	7.1	0.0	0.0	7.1	0.0
3-14	Gladwin	T19N R2E	SE	1.2	13.3	4.8	41.0	8.4	0.0	0.0	15.7	0.0
3-15	Gladwin	T18N R2E	SW	0.0	23.2	7.3	37.8	8.5	0.0	0.0	7.3	4.9
	average			11.1	22.7	18.2	22.5	5.08	1.2	0.11	5.37	1.26
	standard			13.6	7.5	15.3	16.6	4.46	2.85	0.36	5.96	3.03

MINOR SPECIES

SAMPLE	COUNTY	LOCATION	QT	Fir	Ash	Cedar	Elm	Bas-wood	Aspen	Birch	Yellow birch
3-1	Cheboygan	T38N R3W	SE	0.0	0.0	0.0	1.8	1.8	0.0	0.0	1.8
3-2	Alpena	T32N R7E	SE	1.5	0.8	5.4	0.8	0.8	0.0	1.5	0.0
3-3	P. Isle	T34N R6E	SE	0.0	0.0	9.1	0.0	0.0	6.5	9.1	5.2
3-5	Manistee	T24N R14W	SW	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0
3-7	Ogemaw	T21N R2E	NE	0.0	0.0	0.0	0.0	0.0	2.8	0.0	0.0
3-8	Iosco	T21N R6E	NE	1.0	12.5	3.8	7.7	0.0	1.0	1.9	1.0
3-10	Mason	T20N R17W	SW	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3-11	Gladwin	T20N R1E	SE	5.6	5.6	4.5	1.1	0.0	1.1	2.2	0.0
3-12	Arenac	T20N R3E	SE	0.0	4.3	5.8	0.0	0.0	2.9	1.4	0.0
3-13	Gladwin	T19N R2E	NE	1.2	1.2	1.2	2.4	0.0	1.2	3.5	0.0
3-14	Gladwin	T19N R2E	SE	1.2	1.2	3.6	0.0	0.0	6.0	3.6	0.0
3-15	Gladwin	T18N R2E	SW	0.0	0.0	3.7	0.0	0.0	1.2	6.1	0.0
	average			0.9	2.1	3.1	1.1	0.3	1.9	2.5	0.7
	standard			1.5	3.6	2.8	2.1	0.6	2.2	2.7	1.5

Table D4. Citation Frequencies on Non-swampland for Ice Contact Features

MAJOR SPECIES

SAMPLE	COUNTY	LOCATION	QT	Sugar maple	Hem-lock	Beech	White pine	Red maple	White oak	Black oak	Red pine	Jack pine
4-1	Emmet	T34N R4W	SE	45.5	15.9	32.6	1.5	0.8	0.0	0.0	0.0	0.0
4-2	Crawford	T28N R3W	NEce	16.2	27.9	41.6	8.4	1.3	0.0	0.0	0.6	0.0
4-3	Crawford	T28N R3W	SW	31.4	22.9	36.1	1.3	0.0	0.0	0.0	0.0	0.0
4-4	Oscoda	T28N R4E	NW	0.0	0.8	0.0	17.5	0.8	0.0	0.8	45.8	24.2
4-5	Oscoda	T28N R4E	SEcn	0.0	9.9	0.0	9.9	1.0	0.0	0.0	27.7	35.6
4-6	Alcona	T28N R8E	SW	4.2	10.4	19.8	31.3	10.4	0.0	1.0	19.8	0.0
4-7	Alcona	T27N R8E	SE	11.6	17.4	34.8	13.0	7.2	1.4	0.0	7.3	0.0
4-8	Ogemaw	T23N R1E	SE	0.0	0.0	3.1	21.6	0.0	6.2	4.1	46.4	18.6
4-9	Crawford	T27N R2W	NE	0.0	0.0	1.8	25.9	0.0	2.7	0.9	28.6	35.7
4-10	Oscoda	T27N R2E	NW	0.0	1.5	0.0	8.3	1.5	0.0	0.0	26.3	48.1
4-11	Ogemaw	T24N R3E	NE	19.5	22.8	23.6	10.6	1.6	0.0	4.0	12.2	0.0
4-12	Ogemaw	T24N R4E	NW	28.6	15.1	30.3	8.4	0.0	0.0	5.9	4.2	0.0
4-13	Ogemaw	T22N R1E	NW	0.0	4.1	0.0	21.6	1.0	6.2	8.3	45.4	10.3
4-14	Ogemaw	T22N R1E	SW	1.9	2.8	10.4	18.9	2.8	10.4	7.5	37.7	5.7
4-15	Roscommon	T21N R1W	NWcs	0.0	12.6	16.5	25.2	5.5	1.6	4.7	26.0	0.8
	average			10.6	10.9	16.8	14.9	2.3	1.9	2.5	21.9	11.9
	standard deviation			14.1	8.9	15.0	8.7	3.0	3.1	2.9	16.6	15.9

MINOR SPECIES

SAMPLE	COUNTY	LOCATION	QT	Fir	Ash	Cedar	Elm	Bas-wood	Aspen	Birch	Yellow birch
4-1	Emmet	T34N R4W	SE	0.0	0.0	0.0	1.5	2.3	0.0	0.0	0.0
4-2	Crawford	T28N R3W	NEce	0.0	0.0	0.0	0.0	0.6	0.0	3.3	0.0
4-3	Crawford	T28N R3W	SW	0.0	0.0	0.0	1.3	0.0	0.0	6.5	0.0
4-4	Oscoda	T28N R4E	NW	0.0	0.0	0.0	0.0	0.0	9.2	0.8	0.0
4-5	Oscoda	T28N R4E	SEcn	0.0	0.0	0.0	0.0	0.0	13.9	1.0	0.0
4-6	Alcona	T28N R8E	SW	0.0	0.0	0.0	0.0	0.0	1.0	2.1	0.0
4-7	Alcona	T27N R8E	SE	0.0	0.0	0.0	1.4	4.4	1.5	0.0	0.0
4-8	Ogemaw	T23N R1E	SE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4-9	Crawford	T27N R2W	NE	0.0	0.0	0.0	0.0	0.0	4.5	0.0	0.0
4-10	Oscoda	T27N R2E	NW	0.0	0.0	0.0	0.0	0.0	6.0	8.3	0.0
4-11	Ogemaw	T24N R3E	NE	0.0	0.0	0.0	0.8	3.3	0.8	0.8	0.0
4-12	Ogemaw	T24N R4E	NW	0.0	0.0	0.0	0.8	5.9	0.0	0.0	0.0
4-13	Ogemaw	T22N R1E	NW	0.0	0.0	0.0	0.0	0.0	3.1	0.0	0.0
4-14	Ogemaw	T22N R1E	SW	0.0	0.0	0.0	0.0	0.0	1.9	0.0	0.0
4-15	Roscommon	T21N R1W	NWcs	0.0	0.0	0.0	0.0	0.0	3.9	3.1	0.0
	average			0.0	0.0	0.0	0.4	1.1	3.1	1.7	0.0
	standard deviation			0.0	0.0	0.0	0.6	1.8	3.8	2.5	0.0

Table D5. Citation Frequencies on Non-swampland for End Moraines of Coarse-textured Till

MAJOR SPECIES

SAMPLE	COUNTY	LOCATION	QT	Sugar maple	Hem-lock	Beech	White pine	Red maple	White oak	Black oak	Red pine	Jack pine
5-1	Cheboygan	T33N R4W	SE	46.1	14.2	21.3	1.4	0.0	0.0	0.0	0.0	0.0
5-2	G.Traverse	T25N R10W	NW	43.4	16.3	29.5	0.0	0.8	0.0	0.0	0.0	0.0
5-3	G.Traverse	T25N R10W	NE	41.1	16.4	27.4	0.0	0.7	0.0	0.0	0.0	0.0
5-4	Osceola	T20N R8W	NW	38.7	7.7	42.3	0.0	0.0	0.0	0.0	0.0	0.0
5-5	Clare	T19N R5W	SE	4.14	10.3	9.7	31.0	3.4	13.8	9.0	11.7	0.0
5-6	G.Traverse	T27N R9W	NEcw	28.1	26.7	34.8	5.3	0.0	0.0	0.0	0.7	0.0
5-8	Alcona	T27N R5E	SW	6.0	6.0	10.0	5.0	2.0	1.0	2.0	38.0	28.0
5-9	Newaygo	T16N R11W	SW	16.5	28.5	29.7	5.7	5.7	0.0	1.9	3.8	0.0
5-10	Newaygo	T15N R11W	NW	1.3	8.2	25.3	32.9	10.1	2.5	1.3	14.6	0.0
5-11	Osceola	T17N R8W	SW	10.5	26.7	43.8	8.6	2.9	0.0	0.0	0.0	0.0
5-12	Mecosta	T16N R8W	SW	5.5	31.2	33.9	13.8	5.5	0.9	1.8	1.8	0.0
5-13	Missaukee	T24N R7W	SW	21.9	19.0	48.2	2.9	3.6	0.0	0.0	0.0	0.0
5-14	Isabella	T16N R6W	NE	5.5	29.1	32.7	12.7	5.5	1.8	0.0	9.1	0.0
5-15	Oceana	T14N R17W	NE	21.5	3.3	57.9	0.0	1.6	0.8	1.6	0.0	0.0
	average			20.7	17.4	31.9	8.6	3.0	1.5	1.3	5.7	2.0
	standard deviation			15.6	9.2	13.0	10.5	2.8	3.5	2.3	10.1	7.2

MINOR SPECIES

SAMPLE	COUNTY	LOCATION	QT	Fir	Ash	Cedar	Elm	Bas-wood	Aspen	Birch	Yellow birch
5-1	Cheboygan	T33N R4W	SE	0.0	0.0	0.0	12.8	4.3	0.0	0.0	0.0
5-2	G.Traverse	T25N R10W	NW	0.0	0.8	0.0	3.9	2.3	0.0	2.3	0.8
5-3	G.Traverse	T25N R10W	NE	0.0	0.0	0.0	6.8	6.2	0.0	0.7	0.7
5-4	Osceola	T20N R8W	NW	0.0	1.4	0.0	7.0	2.8	0.0	0.0	0.0
5-5	Clare	T19N R5W	SE	0.0	0.0	0.7	0.0	0.0	4.8	1.4	0.0
5-6	G.Traverse	T27N R9W	NEcw	0.0	0.0	0.0	1.5	0.7	1.5	0.0	0.0
5-8	Alcona	T27N R5E	SW	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0
5-9	Newaygo	T16N R11W	SW	0.0	1.9	0.6	0.6	0.0	3.2	1.9	0.0
5-10	Newaygo	T15N R11W	NW	0.0	1.3	1.3	0.0	0.0	0.0	1.3	0.0
5-11	Osceola	T17N R8W	SW	0.0	0.0	0.0	1.0	3.8	1.0	1.9	0.0
5-12	Mecosta	T16N R8W	SW	0.0	0.9	0.0	3.7	0.0	0.0	0.9	0.0
5-13	Missaukee	T24N R7W	SW	0.0	0.0	2.9	0.7	0.0	0.7	0.0	0.0
5-14	Isabella	T16N R6W	NE	0.0	0.9	0.0	0.0	0.9	0.0	1.8	0.0
5-15	Oceana	T14N R17W	NE	0.0	0.8	0.0	5.0	6.6	0.0	0.8	0.0
	average			0.0	0.6	0.2	3.2	2.2	0.7	1.0	0.1
	standard deviation			0.0	0.6	0.4	3.6	2.2	1.4	0.8	0.3

Table D6. Citation Frequency for Non-swampland for Ground Moraines of Coarse-textured Till

MAJOR SPECIES

SAMPLE	COUNTY	LOCATION	QT	Sugar maple	Hem-lock	Beech	White pine	Red maple	White oak	Black oak	Red pine	Jack pine
6-1	P. Isle	T35N R2E	SW	34.1	17.1	33.3	0.0	0.0	0.0	0.0	0.0	0.0
6-2	Cheboygan	T34N R1W	NW	37.0	21.7	25.4	0.0	0.0	0.0	0.0	0.0	0.0
6-3	Cheboygan	T34N R1E	SE	11.8	27.5	18.6	11.8	2.0	0.0	0.0	2.9	0.0
6-4	P. Isle	T33N R2E	NE	14.7	6.2	6.2	13.2	0.8	0.8	3.1	24.8	23.3
6-5	Alpena	T30N R6E	NE	6.0	22.0	42.0	4.0	0.0	0.0	2.0	24.0	0.0
6-6	P. Isle	T34N R5E	SW	27.9	30.2	30.2	0.0	0.0	0.0	0.0	0.0	0.0
6-7	Montmorency	T29N R3E	SW	19.3	19.3	12.8	10.1	0.0	0.0	3.7	22.9	7.3
6-8	Montmorency	T29N R3E	SE	4.7	13.1	5.6	10.3	0.0	0.0	2.8	57.0	1.9
6-9	Alcona	T28N R6E	SE	0.9	2.7	4.5	18.2	2.7	0.0	6.4	48.2	4.5
6-10	Alcona	T27N R7E	SE	1.8	0.0	0.0	25.7	0.9	0.9	5.3	53.1	8.0
6-11	Clare	T19N R6W	SE	6.3	41.7	7.9	18.9	3.1	0.0	0.0	9.4	1.0
6-12	Lake	T17N R11W	NE	27.4	18.5	45.9	3.0	0.7	0.0	0.0	0.0	0.0
6-13	Osceola	T17N R10W	SW	29.4	5.9	45.1	1.3	0.0	0.0	0.0	0.0	0.0
6-14	Isabella	T14N R6W	SW	11.2	32.8	28.0	15.2	5.6	1.6	0.8	0.0	0.0
6-15	Montcalm	T12N R7W	NE	0.8	15.7	33.1	44.1	2.4	0.0	2.4	0.0	0.0
	average			15.5	18.3	22.6	11.7	1.2	0.2	1.8	16.2	3.1
	standard deviation			14.2	18.4	21.8	12.5	1.3	0.2	1.9	17.3	3.3

MINOR SPECIES

SAMPLE	COUNTY	LOCATION	QT	Fir	Ash	Cedar	Elm	Bas-wood	Aspen	Birch	Yellow birch
6-1	P. Isle	T35N R2E	SW	0.8	0.0	4.9	2.4	2.4	1.6	0.0	3.3
6-2	Cheboygan	T34N R1W	NW	0.0	0.0	4.3	1.4	2.9	0.7	6.5	0.0
6-3	Cheboygan	T34N R1E	SE	2.0	0.0	2.9	0.0	1.0	14.7	2.9	2.0
6-4	P. Isle	T33N R2E	NE	0.0	0.0	0.0	0.8	0.8	3.1	2.3	0.0
6-5	Alpena	T30N R6E	NE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6-6	P. Isle	T34N R5E	SW	0.0	0.0	4.7	3.5	2.3	0.0	0.0	1.2
6-7	Montmorency	T29N R3E	SW	0.0	0.0	0.0	0.0	2.8	0.9	0.9	0.0
6-8	Montmorency	T29N R3E	SE	0.9	0.0	0.9	0.0	0.0	2.8	0.0	0.0
6-9	Alcona	T28N R6E	SE	1.8	0.0	0.0	0.0	1.8	5.5	1.8	0.9
6-10	Alcona	T27N R7E	SE	0.0	0.0	0.0	0.0	0.0	2.7	0.9	0.9
6-11	Clare	T19N R6W	SE	0.0	0.8	0.8	0.8	2.4	3.9	1.6	0.8
6-12	Lake	T17N R11W	NE	0.0	0.0	0.0	0.0	1.5	0.0	3.0	0.0
6-13	Osceola	T17N R10W	SW	0.0	0.0	0.0	14.4	3.9	0.0	0.0	0.0
6-14	Isabella	T14N R6W	SW	0.0	0.0	0.0	0.0	2.4	0.0	2.4	0.0
6-15	Montcalm	T12N R7W	NE	0.0	0.0	0.0	0.0	0.8	0.0	0.8	0.0
	average			0.4	0.1	1.2	1.6	1.7	2.4	1.5	0.6
	standard deviation			0.3	0.1	1.0	1.5	1.6	2.4	1.7	0.4

Table D7. Citation Frequency for Non-swampland for End Moraines of Medium-textured Till

MAJOR SPECIES

SAMPLE	COUNTY	LOCATION	QT	Sugar maple	Hem-lock	Beech	White pine	Red maple	White oak	Black oak	Red pine	Jack pine
7-1	Otsego	T30N R2W	NE	37.7	18.8	37.0	0.0	0.0	0.0	0.0	0.0	0.0
7-2	Otsego	T30N R1W	NW	36.9	9.9	46.1	0.0	0.0	0.0	0.0	0.0	0.0
7-3	Montmorency	T30N R1E	NW	33.9	11.6	37.2	3.3	0.0	0.0	0.0	0.0	6.0
7-4	Montmorency	T30N R1E	SE	35.2	11.4	38.1	2.9	0.0	0.0	0.0	5.7	1.0
7-5	Alcona	T25N R6E	SW	11.2	22.4	27.1	11.2	0.0	7.5	1.9	8.4	1.9
7-6	Alcona	T25N R6E	NE	5.3	38.1	15.0	13.3	0.0	0.0	0.0	20.4	3.5
7-7	Manistee	T22N R16W	NE	7.0	13.9	56.5	6.1	5.2	1.7	1.7	5.2	0.0
	average			23.9	18.0	36.7	5.2	0.7	1.3	0.5	5.7	0.9
	standard deviation			14.0	9.2	12.2	4.9	1.8	2.6	0.8	6.8	1.3

MINOR SPECIES

SAMPLE	COUNTY	LOCATION	QT	Fir	Ash	Cedar	Elm	Bas-wood	Aspen	Birch	Yellow birch
7-1	Otsego	T30N R2W	NE	0.0	0.0	0.0	3.6	0.7	0.0	0.0	2.2
7-2	Otsego	T30N R1W	NW	0.0	0.0	0.0	2.8	1.4	0.0	0.0	2.8
7-3	Montmorency	T30N R1E	NW	0.0	0.0	0.8	3.3	3.3	2.5	0.0	4.1
7-4	Montmorency	T30N R1E	SE	0.0	0.0	0.0	0.0	2.9	1.0	0.0	1.9
7-5	Alcona	T25N R6E	SW	0.0	0.0	0.9	1.9	0.0	1.9	1.9	1.9
7-6	Alcona	T25N R6E	NE	0.0	1.8	0.9	0.0	0.0	0.0	1.8	0.0
7-7	Manistee	T22N R16W	NE	0.0	2.6	0.0	0.0	0.0	0.0	0.0	0.0
	average			0.0	0.6	0.4	1.7	1.2	0.8	0.5	1.8
	standard deviation			0.0	1.0	0.4	1.5	1.3	1.0	0.8	1.4

Table D8. Citation Frequency on Non-swampland for End Moraines of Fine-textured Till

MAJOR SPECIES

SAMPLE	COUNTY	LOCATION	QT	Sugar maple	Hem-lock	Beech	White pine	Red maple	White oak	Black oak	Red pine	Jack pine
10-1	Alcona	T26N R6E	NW	7.0	9.0	3.0	26.0	0.0	0.0	3.0	40.0	7.0
10-3	Alcona	T26N R6E	SE	5.4	5.4	3.6	29.7	0.0	0.0	6.3	44.1	0.0
10-4	Oscoda	T26N R2E	SE	2.7	22.3	1.8	8.9	0.9	0.9	0.0	17.0	20.5
10-5	Oscoda	T26N R3E	SWcn	0.0	13.5	2.8	7.1	0.0	0.0	2.8	31.2	34.0
10-6	Oscoda	T26N R4E	SEcw	2.0	1.0	3.0	15.8	3.0	4.0	5.9	35.6	22.8
10-7	Oscoda	T25N R4E	NE	10.6	15.4	11.5	15.4	4.8	0.0	1.9	27.9	7.7
10-8	Oscoda	T25N R4E	SE/W	11.4	19.5	30.9	15.4	2.4	0.8	3.3	11.4	0.0
10-9	Ogemaw	T23N R2E	NE/W	10.6	33.0	17.0	14.9	0.0	1.1	0.0	6.4	0.0
1-10	Ogemaw	T22N R2E	NEcs	11.1	45.5	35.4	1.0	2.0	0.0	0.0	0.0	0.0
10-11	Ogemaw	T23N R4E	NE	14.6	22.5	9.0	27.0	5.6	0.0	1.1	5.6	0.0
10-12	Ogemaw	T23N R4E	SEcw	0.0	41.4	10.3	18.4	2.3	2.3	2.3	11.5	0.0
10-13	Arenac	T20N R4E	NWcs	4.6	28.4	12.8	23.9	1.8	0.0	0.0	16.5	0.0
	average			6.7	21.4	11.8	17.0	1.9	0.8	2.2	20.6	7.7
	standard deviation			4.7	13.2	10.6	8.3	1.8	1.2	2.1	14.1	11.2

MINOR SPECIES

SAMPLE	COUNTY	LOCATION	QT	Fir	Ash	Cedar	Elm	Bas-wood	Aspen	Birch	Yellow birch
10-1	Alcona	T26N R6E	NW	0.0	0.0	0.0	0.0	1.0	3.0	1.0	0.0
10-3	Alcona	T26N R6E	SE	0.0	0.0	0.0	0.0	0.0	1.8	0.9	2.7
10-4	Oscoda	T26N R2E	SE	0.0	0.0	0.9	0.9	0.9	14.3	8.0	0.0
10-5	Oscoda	T26N R3E	SWcn	0.0	0.0	1.4	0.7	0.0	2.8	3.5	0.0
10-6	Oscoda	T26N R4E	SEcw	0.0	0.0	0.0	0.0	0.0	5.9	1.0	0.0
10-7	Oscoda	T25N R4E	NE	0.0	1.0	0.0	0.0	0.0	2.9	0.0	1.0
10-8	Oscoda	T25N R4&5	SE/W	0.0	3.3	0.0	0.0	0.0	0.0	0.8	0.8
10-9	Ogemaw	T23N R2&3	NE/W	0.0	0.0	3.2	3.2	1.1	2.1	6.4	1.1
1-10	Ogemaw	T22N R2E	NEcs	0.0	1.0	1.0	1.0	1.0	0.0	1.0	0.0
10-11	Ogemaw	T23N R4E	NE	1.1	1.1	3.4	1.1	1.1	1.1	4.5	1.1
10-12	Ogemaw	T23N R4E	SEcw	3.4	1.1	3.4	0.0	0.0	0.0	3.4	0.0
10-13	Arenac	T20N R4E	NWcs	0.0	3.7	2.8	0.9	0.9	3.7	0.0	0.0
	average			0.4	0.9	1.3	0.7	0.5	3.1	2.6	0.6
	standard deviation			1.0	1.2	1.4	0.9	0.5	3.8	2.5	0.8

Appendix E

Table E1. Cumulative count data for swamps on outwash plains. Data in these tables represent the cumulative corner and line trees surveyed in swamp or wetlands in each township. The percent of lines that fell in wetlands is presented, however, the number of wet areas is not.

SAMPLE	COUNTY	%AREA SWAMP	Spruce	Ash	Fir	Tam-arack	Cedar	Hem-lock	Birch	White pine	Aspen	Elm	SUM
1-1	P. Isle	31.9	---	---	---	---	---	---	---	---	---	---	--- *
1-2	Otsego	0.0	0	0	0	0	0	0	0	0	0	0	
1-3	Crawford	5.0	0	0	1	2	6	0	1	0	0	0	10
1-4	Mason	7.5	1	2	0	0	3	0	0	2	0	1	9
1-5	Kalkaska	1.2	---	---	---	---	---	---	---	---	---	---	--- *
1-6	Roscommon	23.3	8	2	0	16	8	0	1	2	3	0	40
1-7	Roscommon	46.7	8	0	1	22	29	4	5	2	6	0	77
1-8	Manistee	2.1	0	2	0	0	0	1	0	0	0	0	3
1-9	Manistee	3.1	0	0	0	0	1	1	0	0	1	0	3
1-10	Clare	1.7	1	2	0	4	0	0	0	1	0	0	8
1-11	Lake	2.5	0	0	0	0	0	1	1	0	0	0	2
1-12	Mason	14.6	1	1	0	0	4	4	0	0	0	0	10
1-13	Newaygo	14.6	---	---	---	---	---	---	---	---	---	---	--- *
1-14	Newaygo	6.0	0	0	0	0	2	0	0	1	3	0	6
1-15	Kalkaska	10.4	0	1	0	8	5	1	0	4	0	0	19

* swamp data were not recorded for this sample

Table E2. Cumulative Count Data for Swamps on Ground Moraines of Fine-textured Till

SAMPLE	COUNTY	%AREA SWAMP	Spruce	Ash	Fir	Tam-arack	Cedar	Hem-lock	Birch	White pine	Aspen	Elm	Sum
2-3	Iosco	18.4	1	2	1	7	2	4	0	3	1	0	21
2-4	Iosco	7.3	0	0	0	1	1	3	0	0	0	0	5
2-5	Iosco	7.3	0	0	0	5	1	0	0	0	0	0	6
2-6	Ogemaw	34.6	5	12	1	17	7	5	0	5	2	0	54
2-7	Ogemaw	23.6	0	5	1	11	0	0	0	3	0	0	20
2-8	Ogemaw	14.8	---	---	---	---	---	---	---	---	---	---	--- *
2-9	Clare	22.9	1	3	2	4	19	11	0	3	0	0	43
2-10	Osceola	17.1	0	8	1	1	5	6	0	3	3	2	29
2-12	Clar/Glad	8.3	0	8	0	4	5	4	0	0	0	0	21
2-13	Missaukee	20.8	4	3	0	2	19	5	0	0	0	0	33
2-15	Missaukee	48.3	7	1	1	15	27	18	0	5	0	0	74

* swamp data were not recorded for this sample

Table E3. Cumulative Count Data for Swamps on Lacustrine Sand & Gravel

SAMPLE	COUNTY	%AREA SWAMP	Spruce	Ash	Fir	Tam-arack	Cedar	Hem-lock	Birch	White pine	Aspen	Elm	SUM
3-1	Cheboygan	51.3	12	2	0	25	36	13	2	1	0	0	91
3-2	Alpena	17.5	0	0	0	1	22	7	3	1	0	2	36
3-3	P. Isle	38.3	3	8	4	16	29	3	0	1	0	0	64
3-5	Manistee	27.1	0	8	0	0	14	2	2	0	0	0	26
3-7	Ogemaw	25.4	0	2	0	0	19	2	0	3	0	0	26
3-8	Iosco	10.4	0	3	0	0	0	1	1	4	0	0	9
3-10	Mason	22.1	0	3	0	3	9	4	1	2	0	0	22
3-11	Gladwin	15.4	0	2	0	2	5	2	1	0	0	0	12
3-12	Arenac	21.3	3	1	0	12	6	2	1	5	0	0	30
3-13	Gladwin	25.8	0	3	0	11	9	1	3	2	0	2	31
3-14	Gladwin	22.9	1	0	2	8	7	0	2	8	0	0	28
3-15	Gladwin	15.0	3	6	1	3	6	0	0	5	0	0	24

Table E4. Cumulative Count Data for Swamps on Ice Contact Features

SAMPLE	COUNTY	%AREA SWAMP	Spruce	Ash	Fir	Tam-arack	Cedar	Hem-lock	Birch	White pine	Aspen	Elm	SUM
4-1	Emmet	0.0	0	0	0	0	0	0	0	0	0	0	
4-2	Crawford	0.8	0	0	0	0	0	0	0	0	0	0	
4-3	Crawford	0.0	0	0	0	0	0	0	0	0	0	0	
4-4	Oscoda	0.0	0	0	0	0	0	0	0	0	0	0	
4-5	Oscoda	12.5	0	0	1	1	2	2	0	1	3	0	10
4-6	Alcona	22.7	0	0	0	2	8	5	0	2	4	0	21
4-7	Alcona	25.0	0	0	0	9	15	11	0	0	0	0	35
4-8	Ogemaw	2.9	0	0	0	0	0	3	0	0	0	0	3
4-9	Crawford	0.0	0	0	0	0	0	0	0	0	0	0	
4-10	Oscoda	0.0	0	0	0	0	0	0	0	0	0	0	
4-11	Ogemaw	0.0	0	0	0	0	0	0	0	0	0	0	
4-12	Ogemaw	0.0	0	0	0	0	0	0	0	0	0	0	
4-13	Ogemaw	1.6	0	0	0	0	0	0	0	0	0	0	
4-14	Ogemaw	4.2	0	0	0	0	0	0	0	0	0	0	
4-15	Roscommon	17.1	0	0	2	10	8	3	0	2	0	0	25

Table E5. Cumulative Count Data for Swamps on End Moraines of Coarse-textured Till

SAMPLE	COUNTY	%AREA SWAMP	Spruce	Ash	Fir	Tam-arack	Cedar	Hem-lock	Birch	White pine	Aspen	Elm	SUM
5-1	Charlevoix	0.0	0	0	0	0	0	0	0	0	0	0	
5-2	G. Traverse	8.3	0	1	0	1	6	1	0	0	0	0	9
5-3	G. Traverse	5.8	0	1	0	0	2	4	1	0	0	0	8
5-4	Osceola	3.3	0	3	0	0	0	1	0	0	0	0	4
5-5	Clare	4.2	0	0	0	0	0	0	0	0	0	0	
5-6	G. Traverse	5.8	0	0	0	0	1	3	1	0	0	0	5
5-8	Alcona	4.6	0	0	0	0	1	2	1	0	0	0	4
5-9	Newaygo	2.1	0	2	0	0	0	0	0	2	0	0	4
5-10	Newaygo	0.8	0	0	0	0	0	0	0	0	0	0	
5-11	Osceola	12.5	---	---	---	---	---	---	---	---	---	---	--- *
5-12	Mecosta	13.3	0	5	0	5	6	1	1	3	0	0	21
5-13	Missaukee	1.3	0	0	0	0	0	0	0	0	0	0	
5-14	Isabella	3.8	0	1	0	1	1	0	0	1	0	0	4
5-15	Oceana	0.6	0	0	0	0	0	0	0	0	0	0	

* swamp data were not recorded for this sample

Table E6. Cumulative Count Data for Swamps on Ground Moraines of Coarse-textured Till

SAMPLE	COUNTY	%AREA SWAMP	Spruce	Ash	Fir	Tam-arack	Cedar	Hem-lock	Birch	White pine	Aspen	Elm	SUM
6-1	P. Isle	29.1	4	3	0	3	21	5	0	2	2	1	41
6-2	Cheboygan	15.4	---	---	---	---	---	---	---	---	---	---	--- *
6-3	Cheboygan	40.6	6	0	0	10	22	12	5	6	2	0	63
6-4	P. Isle	16.7	4	1	0	10	14	1	0	3	2	0	35
6-5	Alpena	49.6	4	2	0	8	39	2	3	1	2	0	61
6-6	P. Isle	41.6	7	3	0	7	37	8	3	1	0	0	66
6-7	Montmorency	10.8	3	0	0	4	8	0	0	1	0	0	16
6-8	Montmorency	13.3	1	1	1	5	8	0	0	1	0	0	17
6-9	Alcona	6.3	0	0	0	1	5	1	0	1	0	0	8
6-10	Alcona	5.4	---	---	---	---	---	---	---	---	---	---	--- *
6-11	Clare	12.5	0	3	1	5	4	4	2	4	0	2	25
6-12	Lake	5.6	0	0	0	2	0	1	1	1	0	1	6
6-13	Osceola	17.3	2	7	0	4	1	12	1	0	0	0	27
6-14	Isabella	0.0	0	0	0	0	0	0	0	0	0	0	--- *
6-15	Montcalm	17.5	0	0	0	2	5	3	1	0	0	0	11

* swamp data were not recorded for this sample

Table E7. Cumulative Count Data for Swamps on End Moraines of Medium Till

SAMPLE	COUNTY	%AREA SWAMP	Spruce	Ash	Fir	Tam-arack	Cedar	Hem-lock	Birch	White pine	Aspen	Elm	SUM
7-1	Otsego	5.0	0	0	2	0	4	2	0	0	0	0	8
7-2	Otsego	3.3	3	0	0	0	2	0	2	0	0	0	7
7-3	Montmorency	7.3	0	0	0	2	4	2	0	0	0	0	8
7-4	Montmorency	10.2	1	1	2	0	8	5	0	0	0	0	17
7-5	Alcona	3.3	0	0	0	1	1	0	1	0	0	0	3
7-6	Alcona	9.4	1	2	3	1	0	0	1	0	0	0	8
7-7	Manistee	0.8	0	0	0	0	0	0	0	0	0	0	0

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