METHODS OF ANALYSING ORIGINAL VEGETATION COVER

USING EARLY LAND SURVEY RECORDS

METHODS OF ANALYSING ORIGINAL VEGETATION COVER USING EARLY LAND SURVEY RECORDS

By

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SCOPE AND CONTENTS:

An investigation into possible methods of obtaining the maximum amount of information pertaining to the primaeval forest cover of a township in Southern Ontario.

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INTRODUCTION

It is evident, even from examination of national topographic sheets that extensive areas of deciduous woodland are now uncommon in Southern Ontario. The remaining woodlots by no means constitute part of the presettlement forest for the majority are secondary growth stands arising primarily from the advance of civilisation in the form of pioneer settlement with its associated forest clearance beginning in the last decade of the 18th century.

From the realisation of the drastic nature of the original and later depletion of forest resources which occurred throughout N.E. North America came the need for conservation and the interest by botanists of the northern states of the U.S.A. in reconstruction of the general characteristics and distribution of the original vegetation. Some of the maps constructed to depict this presettlement vegetation are based, to a large extent, on contemporary field studies but it is obvious that second growth stands and scattered remnants of the original forest, cannot, without great hazard, be used alone to delineate presettlement forest types, much less provide reliable information on its composition. Disturbed tracts are usually radically altered from their former character, while remnants often represent sub-climax types in which man's protection may have induced equally great change (1). There is too, a less plausible but possible suggestion that climatic change during the last 200 years may have altered the species composition at any one place as species either extended or reduced their ranges.

The main sources of information then, concerning analysis of past vegetation patterns, aside from examination of present day remnants is provided by fossil pattern and early land surveyor's records. D. Löves' work on the Flora of Manitoba (2) and Wright's study on post-glacial forest succession in the Great Lakes region (3) are Canadian examples of reconstruction based on pollen analysis. While pollen records provide invaluable evidence on evolution of post-glacial vegetation involving considerable time periods they are of limited use for vegetation 'analyses' of one or two centuries from the present. It is in this context that the surveyor's reports are of greatest use.

Government Land Survey Records

In Southern Ontario, the surveys were commenced in the late 1780's when it became necessary for the Government of Upper Canada to allocate land to the large influx of United Empire Loyalists from the United States. As well as providing the Government with a catalogue of forest resources they indirectly supplied a rough indication of land capability. In order to appreciate fully how the survey records could supply information of this nature, govennment specifications presented to the surveyors in respect to actual required surveying procedure may be enumerated:-

1. Every major change of vegetation cover was to be reported and the chainage given.
2. All rivers, creeks and smaller streams of water, with their right-angled width and the course they run where the lines of the survey intersect them was to be noted.

3. All lakes and ponds and their width at the point of intersection of survey to be recorded.
4. All prairies, swamps and marshes and their chainage to be given.
5. All precipices, ravines and caves to be recorded.
6. The tracks of tornadoes and strong winds to be indicated as 'windfall' or 'fallen timber'.
7. The distance at which any ascent or descent begins and ends with the course and estimated height above the level of the surrounding land or above bottom lands, ravines or waters on which they are situated must be noted.
8. Indications as to the nature of the soil should be given at intervals.

The actual form and presentation of this material may best be appreciated by study of a sample page from the surveyor's note book as on page 4. (4)

5.00	Maple and Ironwd with Beech & Maple Brush to a Black ash Swale
3.60	Through the Black ash Swale.
1.40	Beech maple and Bass
10.00	to stake 7/8 in the Broken Front, at .50 northerly intersected by 2 Maples and a Beech.
3.00	Beech maple and Bass clay soil
4.00	Maple Beech oak & Bass Beech & maple Brush
3.00	Oak Maple and Bass
10.00	to stake at .50 each way
	4/5 in the 6th Con intersected 2 Black oaks & an Elm
	8/9 in the Broken Front intersected by 2 Irons and a maple.

SAMPLE PAGE FROM SURVEYOR'S NOTEBOOK

Fig. 1

PART I: INTRODUCTORY

1.1 Aims

The fundamental aim of this study is to devise objective methods of manipulating the survey record data in the analysis of the 'original' or primaeval vegetation of a township in Southern Ontario. In so doing, the advantages and limitations of the surveyor's notes for this type of study will be brought out. The term 'analysis' in this context refers to the extraction from survey notes, of the maximum amount of valid information pertaining to the forest cover at the date of the survey. Fundamental to such an analysis is a knowledge of the nature and distribution pattern of the vegetation; thus the major part of the thesis will be aimed at devising and testing techniques for the reconstruction of forest cover by means of maps. By extracting all the available evidence concerning forest cover, the intention is to produce maps which depict the general character and overall pattern of vegetation cover rather than merely the location of individual arboreal types on separate maps. Although reconstruction by verbal description may prove adequate for some investigations, it lacks the objectivity aimed at here.

The second part of the study is aimed at examining the extent to which the surveyor's notes can provide an insight into factors which control the form and distribution of forest vegetation on the township, as established by the various reconstructions. It was postulated therefore, that the records may be used to determine the nature of:-

1. Physical environmental factors controlling the vegetation distribution.
2. Anthropogenic influences controlling the vegetation distribution.

3. Bias and selective observations of the surveyor himself, while recording the forest cover of the area.

Once again, in examining these postulates, the advantages and limitations of the survey records as an aid in obtaining a full analysis of the vegetation cover of an area at a definite date in the past, will be brought out. It must be stressed here, that this is essentially a thesis with a methodological as opposed to a hypothetical theme.

It is hoped, then, that this study will be of use in the investigations of biogeographers and botanists into such problems as the ranges of particular plant species[1] or vegetation - habitat relationships[2] as well as those of historical geographers and archaeologists indirectly interested in vegetation as an aid in research into past population distributions or anomalies in settlement patterns.

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[1]For instance - Fox and Soper, J.H., 1952. The Distribution of some trees and shrubs ofthe Carolinian zone of S. Ontario. Part I. Trans. Roy. Can. Inst. 29 (2), p. 65-84.

[2]For instance - G. T. Trewartha, 1940. The Vegetal Cover of the Driftless Cuestaforian Hill Land: Presettlement record and Post-Glacial Evolution. Trans. Wisconsin Acad. Sci. Arts and Letters. Vol. 32, pp. 361-382.

1.2 Review of the Literature

Past studies on the surveyor's records fall into four categories:-

1. Those concerned with methods of using the surveys in vegetation reconstruction., eg. E. Bourdo.
2. Those utilising the records for reconstruction purposes per se., eg. Lutz (1930); Kenoyer (1930, 1940); B. Dick (1936); G. T. Trewartha (1940); Finley (1951); Curtis (1958); J. Potzger (1952) and Quadir, Lindsay and Crankshaw (1965).
3. Those confined to the evaluation of the surveys in quantative studies of former vegetation, eg., E. Bourdo, (1956).
4. Those dealing with the general application of the surveyor's notes, eg., W. Pattison, (1955).

Only those papers occupying categories 1 and 2 will be considered in more detail. Considering Group #2 first, it must be pointed out that these papers are concerned with establishing the presettlement pattern, for its own sake, in order to appreciate some specific problem. For instance, Potzger et al, 1956, used the survey records in an attempt to delineate the eastern boundary of the Prairie vegetation in Indiana (5). An absence of or vagaries in the methods of mapping vegetation in this group of papers, is apparent, the emphasis being laid on the results obtained. Early methods, particularly of analysing past vegetation were largely qualitative. For instance, Kenoyer (1930) described the vegetation of Kalamazoo Co., Michigan (6) on the basis of frequency of 'reference' species. These were trees nearest the stake, erected at each section corner onto which compass bearings were made. He assumed that the frequency of the different species on the list of reference trees would provide an index to their frequency in the county as a whole. The methods of mapping this information are described in vague terms: 'The plotting of these bearing trees on the county map helps one to judge with considerable accuracy the original limits of the four important plant associations: beech - maple forest, oak - hickory forest, swamp forest and prairie'. Presumably, he uses the associations defined by earlier or contemporary botanists when attempting to map the vegetation of North America. Kenoyer was fortunate in that his study area possesses not only easily defined associations but different physiognomic categories as well, in the form of forest and prairie. Kenoyer was obviously one of the pioneers in this field - he writes 'The writer will welcome any suggestions bearing on the proper interpretation and use of such material'.

Lutz (7) writing contemporaneously with Kenoyer uses the survey notes to obtain information on original forest conditions. He also bases his findings on abundance and frequency values calculated for all species mentioned by the surveyor. He does not attempt to map the results and merely describes them qualitatively.

At a later date, J. Potzger (8) one of the most prolific users of the survey note data, in attempting to procure an overall picture of the original vegetation cover of Indiana, employs more objective methods of presenting survey note data. He, however, also classifies his vegetation groups into previously determined associations. He allocates the assemblage in each township into a particular association on the basis of dominance. For instance, townships in which at least 50%

of witness trees[1] were beech, sugar maple and upland ash individually or in any combination were considered to have been occupied by beech - maple - ash forests. The same applies to the oak - hickory ecological grouping. The data thus compiled was graphed, township by township, on three maps of the state of Indiana. Each so-called 'map graph' showed by means of bargraphs for each township the distribution of the major associations as a percentage of the total witness trees recorded by townships in the original U.S. Land Survey. As mentioned already the percentages are represented by three extremely small scale bar graphs of the appropriate proportions. The first map showed the percentage beech, sugar maple and upland ash within each township. The second depicts percentage oak, hickory and oak openings, Fig. 2, while each township on the 3rd map possesses 4 bar graphs which present a summary of the original forest association in Indiana as combined percentages of beech - sugar maple - upland ash, of upland oak - hickory, of oak openings and of all remaining tree species of total witness trees recorded by townships in the original survey. The end product is a clear, easily interpreted checkerboard pattern representation of the primaeval forest cover, somewhat disjointed in appearance by the very nature of its compilation. (Fig. 2)

The most statistical approach yet devised to vegetation analysis using survey records is that of Quadir, Lindsay and Crankshaw, 1965, (9) who also worked with the Indiana survey reports. Using survey reports and the 1941 soil maps of Indiana, the presettlement distribution of beech, maple; maple - oak - hickory; mixed; depressional mixed and floor

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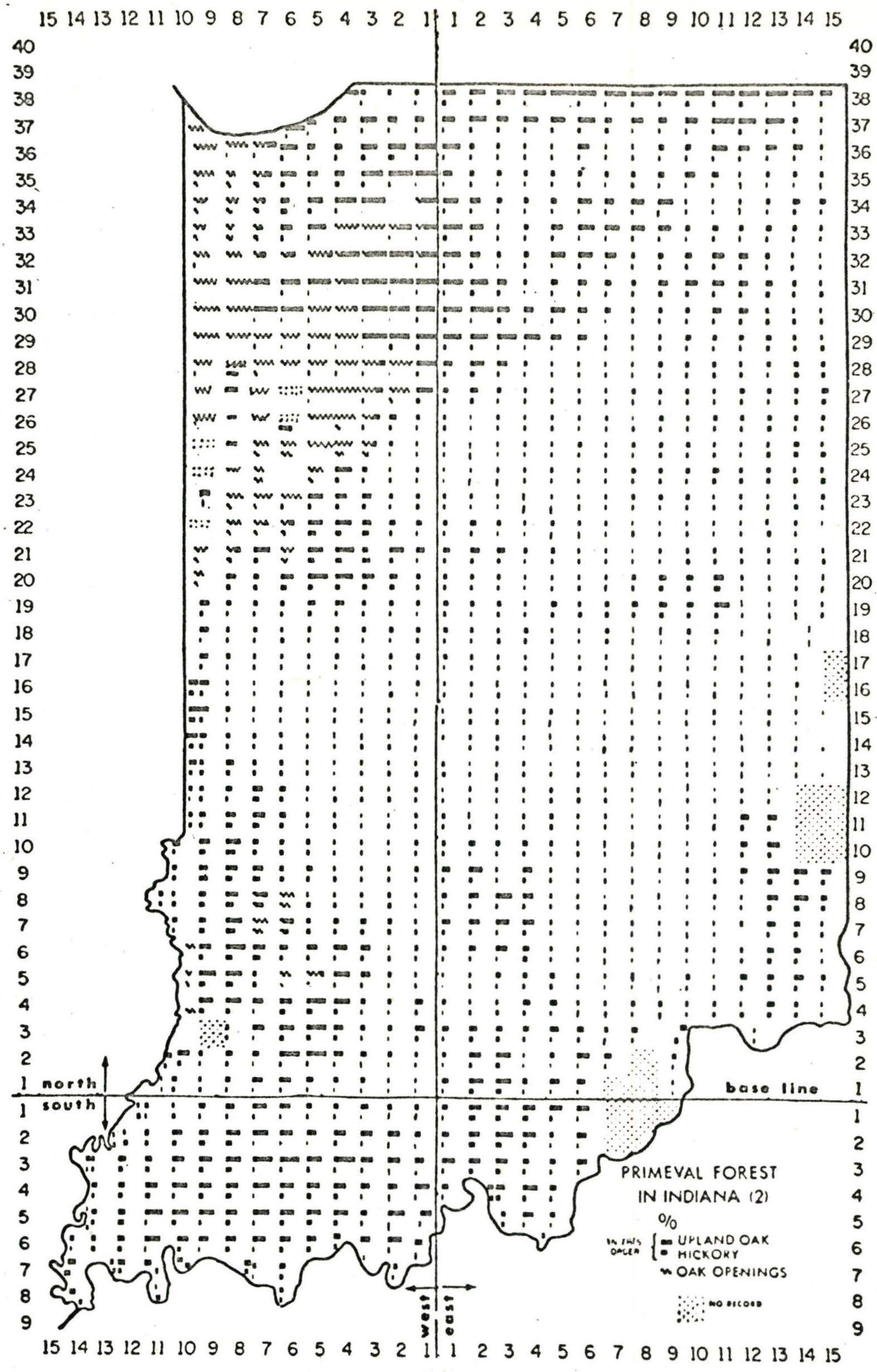
[1]Witness tree - Trees nearest the stake erected at each section corner onto which compass bearings were made.



Map-graph showing distribution in Indiana of the upland oak-hickory forest association as percentages of total witness trees recorded by townships in the original U. S. Land Survey.

POTZGERS' AND McCORMICK'S MAP GRAPH

Fig. 2

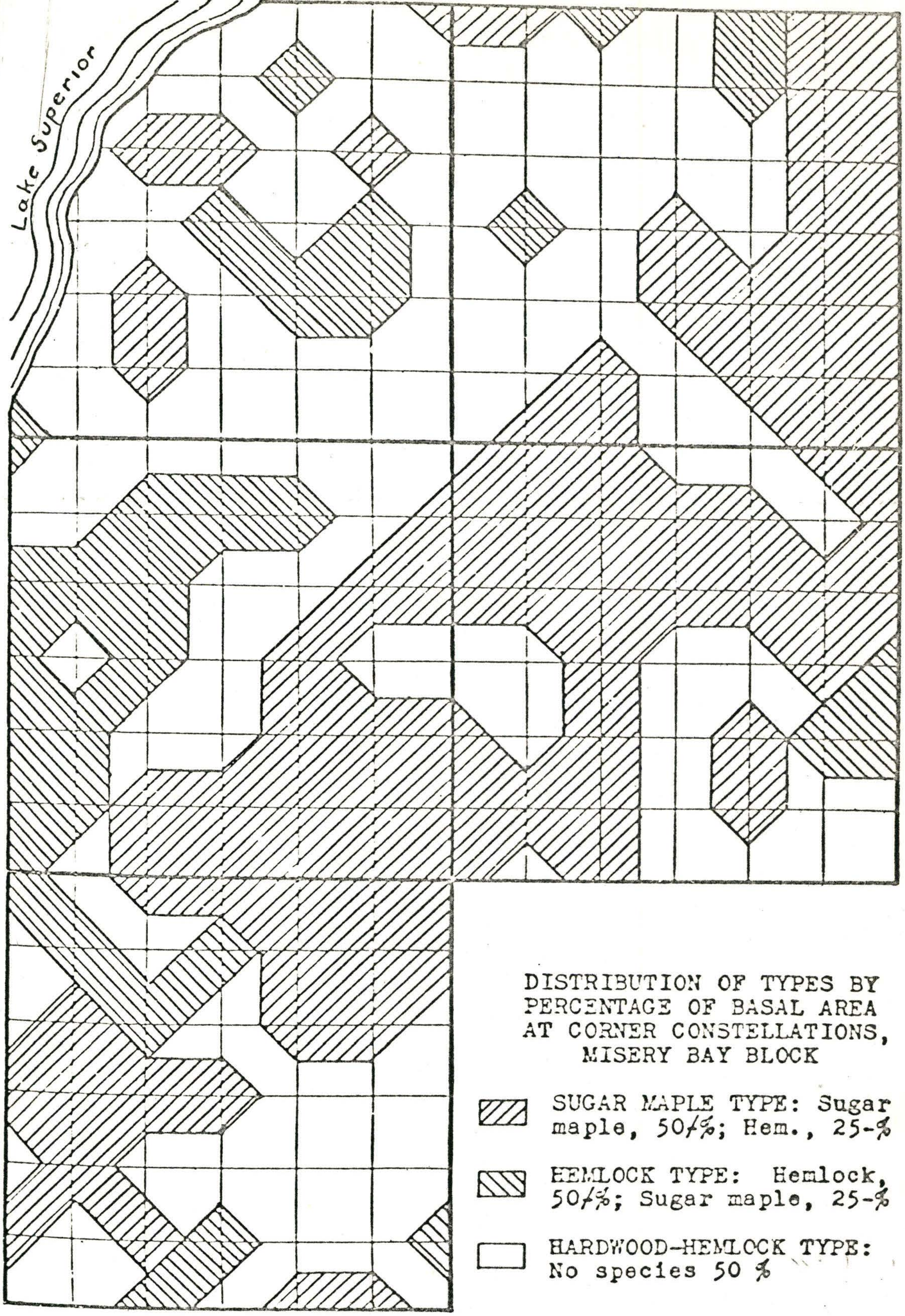
plain forest types was correlated with the major soil texture and soil drainage types. A punch card record of 70,240 individual trees was amassed. Vegetation was mapped on the basis of the above associations but no indication of the methods used to define them was given. With the aid of a computer, the relative influence of 11 soil factors was determined for the individual tree species using for each species, an importance value, basal area per acre and mean individual basal area as the dependent variables in 3 separate step-wise multiple regression analyses. Soil relationships were emphasised in this paper rather than vegetation reconstruction which was probably based on records of trees at section and quarter-section corners from which the relative density and dominance status of species for each township could be calculated to constitute the Importance Values used in the final analysis. Importance Value was defined as the percentage figure obtained by averaging the relative density and relative basal area of a given species on a particular soil type. In terms of quantification of survey note analysis, this paper constitutes an important step forward. In terms of delineating vegetation associations by approximation to the distribution of certain soils, the principles behind the paper are by no means novel. W.B. Dick (1936) (10), for instance, used soil types as an aid in determining the natural vegetation of Wayne County, Michigan. There can be no doubt that where sharp differences in soil type exist, they provide a means of delineating closely the boundaries of vegetation types, but so often in nature intergrading of types precludes the existence of sharp divisions.

As seen on page 8, papers based on presettlement vegetation analysis using survey notes are numerous. Therefore the choice of papers discussed here was governed by the fact that they represent a cross-section of the ideas and approaches to the problem at hand.

Bourdo's paper (11) is the only one of its kind which can be considered as falling into the category dealing with methodology. Entitled 'A validation of Methods used in analysing original Forest Cover' the paper has its stated objective, the critical examination of methods used in reconstructing original vegetation from General Land Office survey records. Two methods, he considers, are based on the use of environmental factors in delineating vegetation boundaries. Soil drainage conditions and landforms are the two interdependent factors in consideration. He writes for instance:- 'the differences in the composition of the forest growth on sand plains, rocky highlands, bogs and swamps, lake beds and high moraines, as well as on other equally distinctive physiographic features' has been noted. However, he then proceeds to elaborate on the limitations of using such means of demarcation.

The other two methods discussed by Bourdo provide a mathematical means of dealing with the problem more objectively. The first of these is the demarcation of forest types by the percentage species in each corner constellation. A constellation is the group of trees recorded by the surveyor at a section corner and on the half miles of survey line adjacent to it. For instance, a constellation may be assigned to the sugar maple type when 50% of the trees in that particular constellation are sugar maples so long as no more than 25% of the remainder are some other tree type. The boundaries of each vegetation type so constructed are drawn by connecting quarter section corners which enclose constellations of similar composition resulting in a series of polygonal units on the map. (Fig. 3)

The second method is described as species association by random pairs. The tendency of some species to be gregarious and of others to associate can be expressed mathematically by determining ratios to random expectation for the occurrence of pairs at corners. Such a ratio is obtained by dividing the percentage of all the bearing trees represented by each species by the percentage of that species in different combinations. This method of manipulating the survey data is of especial value in that it enables the distinction to be made between gregarious species and those which associate with members of other genera. This seems a useful piece of information contributing to the overall appreciation of presettlement vegetation using survey records.



E.BOURDO'S MAP OF TREE TYPE DISTRIBUTION BY THE 'CORNER CONSTELLATION METHOD'

Fig. 3

1.3 Reasons for the necessity of the present study

With the review of past literature in mind, notice must be brought to the fact that all the studies mentioned in that section were carried out on the American survey records. The primary reason, therefore, for carrying out research in this field is that, to date, there have been no papers published based on the Canadian surveys. Although there have been a considerable number of American studies, much of the information they contain is not applicable to the survey notes of Southern Ontario. This is due to the different survey procedures and the more restricted data afforded by the latter. For instance, the American surveyors were instructed to record the name, direction, diameter and basal area of the trees nearest the corner posts situated at every township and section corner, recording, at the same time, the distance of these trees from the corner posts and from each other. The Ontario surveyors noted any change in tree cover as they proceeded along concession lines and merely named the tree or trees used to identify the position of lot corners. No dimensions were noted. These differences are significant in using survey notes to reconstruct past forest types since the Ontario surveys enable only Relative Frequency to be calculated:-

Relative Frequency - the total number of trees of a particular species as a percentage of the total number of species.

However, the data provided by the American surveys enables the investigator to calculate:-

Relative Density - the number of points of occurrence of a species as a percentage of the total number of points sampled.

<u>Relative Dominance</u> - total basal area of one species as a percentage of the total basal area of all species.

An <u>Importance Value</u> - summation of Relative Frequency, Density and Dominance.

With the above parameters in hand, the investigator using American survey notes can obtain quantitative information, not only on forest composition, but also on the spatial arrangement and size class distribution of trees within forest stands.

A second reason for research in this field stems from the fact that in spite of the fuller data in general, much of the American work is of a qualitative nature. It is hoped that this study will suggest to the user of the records more objective methods of manipulating the data.

A noteworthy point of lesser importance is that most of the previous work deals with large areas ranging from the size of a state to that of a county, whereas in this study an area the size of a township will be considered. Such an enlargment of scale will necessarily involve certain differences of technique.

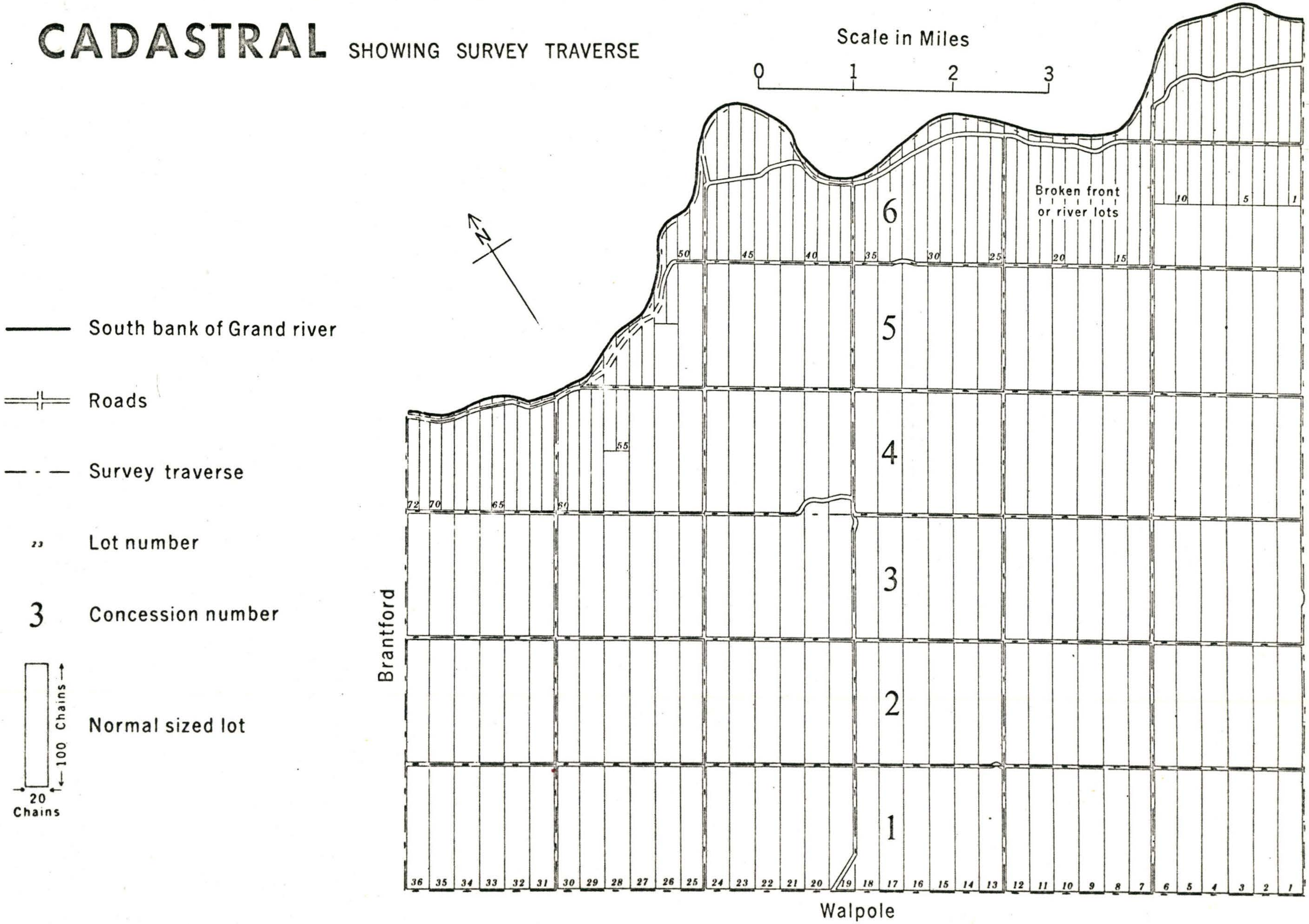
In concluding, it cannot be over-emphasised that the same techniques used for vegetation reconstruction based on American General Land survey records cannot be readily applied to those of its northern counterpart.

1.4 Choice of Area for the Study

The foremost factor governing the choice of area for study was obviously the amount of information contained in the survey records pertaining to vegetation cover. This type of detail varied considerably between surveys, the earlier surveys - pre 1820 - tending to be less detailed than those carried out after this date. Legibility of the records is, of course, imperative. From the point of view of obtaining the maximum amount of information on vegetation in the area it was desirable to have a minimum amount of disturbance both prior and subsequent to the survey. A point of practical nature was the accessibility of the area both from within and without in order to facilitate relevant field work.

With the above factors in mind, Tuscarora township in Brant County, surveyed in 1842 by William Walker, deputy surveyor of Brantford was chosen. From the point of view of disturbance it is not ideal since some settlement had taken place prior to 1842, with its associated clearance. Although the area has a considerable acreage of woodland today, it is virtually all secondary growth. The survey, however, was considered to be representative of the surveys of Southern Ontario and was one of the most detailed, legible and methodically presented of those within at least 50 miles radius of Hamilton. Tuscarora is laid out on the Single Front system(12)(Fig. 4) and Walker surveyed along the eight east-west concession lines and then along each seventh north-south trending lot line. He recorded at least three tree types for each observation he made and on the average made four observations per 20 chains (1/4 mile).

CADASTRAL SHOWING SURVEY TRAVERSE



1.5 Environmental characteristics of the study area

Tuscarora township itself is situated some 30 miles from Hamilton, on the south bank of the Grand River (inset fig. 5) and covers an area of 65 square miles. Topographically, it is an area of low scarp and vale relief with a maximum elevation of 725' above sea level. It is underlain by Paleozoic bedrocks of shales, dolomites, sandstones and limestones. Most of the present day surface features however, are the effects of erosion and the deposition during the Wisconsin glaciation when a till plain was formed in parts of the Niagara Peninsula (13). The results of this are manifest in the presence of scattered drumlins, noteably in the eastern section of the township (Fig. 5). During the retreat of the Wisconsin, glacial lakes such as Lake Warren, were formed in which thick lacustrine deposits of clays and silts were laid down to form the Haldimand clay plain. These deposits were responsible for partially burying the drumlins mentioned above. In the south-west of Tuscarora, the clay and silts have been replaced by deposits of a sandier nature laid down as a delta in glacial lakes Warren and Whittlesey. This area forms part of the northern extent of the Norfolk Sand Plain which has its base along Lake Erie. There has been considerable dissection of the soft surface deposits by the McKenzie and Boston Creeks, tributaries of the Grand River. The Grand River itself, marking the northern boundary of the township, has cut a wide but relatively shallow valley in the silt and clay deposits. As far as influence upon natural vegetation cover is concerned, four types of physiographic area may be distinguished: the flood plains of the Grand River and its tributaries; the level lake plains of sand and clay and the hummocky drumlin areas.

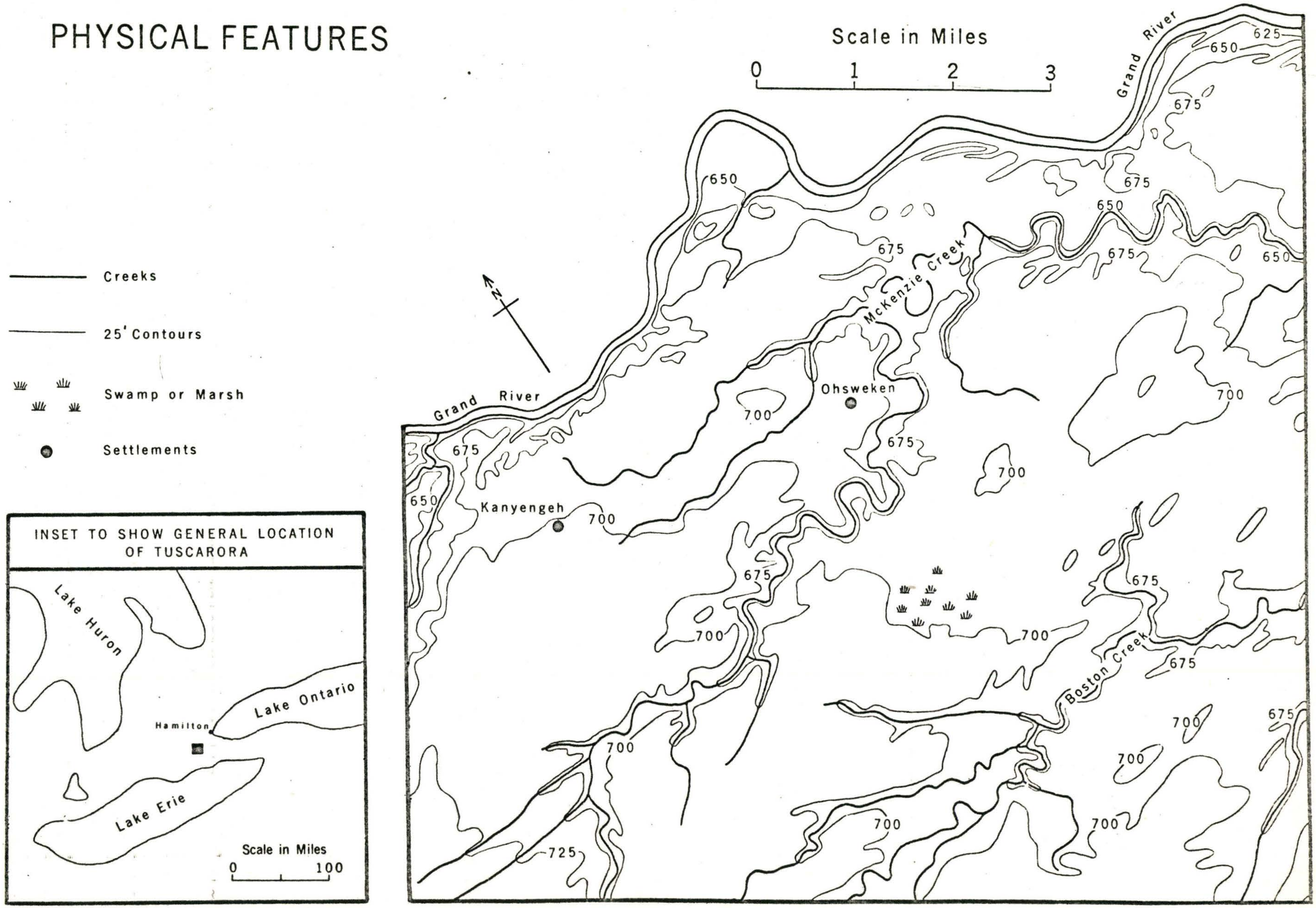

PHYSICAL FEATURES
Scale in Miles
0 1 2 3
Grand River
Grand River
625
650
675
700
725
McKenzie Creek
Boston Creek
Ohsweken
Kanyengeh
Creeks
25' Contours
Swamp or Marsh
Settlements
INSET TO SHOW GENERAL LOCATION OF TUSCARORA
Lake Huron
Lake Ontario
Lake Erie
Hamilton
Scale in Miles
0 100

Fig. 5

Soils

These are derived from three parent materials:- drumlin material, Norfolk Sand Plain and Haldimand Clay Plain. Eight types of soil may be found in the following proportions (Fig. 6)

TABLE 1. Percentage Proportions of Soil Types on Tuscarora

Bottomland	10%
Brantford clay loam	14
Berrien sandy loam	16
Caistor clay loam	5
Haldimand clay	51
Oneida clay loam	5
Oneida loam) Tuscola loam)	1

The properties of these soils do not vary significantly since they all have a pH ranging from 5 to 7, are deficient in phosphates and lime and are stone free. All except for the Brantford clay loam, Oneida clay loam and Oneida loam, which constitute only 15½% of the area of the township are poorly drained and heavy. More details concerning soils will be given in Part III, page 88.

Climate

As regards the climate of the area in which Tuscarora is situated, the following table summarises factors which determine the nature of the forest vegetation.

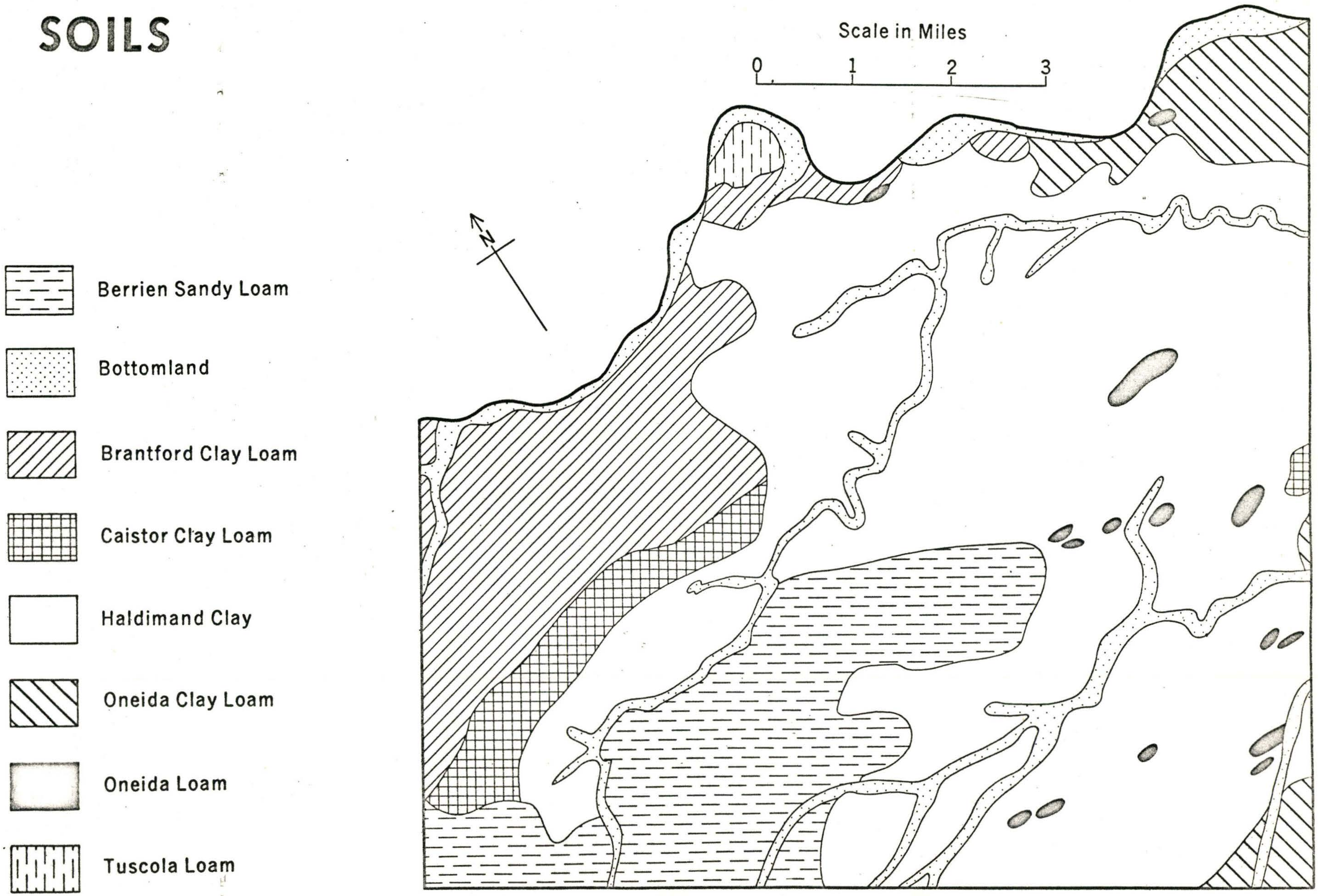

SOILS
Scale in Miles
0 1 2 3
N
Berrien Sandy Loam
Bottomland
Brantford Clay Loam
Caistor Clay Loam
Haldimand Clay
Oneida Clay Loam
Oneida Loam
Tuscola Loam

Fig. 6

TABLE 2. Summary of Averages for the important climatic features of the region in which Tuscarora is situated (15)

Climatic Factor	
Mean Annual Temperature	49°F
Winter Temperature	27°F
Summer Temperature	67°F
January Isotherm	23°F
July Isotherm	71°F
Extreme Low Temperature	-23°F
Extreme High Temperature	102°F
Beginning of Growing Season	April 10th
End of Growing Season	November 4th
Length of Growing Season	208 days
Average Length of Frost Free Period	166 days
Annual Precipitation	30"
Potential Evapotranspiration	25"
Water Surplus	5"

Local variations in climate are slight since relief features are fairly uniform throughout the township.

PART II: METHODOLOGY

2.1 Notes on the determination of the identify of trees encountered in the surveyor's notebook

From a preliminary reading of the survey records it was appreciated that eleven different tree types were identified by the surveyor on a regular basis. In other words, eleven types were recorded in the observed assemblages of trees noted by Walker as he surveyed along the concession and certain of the lot lines. A total of nearly 20 different trees was, in fact, mentioned by the surveyor but this total includes those trees used as witness trees or identification posts at the corner of each lot and these were not taken into consideration. Such trees include white ash (Fraximus americana); black cherry (prunus serotina) and the blue beech (carpinus caroliniana). Walker used the popular names of the trees which, in some cases, allows identification of the actual species he was referring to; in other cases however, it enables identification of the genus only. Identification of the actual species is simple when there is actually only one species of a particular genera occurring in Southern Ontario, as for instance, basswood.

Each of the 11 tree types will now be considered separately with notes on the interpretation of its presumed identity.

Maple[1]

Two species of maple are mentioned by the surveyor; these are hard and soft maple or acer saccharum and acer rubrum respectively.

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[1]With the exception of this brief section, all arboreal types will be referred to by their botanical names. A glossary of botanical names and english equivalants is found in the Appendix.

Although he may have witnessed the silver maple (acer saccharinum) the two above mentioned trees are those most commonly occurring in natural woodlands in Southern Ontario. Both acer saccharinum and acer rubrum require moist, well-drained soils for best development.[2]

Beech

Since only one species of beech is native to North America this can only be the American beech (Fagus grandifolia). This tree prefers rich bottom lands and moist well-drained soils on ridges (16).

Oak

As with maple, there are two major species of oak which occur in more or less equal proportions in natural woodland. These are the white and red oaks (Quercus alba and Quercus rubra). The surveyor occasionally distinguishes between the two but uses the term black oak as opposed to red oak. He may, of course, be referring to Quercus velutina more commonly known as the black oak, however, in view of the ecological preferences of the black oak for poor gravelly, sandy soils, it is more likely that he is actually referring to Quercus rubra which, in some botanical texts, is also known as the black oak.(16)

Pinus

This is presumably the white pine (Pinus strobus). It may grow on a wide variety of sites from dry sandy ridges to sphagnum bogs but does best on a moist sandy soil.

Basswood

This is the only basswood known to occur in Canada, therefore

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[2]Information pertaining to the ecological preferences of the species or generic groups was extracted from sources of a general character - 'Native Trees of Canada' Lands and Forests, 1963, and merely serves to introduce the types of tree found in Tuscarora in 1842.

its identity cannot be mistaken for any species other than Tilia americana. This tree prefers a deep loam soil on low slopes and along streams.

Ironwood

There appears to be some confusion in botanical texts as to the correct name of this tree. Although, it is known as Ironwood in all books published during the past generation, the Blue Beech (Carpinus caroliniana) is still commonly called Ironwood in many areas because of the strong, muscular appearance of the trunk. This results in the confusion of two 'ironwoods' and is further complicated by the alternate names of American hornbeam and Hop hornbeam applied to Ostrya virginiana and Carpinus caroliniana respectively (17). Since, however, the surveyor uses the term 'blue beech' for Carpinus caroliniana as a witness tree it is presumed that when ironwood is noted, he is, in fact, referring to (Ostrya virginiana). This tree is extremely shade tolerant and prefers rich, well drained loamy slopes and ridges.

Elm

Although there are three species of elm native to Eastern Canada, that identified by the surveyor is probably the white elm (Ulmus americana). It thrives on a rich, moist, well-drained sandy laom or gravelly soil where the water table is near the surface.

Hickory

Two species of hickory are commonly found in the Niagara Peninsula: butternut hickory (Carya cordiformis) and shagback hickory (Carya ovata). Recent examination of the vegetation in Tuscarora township show the latter to be by far the most abundant of the two. It is probably Carya ovata to which Walker refers most.. This requires a moist, fertile soil and considerable light. It is here in the northern part of its range.

Poplar

This could be a reference to any one or all of four possible members of the genus 'populus' but in most cases the surveyor is probably referring to the trembling aspen (Populus tremuloides) and the large toothed aspen (Populus grandidentata). However, one may note that neither of them is called 'poplar' in the vernacular. The two aspens are similar in general habitat requirements for they are intolerant of dense shade and are found on a variety of soils. They both reproduce vegetatively.

Black Ash

There can be no mistake that the surveyor is here referring to Fraximus nigra, a tree confined to wet sites.

Tamarack

This is undoubtedly Larix laricina. It is here in the southernmost extent of its range and prefers wet sites.

2.2 Data Collection

In order to have the survey note information in an accessible summarised form, the data pertaining to vegetation and physical features was tabulated on prepared sheets from microfilm. This information was tabulated in the following manner:-

TABLE 3. Sample Data Tabulation Sheet

Con.	Lot	Chains	Maple	Oak	Beech	Bass	Elm	Pine	Iron	Hick.	Pop.	Black Ash	Tam.	Remarks
1	1	7.50	x		x				x					
"	"	3.00		x				x						
"	"	1.45										x		
"	"	8.05	x	x		x				x				
	2	2.35	x	x	x									

Observations referring to soil qualities, nature of terrain and windfalls were entered in the column entitled 'remarks'. As explained in the section dealing with tree identities, only those trees occurring along the survey lines were recorded in the columns above. Other trees used by the surveyor as witness trees at lot corners were noted in the 'remarks' column. Using these tabulated sheets the data was then punched onto 1,553 I.B.M. computer cards; one card representing one observation, i.e., one of the above rows. In this way a data deck was assembled from which all calculations needed in vegetation analysis could be computed.

With the above sample table in view, the limited nature of the data can be seen. Only the length of chain occupied by a given tree assemblage is noted with the exception of the swamp vegetation which, owing to its more easily definable nature, is measured as a separate distinct entity. There is no indication of the relative abundance of a tree type within an observation. It could be assumed that the first tree mentioned in each case is the most abundant, but on the other hand, it could be that the first tree mentioned was the nearest one to the surveyor at the time he was making an entry. Alternatively, the trees may have been recorded according to some pre-arranged order or most likely they were recorded at the surveyor's will. It would seem then, that there are too many deductions to be made in allocating greater abundance or dominance to any genus at any one time. That the length of the surveyor's observation extended for equal distances on either side of the survey line and that it remained a constant distance throughout the survey was likewise assumed.

Thus the three assumptions:-

1. All trees in an observation are of equal abundance, unless otherwise stated.
2. All trees in an observation are of equal importance, unless otherwise stated.
3. The area covered by the surveyor's observation is equal throughout the township

govern both data manipulation and mapping methods.

2.3 Vegetation Reconstruction based on Trend Surface Analysis

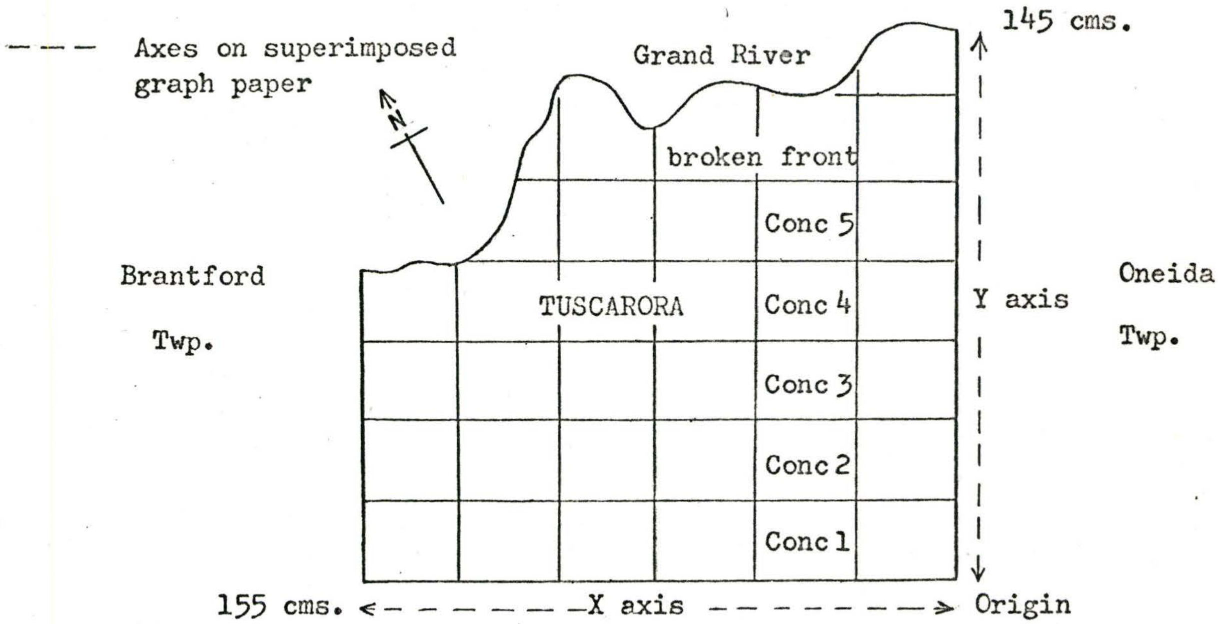
Trend surface analysis as a technique for reconstruction differs widely from the other methods proposed. To begin with, while they will be based on relatively simple arithmetic calculations, the construction of trend surfaces involves sophisticated statistical techniques for which the computation even for high speed computers becomes considerable at the higher order surfaces with their large arrays of data. Second, the maps produced by the other methods will have to be constructed by 'manual' interpolation while the surfaces produced by trend surface analysis have been evolved by statistical interpolation.

Basically a 'trend surface' may be defined as a contour model of areally distributed data in which surfaces of increasing complexity are fitted as closely as possible to sets of points in three dimensions, two of which are map coordinates and the other representing various values of the variable. The 'fitting' to the points is carried out by the method of least squares whereby the squared distances between the computed surface and the observed values are reduced to a minimum (18). It is thus analogous to the calculations of a regression line in two dimensions. The purpose of the resultant surfaces is to elucidate the systematic regional trends inherent in the data and eliminate the effect of purely local irregularities or 'noise'. It is for this reason and the objective nature of this technique that trend surface analysis was carried out first as opposed to the other less complex analyses.

Data for computer input.

In the construction of the trend surfaces for each arboreal type, the data consisted of 'Importance' values (the method of calculation will be discussed) for each north and south extremity of lots in which vegetation was recorded and the map coordinate positions of these values. Using a 1:50,000 scale topographic sheet of Brant County, an x axis running parallel to the Indian line (Fig. 7) and a y axis running parallel to the Oneida - Tuscarora township line was established. A sheet of graph paper with centimetre squares, overlaid the map and the lot and concession positions were obtained.

Fig. 7



POSITION OF AXES FOR CO-ORDINATE PLOTTING IN TREND SURFACE ANALYSIS

The original data deck provided the essential data for the calculation of the z values (the value in the third dimension). The total number of z values was 257.

<u>Methods of calculating the z values - genus importance.</u>

Two methods were attempted:-

The first was based on the percentage length of occurrence of genus x per unit length of vegetation cover of each lot width or concession length. This was expressed as:-

$$I = \frac{m}{l} \times 100$$

where I = importance value

m = length of lot occupied by vegetation cover (as opposed to clearings, ponds and rivers)

l = chainage denoting length of occurrence of genus x in each lot.

The second was based on length of occurrence of genus x relative to other genera occurring in the same observation as a percentage of the total length of vegetation cover of each lot width or concession length. This may be expressed as:-

$$I = \frac{m}{l/q} \times 100$$

where I = importance value

m = length of lot occupied by vegetation cover (as opposed to clearings, ponds and rivers)

l = chainage denoting length of occurrence of genus x in each lot

q = number of other genera in observations in which genus x occurs

TABLE 4. Sample of Original Data Deck to show the methods used in calculating the 'Importance' value of Ostrya

				Genera										
Observation	Concession	Lot	Chains	A	Q	F	T	U	P	O	C	Po	F.N.	L
1	0	01	03.10	1	0	1	1	0	0	0	0	0	0	0
2	0	01	01.90	1	0	0	1	1	0	1	0	0	0	0
3	0	01	09.80	1	0	0	1	1	0	1	0	0	0	0
4	0	01	01.17	1	0	0	0	0	0	0	0	0	1	0
5	0	01	03.03	1	0	0	1	1	0	0	0	0	0	0

Total = 19.00 chains

To calculate the frequency of Ostrya by method 1.

$$m = 19 \text{ chains}$$

$$l = 1.90 + 9.80 = 11.70$$

$$I = \frac{19.00}{11.70} \times 100$$

$$I = 61.58\%$$

Method 2.

$$l = 11.70 \text{ chains}$$

$$q = 8.00 \text{ chains}$$

$$m = 19.00$$

$$I = 19 \quad \frac{11.70}{8} \times 100$$

$$I = 15.39\%$$

It would seem from examination of Table 4 that Method 1 overemphasises the ecological status of ostrya in the lot since it is based on the assumption that the tree type is the only one occurring, in observations 2 and 3. Method 2 provides a more realistic representation of the vegetation in that it takes into consideration the presence of acer, tilia and ulmus as well as ostrya in observations 2 and 3. It, however, is based on the assumption that in observation 2, for instance, the 4 genera present will each occupy equal proportions of 1.90 chains, i.e., 25% of 1.90. This is highly unlikely owing to the existence of the parameter 'dominance'. This method was chosen eventually since it appeared to have greater validity than the other formula and also because the lower values obtained were more suited for trend surface analysis in that they reduce the standard error of the surfaces, as will be shown later.

An analysis was carried out for nine of the arboreal types recorded by the surveyor. Populus spp. and larix spp. were omitted since the number of occurrences of both genera was so low that it was highly unlikely they have yielded significant surfaces.

Computer Output - Results

Output takes the following form:-

1. List of 10 x 10 matrix of cross products values
2. Equation coefficients for each surface
3. Correlation coefficients for each surface
4. Percentage variation explained by each surface
5. Standard Error of the estimate of each surface
6. Analysis of variance for each surface
7. Arithmetic mean for z values (genus Importance Value)
8. Average z values for each surface
9. Trend surface maps for linear; quadratic; linear + quadratic + cubic surfaces
10. Maps of residuals of all surfaces

Analysis of Trend surfaces

The simplest type of trend is a plane which represents a simple gradient of the variables, this is the linear surface. In the quadratic surface the form is such that there is a ridge or trough while in the cubic surface the pattern can be a dome or basin and the curvature can change twice on any cross section (19). All three surfaces were computed but only the highest order surface (linear plus quadratic plus cubic) will be examined since the percentage variability explained by the linear surface of Tilia is 4.6251 whild that of the linear plus quadratic plus cubic surface is 20.8477. Since percentage variability is a measure of the goodness of fit of the surface the form of the linear trend does not describe the trend of the data as well as that of the higher order surface.

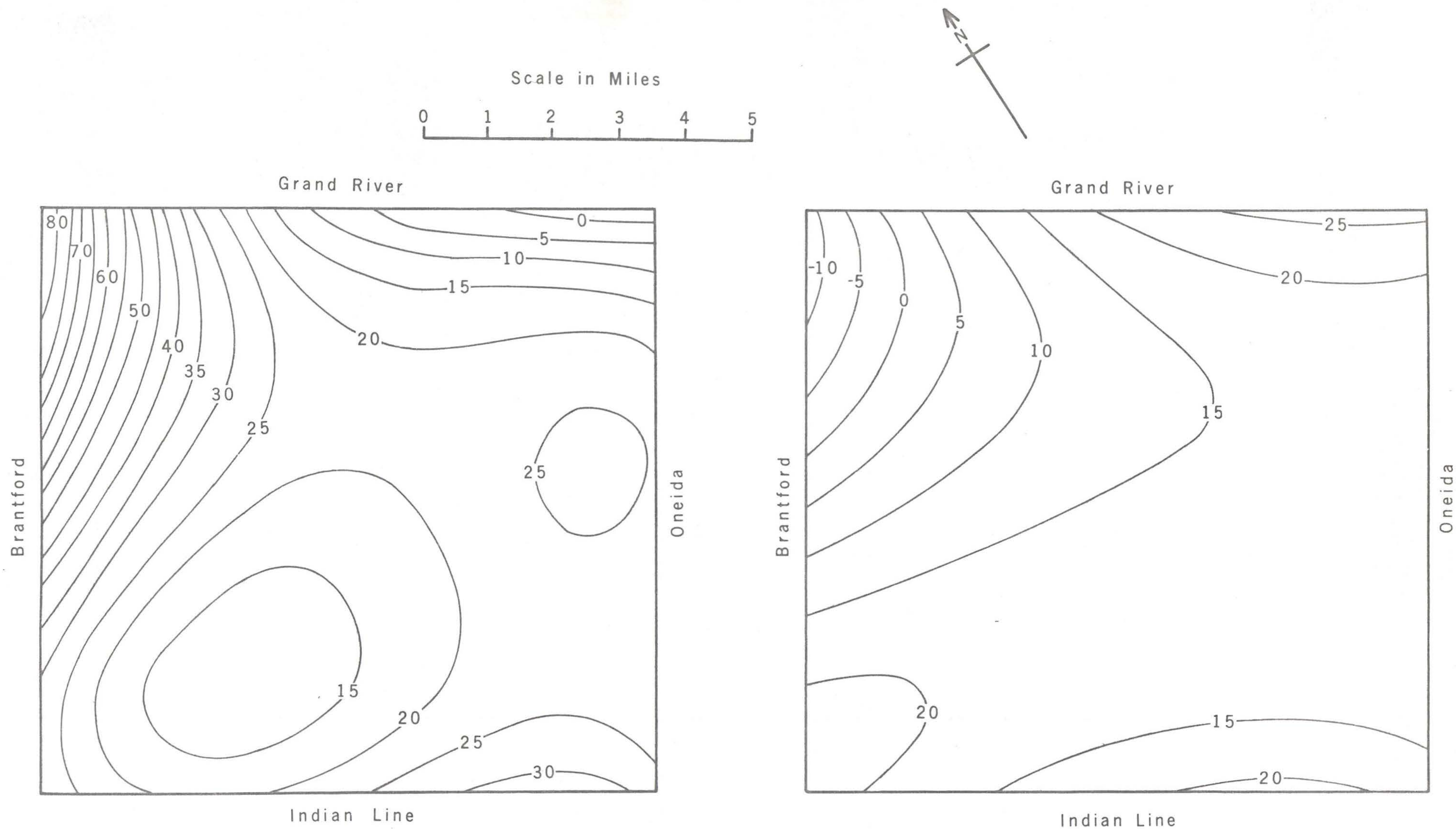
From an examination of the trend contours (Fig. 8) certain factors are apparent:-

1. There is considerable variation in form and contour value. Pinus (Fig. 8e) and Carya (Fig. 8g) are two contrasting examples. This is obviously explained by the differences in value ranges of the two genera for while the z value range of Pinus was 100, the maximum, that of Carya, was only 25.
2. There is a tendency for steep contour gradients in the northern sector of the maps, i.e., towards the Grand River, gradients generally increasing in a northwesterly direction, Figs. 8a and 8e for acer and pinus respectively. This phenomenon may be meaningless in that there was no data available for vegetation cover from lots 33 to 60 in the Broken Front since this area had already been extensively cleared. These are essentially, contours predicted from values encountered to the south of this area and carried over to this section of data absence.

These are the only two valid generalisations that can be made concerning the surfaces as a group.

Statistical Significance of the Results

It is obvious that the surfaces produced cannot be taken at their face value. They can only be viewed for their true worth when



Acer

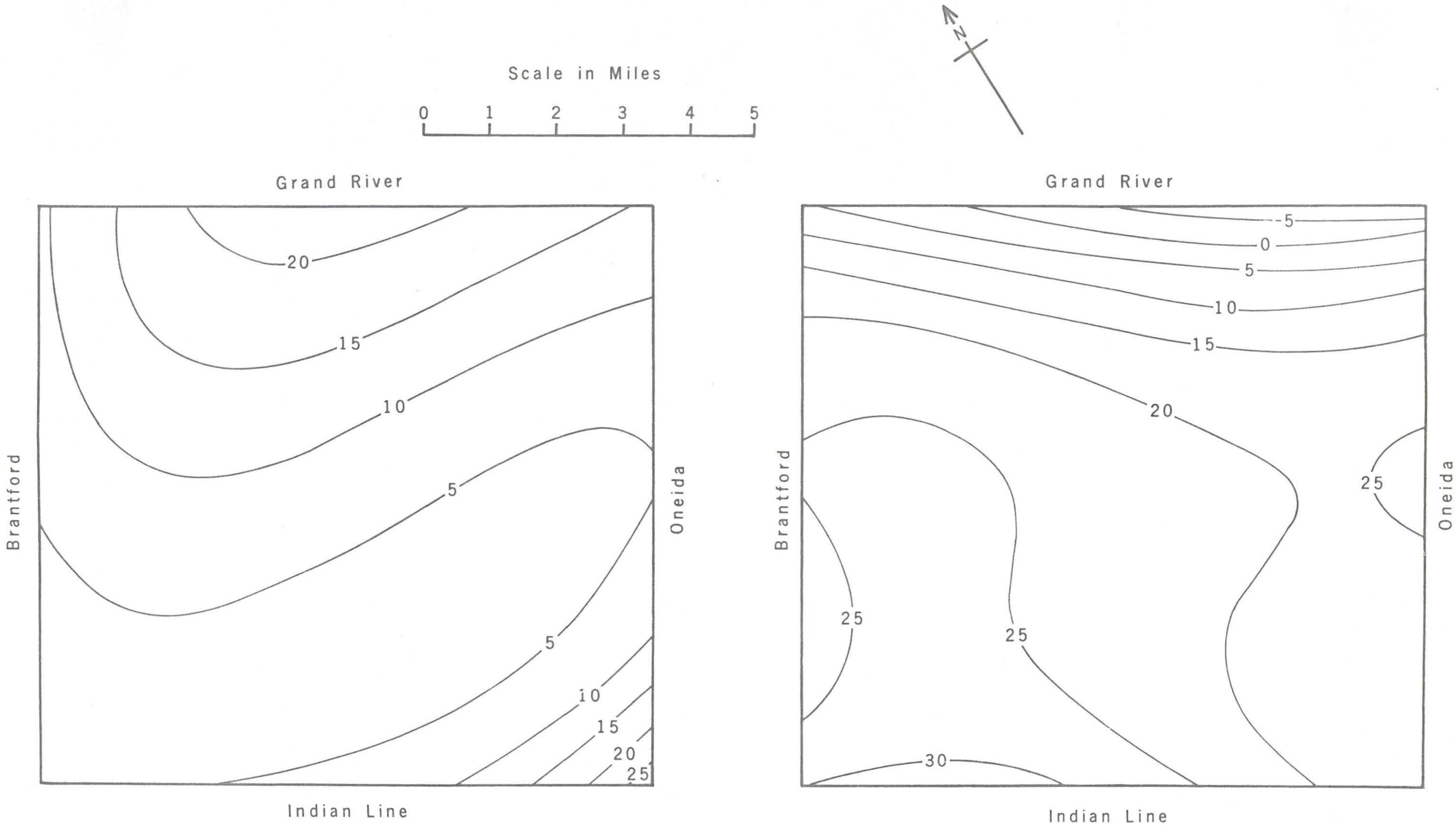
a

Quercus

b

TREND SURFACES

Fig. 8



Tilia

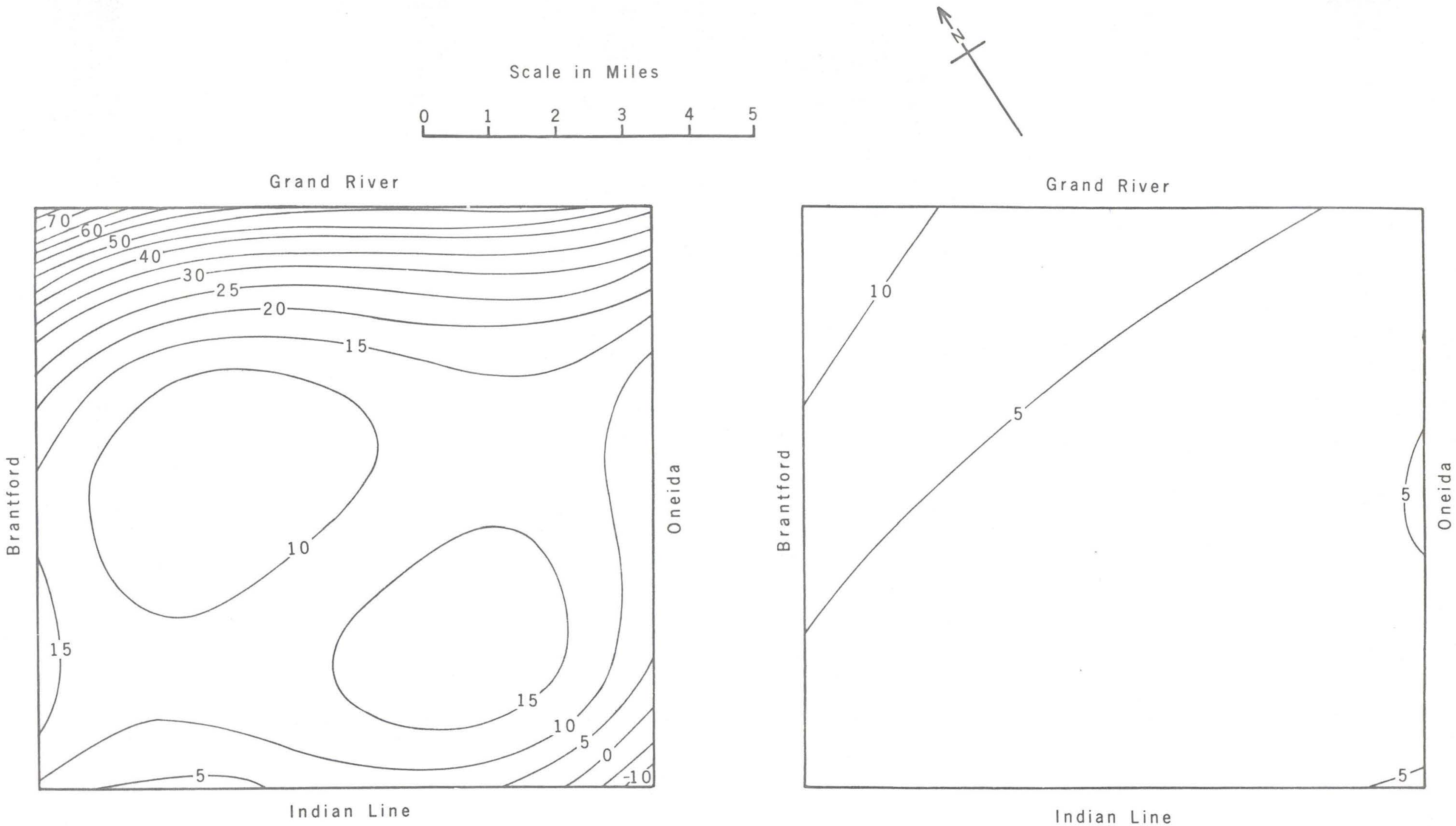
c

Fagus

d

TREND SURFACES

Fig. 8



Pinus

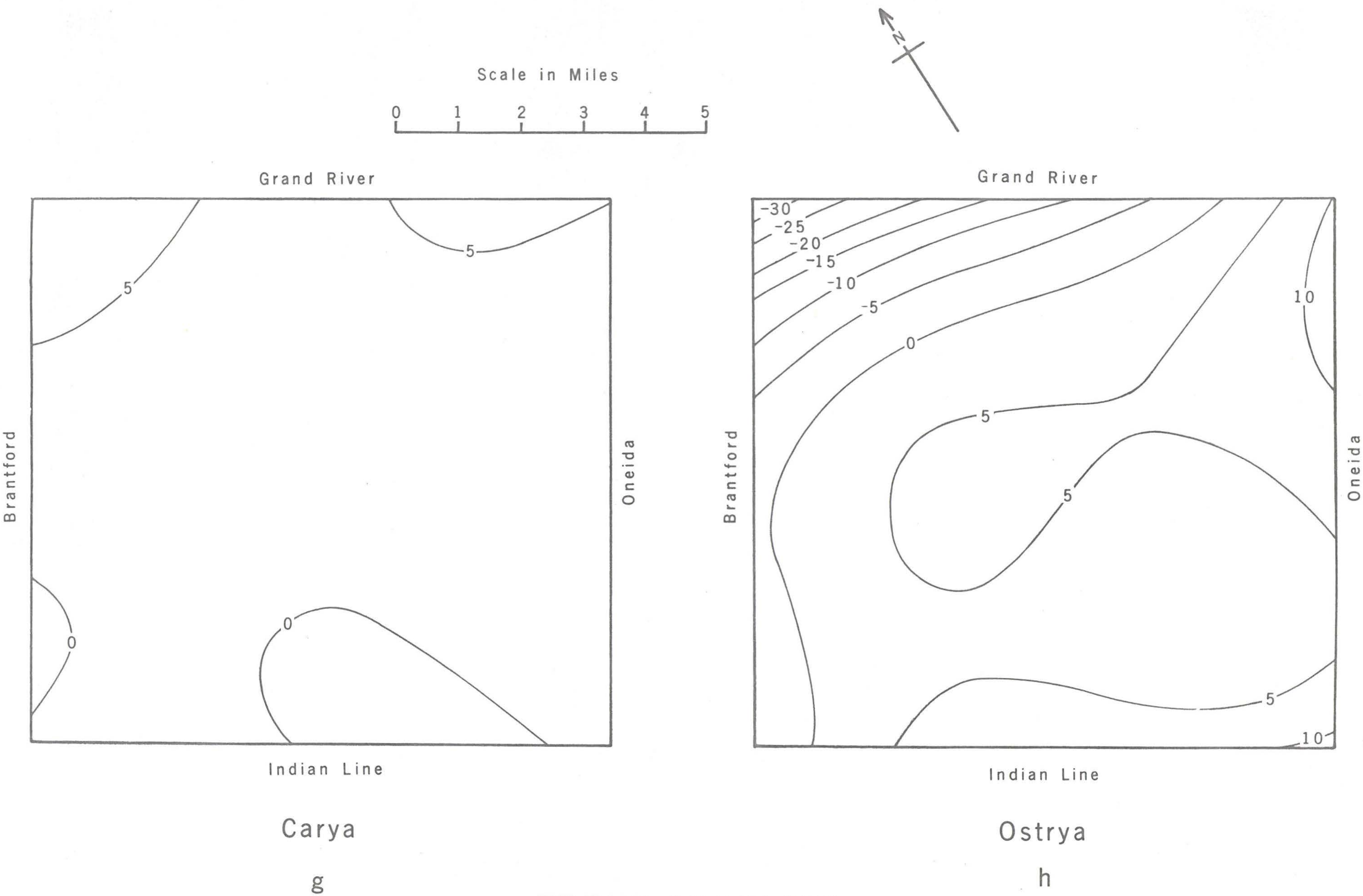
e

Ulmus

f

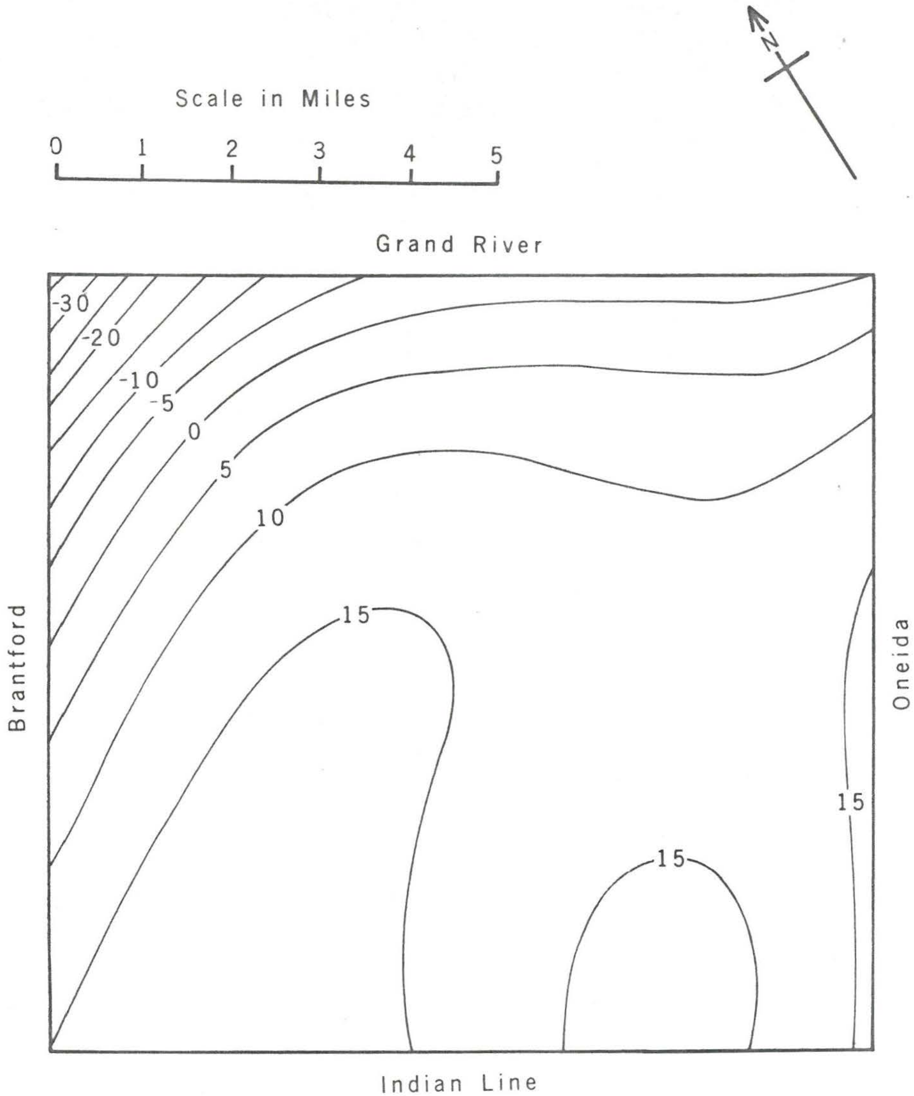
TREND SURFACES

Fig. 8



TRENDSURFACES

Fig. 8



Fraxinus Nigra

TREND SURFACE

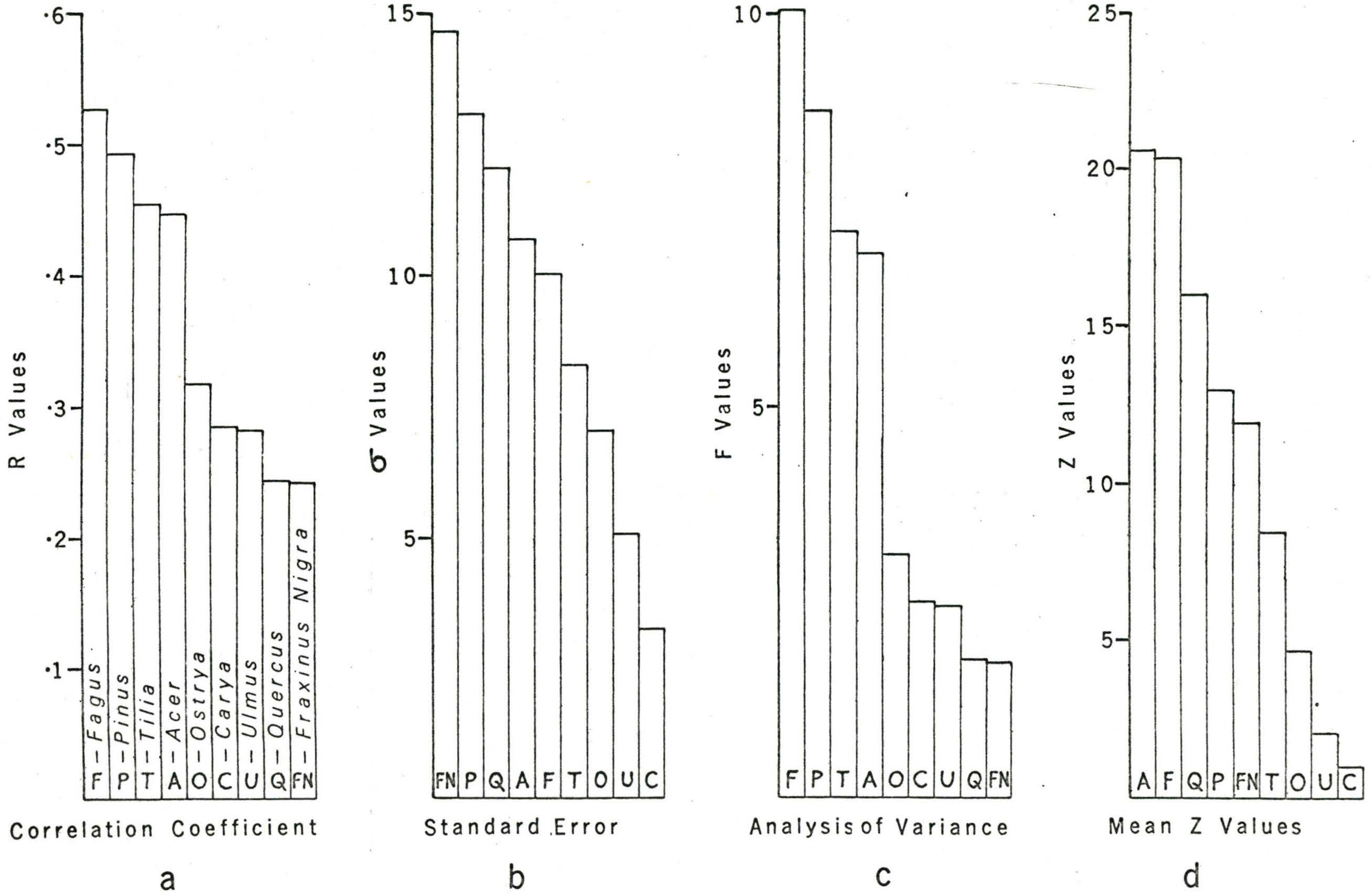
Fig. 8 i

the structural perimeters of their statistical framework are appreciated. The aim of this section therefore, is to determine for which genera, if any, do the surfaces most approximate reality. In so doing the type of data best suited to this technique will be exposed. The statistical parameters which will provide the most meaningful analysis in this context are:-

1. Correlation coefficients of the horizontal and vertical values
2. Standard Error of the linear plus quadratic plus cubic surfaces
3. Analysis of Variance of the linear plus quadratic plus cubic surfaces

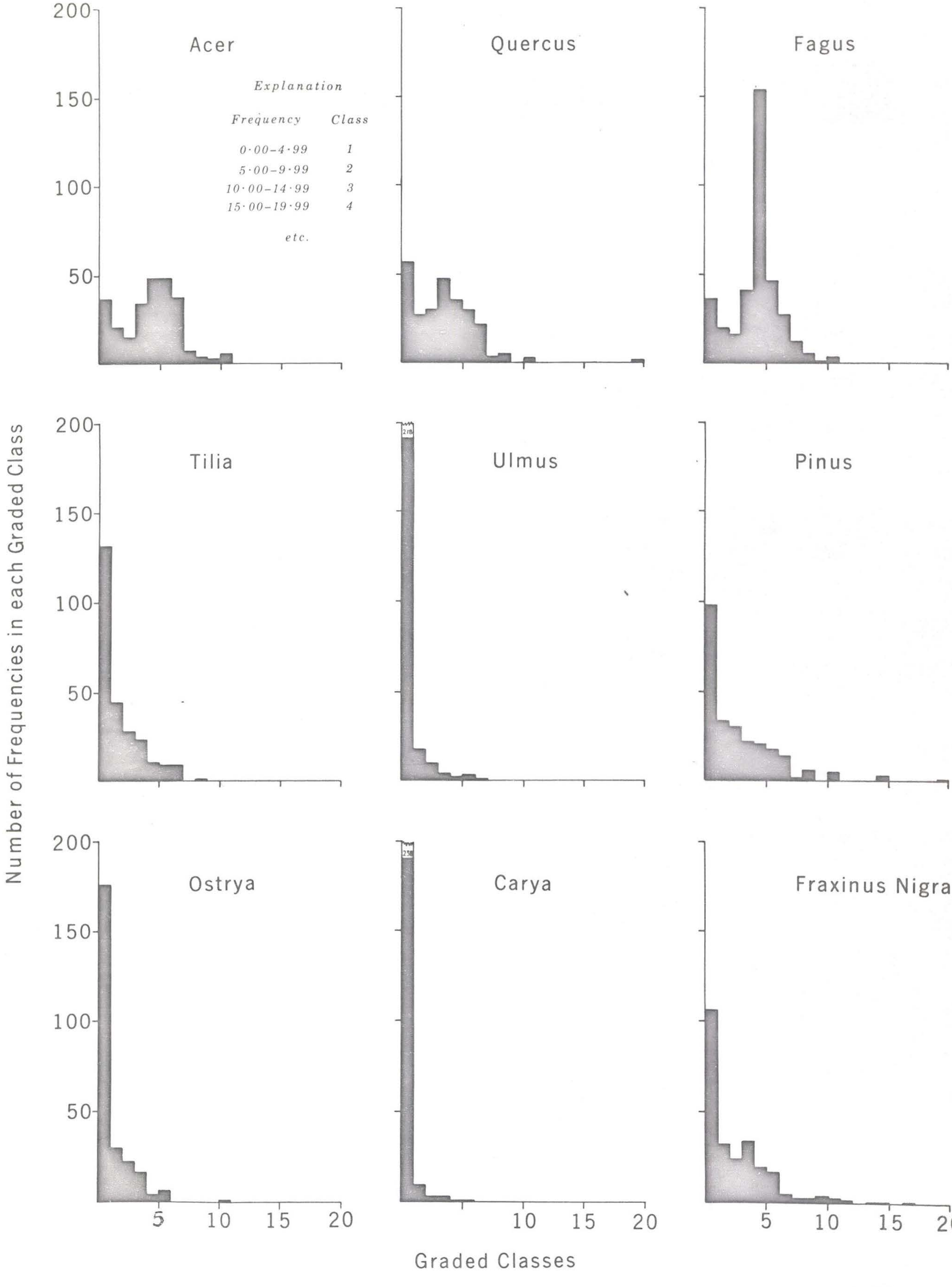
The relevant statistical parameter values have been illustrated in the form of bar graphs (Fig. 9) for ease of reference and to facilitate comparison within the genera. The results for each calculation are presented in order of magnitude from left to right.

1. Taking the <u>correlation coefficient</u> first, this is basically the measure of the goodness of fit of the least squares line to set of data which in this case consists of 3 variables - the z values, and the x and y co-ordinates. In effect it involves a comparison of the sum of squares of the vertical deviations from the least square line with the sum of the deviations of the z values from their mean. When there is a close fit (high correlation) the former values are much smaller than the latter and when there is low correlation the two sums of squares are almost the same (20). As seen from Figure 9a the highest values are those for fagus and pinus. It must be noted that these values do not denote a high degree of correlation in the absolute sense.



GRAPHS OF STATISTICAL PARAMETERS OBTAINED IN TREND SURFACE ANALYSIS

Fig. 9



FREQUENCY HISTOGRAMS

Fig. 10

However, it is upon the relative value that interest is centred. The high coefficient of fagus is probably attributable to the low degree of scatter of z values for as seen from the frequency histogram (Fig. 10 fagus) and the bar graphs of average z values (Fig. 9d) the mode and mean are almost coincident. The reason for the relatively high coefficient for pinus is more difficult to establish, however. Although there are high z values (several 100's occur) as well as zeros (approximately one-third of the observations) the variance is minimised owing to the tendency for the clumping in space of values of equal magnitude - as many as 9 consecutive zeros occur. The high values also usually occur in clusters. The lowest coefficient values belong to quercus and fraxinus nigra whose z values show a large fluctuation and no clumping.

The data most likely to produce high correlation coefficients are the ones not necessarily with a low range of z values but those with small fluctuations in consecutive values as in Fig. 11a compared with those in Fig. 11b.

Fig. 11a Hypothetical example of data array of z values likely to produce high correlation coefficients

8.87	9.36	2.90	4.80	0.00	0.00	0.00	7.00	9.50	8.59	z values
Lots 1	2	3	4	5	6	7	8	9	10	Concession 1

Fig. 11b Hypothetical example of data array of z values likely to produce low correlation coefficients

18.50	0.00	72.99	12.00	45.81	19.00	32.88	6.06	33.40	0.00	z values
Lots 1	2	3	4	5	6	7	8	9	10	Concession 1

2. Standard Errors of the surfaces

The purpose of the standard error of the estimate is to express the extent to which actual observations deviate from the generalisation of the surface or the degree of uncertainty inherent in the estimate surface. In short, it is the standard deviation of the residuals and may be expressed as:

$$\sqrt{\frac{\text{Sum of squares of the residuals}}{\text{number of items (z values)}}}$$

Since n = 257 for every genus, the controlling factor is the size of the standard deviations. As can be seen from the graphs of the statistical results (Fig. 9b) the highest values are those for F. nigra and pinus while ulmus and carya are at the other end of the scale. The genera with a number of very high residuals correspond to those with high standard errors, the highest residual of F. nigra being 83 and that of pinus, 66.

An example of the type of data array producing high residuals is:-

TABLE 5.

z values	Residuals of linear + quadratic + cubic surface
0.00	-19.15
72.99	53.67
12.00	-7.46
45.81	26.36
19.00	-0.32

As with the correlation coefficients, this results from the juxtaposition of high and low values.

The low Standard Error of the Ulmus and Carya surfaces (Fig. 9b) probably stems from the low number of positive z values - 60 and 26 respectively, out of a possible of 257, which will obviously result in a smaller variance. These low standard errors do not signify, therefore, that the surfaces calculated for these two genera approximate reality any more closely than do those of the other tree types.

3. Analysis of Variance

While the percentage variation provides a measure of the goodness of fit of the surfaces the F values calculated in the Analysis of Variance indicate the degree of significance of the surface (18). As can be seen from figure 9c none of the F values for the 9 surfaces are very high. It is unlikely, however, that the surfaces have been generated by chance.

There is one important drawback in analysing these F values too literally for the calculations upon which they are founded are based on the assumption that the original data (z values) is normally distributed. A cursory examination of the frequency histograms (Fig. 10) will show that the distribution curves all have a positive skew. Although they have to be treated with care when being used as estimates of the statistical significance of the surfaces, they provide information on the relative reliability of the surfaces. Fagus, pinus and tilia all have far greater values than ulmus, carya and F. nigra while acer, ostrya and carya occupy intermediate positions.

Ideally, trend surface analysis is most successful and easy of interpretation on data which is:-

i) normally distributed

ii) has a high correlation coefficient

iii) has a low standard error

iv) produces surfaces which are statistically significant

Obviously, this ideal situation is seldom reached. However, certain of the genera for which surfaces were produced, conform to this ideal, to a greater extent than others. Fagus, acer and tilia on Tuscarora are probably the most suited for this type of statistical technique. Pinus too, could be included except for its relatively high standard error. The data of the first three arboreal types has the following properties in common:-

a) Intermediate absolute ranges of z values

b) The mean and mode are more nearly coincident than for the other genera

c) They have intermediate residual ranges, since they do not have wide fluctuations in z values situated in close juxtaposition

d) The trend contour maps produced by these three types show definite patterns as compared with those produced by carya and ulmus (Figs. 8g and 8f) whose surfaces are almost on a uniform plane.

As an experimental test of the technique on survey record data, this analysis has been a success. The survey note data does not require a great deal of manipulation, for both z and x, y values are quite readily obtained. The area itself is conducive to trend surface analysis in that its limits are well defined, except in the north west sector near the Grand River where no observations of vegetation cover were abailable owing to clearing. Although the technique is valuable in producing smoothed surfaces from which local fluctuations have been removed, examination and interpretation of these 'local effects' or residuals could prove extremely useful and enlightening in the analysis of the vegetation.

2.4 Vegetation Reconstruction by means of 'Important' Tree Types

No vegetation analysis would be complete without an analysis of the relative importance of its individual components within an area. 'Importance' is used here in the broad sense of the word rather than the strict botanical meaning signifying the summation of the parameters of Relative Frequency, Relative Density and Relative Dominance. The Association analysis already outlined may, of course, be taken as a measure of importance of the relationship between the given tree types but it does not provide an impression of the relative status of the individual types. Trend surface analysis, too, gives an idea of the status of a single genus over the area but what is aimed at in this section is an assessment of the amount of coverage of all vegetation types on one map. It was thought that the best way of achieving this was to calculate for each lot an 'Importance Value' for each genus based on the formula used in the computation of z values for the trend surface analysis. (See page 35). This was:-

$$I = \frac{m}{l/q} \times 100$$

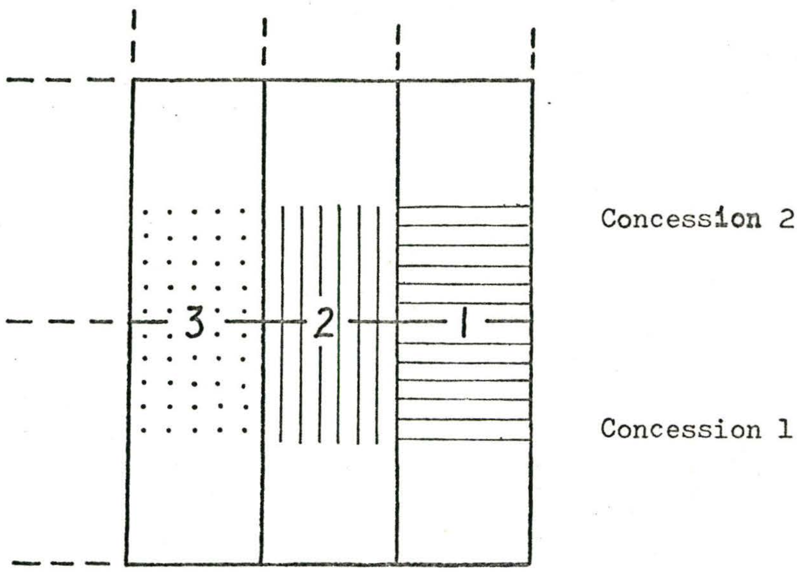
m = length of vegation cover in lot (as opposed to total length of lot, in which case clearings, creeks, ponds would be included)

l = length of vegetation assemblage in which genus x occurs

q = number of other genera in observations in which genus x occurs

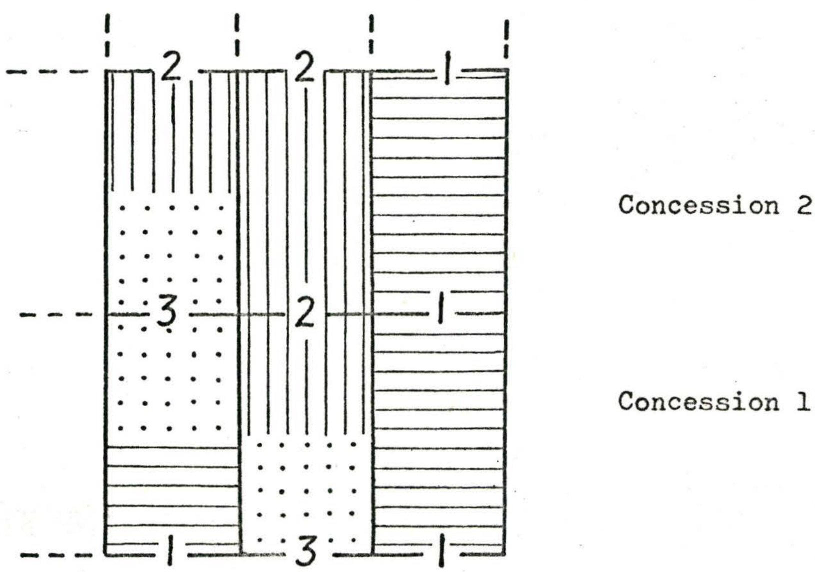
From a list of the percentage values produced from this formula the tree types of each lot whose combined values reached 50% or more were plotted onto a map along the appropriate lot line. This meant that any lot could contain several tree types. The stages involved in the actual compilation of the map are best described with the aid of diagrams. (Fig. 12)

Fig. 12a



As illustrated by the first diagram, the basic assumption in interpolation is that the tree types 1, 2, 3, encountered on the concession line extend equidistant into concessions 1 and 2.

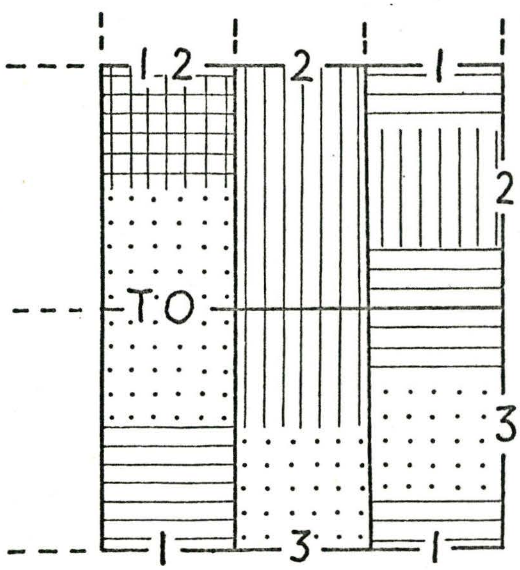
Fig. 12b



With the fundamental assumption in mind and presuming that the concession lines have been allocated the tree types denoted in diagram 12b, then the symbols will be distributed as above.

'Importance' values were also calculated for the north-south lines of the survey grid, i.e., every 7th line from the township line. This was the case in the first lots of the first and second concessions of the hypothetical example below:-

Fig. 12c



In lots 1 and 1a genus 3 and 2 respectively represented the genera with the highest values along the lot boundary (N-S line). Therefore the horizontal lines denoting genus 1 are reduced to extend only 25% of the concession length on either side of the concession line so as to allow the symbols representing genera 2 and 3 to be extended across the lot.

Only six tree types - acer, fagus, quercus, pinus, fraximus nigra and larix laricina are represented by 'spatial' symbols. When the remaining types constitute an 'important' component of the forest cover they are represented by an appropriate letter symbol as in the concession line between lots 3 and 3a. The letters are not extended into the concessions as they would tend to obscure the other symbols. When two genera are allocated to one lot, the cartographic effect is observed in lot 3a where the symbols denoting genera 1 and 2 are superimposed to form a grid pattern.

As far as possible, symbols were standardised with those of the Association Map. (Fig. 15)

IMPORTANCE

METHOD a

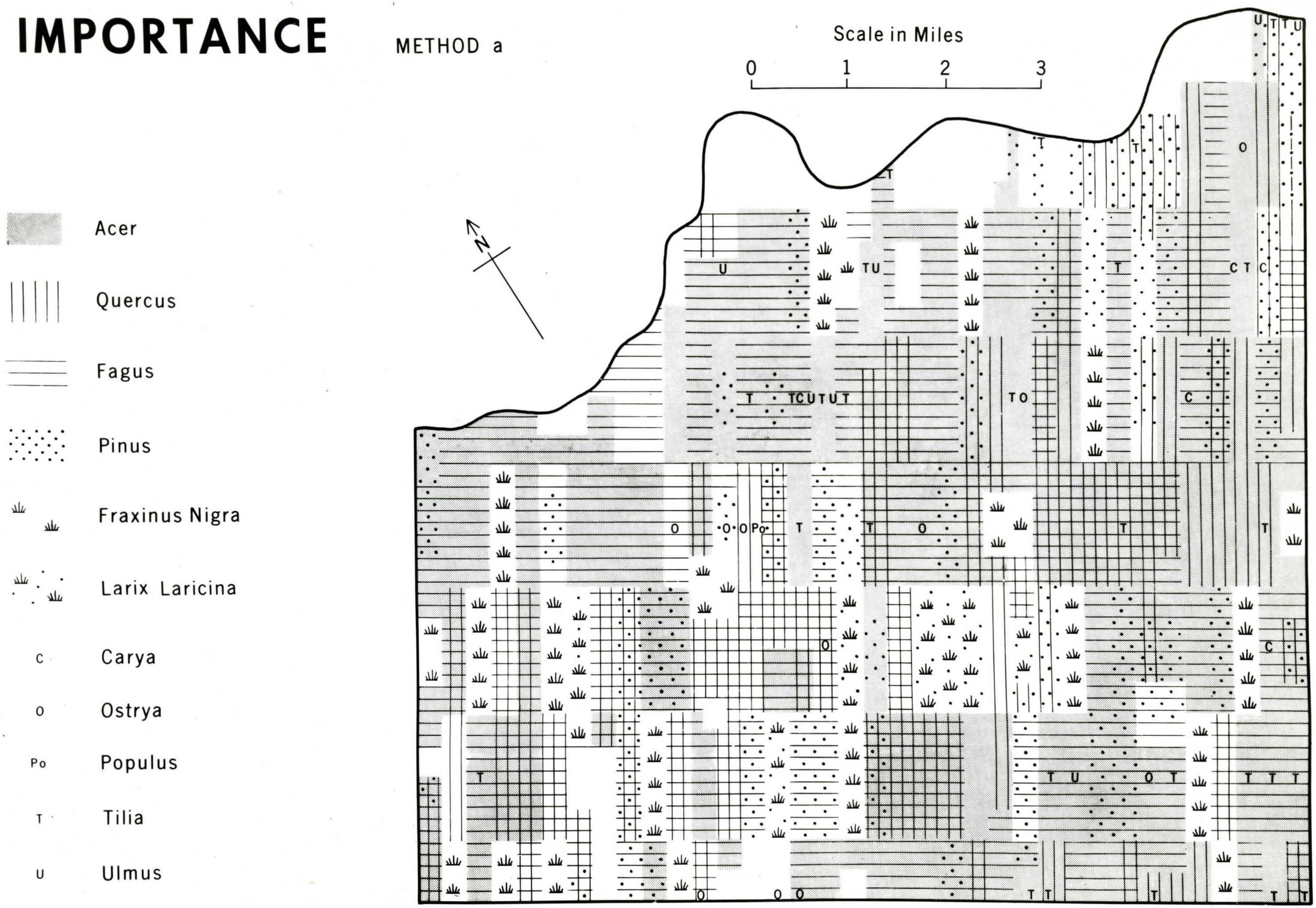


Fig. 13a

2.5 Method b.

The 'Importance' parameter data can also be expressed in the form of divided circles. This operation has the following stages:-

1. The average importance value of each tree type is calculated for every six lots (section).
2. Using these mean values, the circle is divided into segments for each genus, the size of the segment being proportionate to the average of the 'Importance' value.
3. The size of each circle, in turn, is dependent upon the amount of vegetation cover of the section. Thus, any section in which there are no clearings, rivers and ponds will have a circle of 1" diameter. Where approximately 75% of the section line is occupied by forest cover, then the diameter of circle is 3/4".
4. Each circle, thus constructed, is placed along the appropriate concession or lot line from which the calculations were derived.

The Sample result is seen on page 53 (Fig. 13b).

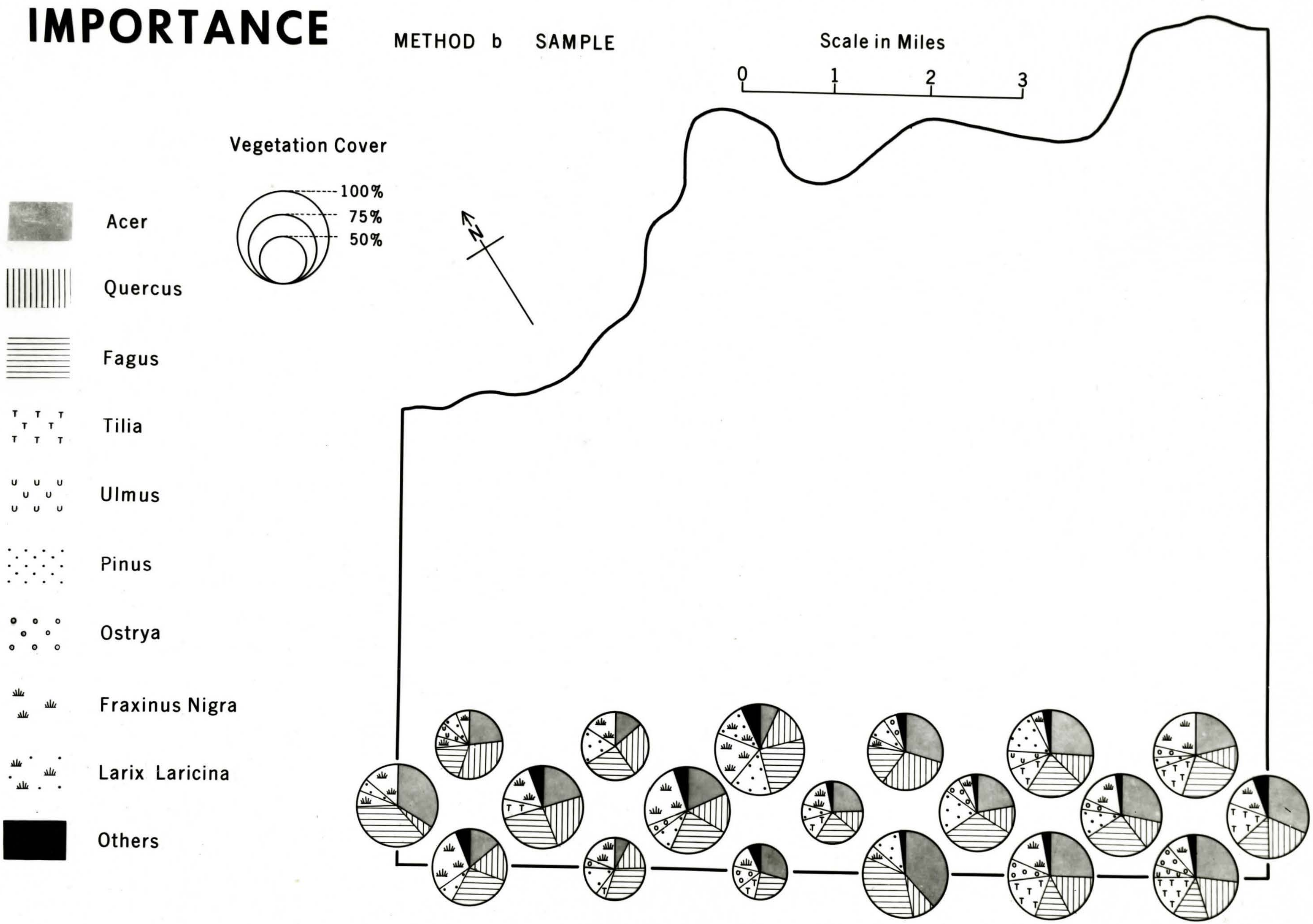

IMPORTANCE
METHOD b SAMPLE
Scale in Miles
0 1 2 3
Vegetation Cover
100%
75%
50%
N
Acer
Quercus
Fagus
Tilia
Ulmus
Pinus
Ostrya
Fraxinus Nigra
Larix Laricina
Others

Fig. 13b

2.6 Reconstruction by means of Association Analysis

In order to extract as much information as possible relative to the characteristics of the vegetation of Tuscarora in 1842 and to present it in a form suitable for mapping, the investigator is always seeking methods of summarising the data. As has been shown, trend surface analysis and both 'Importance' methods fulfill this requirement to some degree. In view of the restricted nature of the survey data, the classification of tree types into associations was thought to be another useful method of grouping. When the members of a plant community show a non-random distribution, as they do in Tuscarora, study of association between the members of that community might provide evidence of any grouping of the members into assemblages of like response to certain influencing factors such as soil moisture content or soil depth (21).

METHODS

First, the term 'association' as used here may be defined as: the number of co-occurrences of two genera in excess of that expected by random distribution. Reconstruction of the vegetation of the township in terms of mappable 'associations' must be approached in two steps:-

1. The genus content of the associations must first be established.
2. Once established they must be mapped in terms of their areal distribution.

Briefly these steps are carried out by:-

a) Assessing the degree of associations between the genera themselves by the use of 'association indices'.

b) Intercorrelating of the indices of association to form groups by the technique of cluster analysis.

c) Establishing the distribution of the associations within the township.

Each of the above steps a, b and c will be elaborated upon but first it must be mentioned that all of the following calculations are based on the original data deck of 1,553 I.B.M. cards, the compilation of which has already been described and which also formed the raw data for the trend surface analysis.

Methods of establishing the degree of association between tree types

In view of the restricted nature of the data - only nominal level of measurement and also the size of the data deck - methods of assessing degree of affinity are limited to the simpler types of computation. In other words, the normal types of correlation coefficient such as Pearson's Product Moment or Kendall's coefficient cannot be used. The suggested computations, then, are simply based on co-occurrences of the two genera being correlated but this is best understood if a contingency table is constructed upon which all the calculations used are founded. (22)

TABLE 6. Contingency Table for calculation of similarity coefficients

		Genus (k) Present	Absent	Totals
Genus (j)	Present	Njk	Njj-Njk	Njj
	Absent	Nkk-Njj	N-Njj-Nkk+Njk	N-Njj
	Totals	Nkk	N-Nkk	N

N = total number of surveyor's observations, i.e., no. of data cards

jj = number of occurrences of genus j only without genus k

kk = number of occurrences of genus k only without genus j

jk = number of co-occurrences of genus j and genus k

By subtraction:-

Njj - Njk = number of occurrences containing genus j without k

Nkk - Njk = number of occurrences containing genus k without j

N - Njj - Nkk + Njk = number of occurrences containing neither genus j nor genus k

To simplify the procedure the following notations were substituted for the above:

$$a = Njk$$

$$b = Njj - Njk$$

$$c = Nkk - Njk$$

$$d = N - Njj - Nkk + Njk$$

$$a + b + c + a = N$$

Numerous 'association indices' have been devised in the past 40 years, varying largely in the combination of parameters used in the numerator and denominator[1]. It seemed necessary to examine only a few of these to show how they may be used with survey note data as their basis. Therefore, only a cross-section will actually be calculated.

---

[1]Others include: 'Fourfold Point Correlation Coefficient' (Nash 1950); Cole (1949 and 1957) 'Coefficient of Interspecific Association', coefficients of Russell and Rao (1940); Yule and Kendall (1953).

The following formulae were calculated:

1. Dices' 'Association Index' (1945)

$$\rho = \frac{a}{b} \quad \text{or} \quad \frac{a}{c}$$

This formula produces a non-symmetrical matrix and is the only one out of the four presented here that does so. Correlation value ranges from zero to one.

2. Dices' 'Coincidence Index'

A symmetrical matrix is produced by this formula. Correlation value ranges from zero to one.

Values of one are obtained when b = c.

$$\rho = \frac{2a}{b + c}$$

The matrix produced by this formula provided the basis for the cluster analysis computations (page since it is symmetrical and its values fall between the conventional range of zero and one.

3. Sneath's simple matching coefficient (23) or Whittaker and Fairbanks' Percentage Occurrence (1958)

$$\rho = \frac{a}{b + c - a}$$

A symmetrical matrix is the outcome. Correlation value ranges from zero to one. Values of 1 are obtained when b = c.

4. Williams' and Lambert's coefficient (1959)

$$\rho = \frac{N(ad - bc)^2}{(a+b)(a+c)(b+d)(c+a)}$$

A symmetrical matrix is produced. Correlation values have no limit. The resulting indices are directly controlled by N. This is identical to X^2.

As they stand, these formulae provide the measure of the degree of association between two genera only, whereas 122 values are actually required, i.e., one value for every combination of the 11 genera found in Tuscarora. The format of the computer program was therefore designed to arrange the output in the form of an I x K matrix whose rows and columns both represent trees.

It must be pointed out here that the proposed formulae may be based on two types of data:-

a) data merely based on occurrence or non-occurrence (presence and absence) of a genus in an observed vegetation assemblage. For purposes of clarity this was termed '<u>point data</u>'

b) data which takes into account variations in the length of occurrence of a genus in the observed vegetation assemblages - '<u>weighted data</u>'

It is arguable that more value should be assigned to an occurrence occupying 9 chains, for instance, compared with one merely occupying 2 chains. However, it is not necessarily true to assume that genera occurring together over a short distance have a lower degree of association than those occurring together over longer distances. One disadvantage of using 'weighted' data and therefore heterogenous sized 'samples' is that if the sample (surveyor's observation) is a long one, 8 or 9 chains for example, almost all the genera may occur in it, so that establishing any differences in association on this basis may be invalid. Over a small distance however, fewer genera will be recorded so that a more realistic view of trees closely associated with each other may be obtained. In order to compare the two types of data, calculations were carried out, first using 'point' data based on number of occurrences and then by 'weighted' data - length of occurrence. The results are shown in Tables 1 and 2 of the Appendix.

In this particular survey use could be made of the trees used by Walker as identification posts, to gain some indication of association between types. The surveyor invariably records two or three trees to mark the position of the lot corners which should, therefore, theoretically be located in close proximity to one another. However, after calculating Frequency values of trees used as identification positions (Table 7) and comparing it with Frequency values calculated for the whole township, using both 'Point' and 'Weighted' data (Tables 1 and 2 - Appendix respectively) it was decided that witness trees could not be used on the grounds that they did not constitute a representative sample of the vegetation. Reasons for this will be suggested in Part III, page 101.

TABLE 7. Relative Frequency Values of trees used as Identification Posts

Tree Type	%
Fagus	33.26
Acer	27.95
Ostrya	22.24
Pinus	11.20
Fraxinus Nigra	9.18
Tilia	7.55
Quercus	6.50
Ulmus	5.90
Fraxinus Americana	5.80
Carpinus	4.08
Carya	3.06
Populus	1.42
Betula	1.40
Prunus	0.61
Salix	0.41
Juglans	0.41
Cornus	0.20

Results of Association Analysis - Degree of Association between generic groups, established by the Association Indices.

So as to gain an impression of the relative abundance of each tree, a list of total occurrences of each genus was printed out. This information also facilitates interpretation of the association indices since the parameters b and c are directly dependent upon it. On the whole, there are few divergences between abundance values obtained from mere occurrence (point) data and those based on length of occurrence. Acer and fagus, as expected, dominate the scene on an equal basis followed by quercus and pinus. Tamarack (larix laricina) occurs very occasionally which is to be expected since it is here in the southernmost extent of its range and so is confined chiefly to bog and swamp areas. The only major difference between abundance results pertaining to point and weighted data is that fraxinus nigra which occupied 7th position in order of prevalency using weighted data moves up to 5th position after pinus in the 'point' data results. This is probably due to the dissected nature of the terrain of the township. Many survey runs intersect the drainage channels at right angles resulting in a series of alternating depressions and ridges, the former occupied by black ash swamp. In this way the abundance of black ash is possibly over-emphasised by the point method of data analysis.

As regards the results of the various association indices, there are obviously divergences both between each index type and between the two types of data. However, certain general trends may be extrapolated. Each genus will be considered separately:-

i) Acer shows a high degree of association with the majority of the other genera, mainly because of its abundance, but its affinity to fagus is especially noticeable. In some indices, the co-efficient of similarity between the two trees is twice as great as the next coefficient in order of magnitude. Acer also appears to be highly associated with quercus and to a certain extent with tilia.

ii) There is no one genus which shows an outstanding degree of affinity to quercus but fagus, acer and to a lesser extent, pinus show high similarity coefficients in most of the matrices. Pinus is most closely associated with quercus the so-called 'oak - plains' which occur in the north-west of Tuscarora. The cause of these areas of grassland vegetation dotted with quercus and pinus, amongst the 'climax' deciduous forest of this region is under debate. Some maintain that they are prairie relics, edaphically controlled (24) while others argue that they are attributable to Indian clearing in the past (25).

iii) Fagus, like acer, shows a relatively high degree of association with most of the other tree types, excluding the swamp vegetation, viz black ash and tamarack. It is most closely associated with acer and quercus.

iv) Tilia shows most affinity with fagus and acer.

v) Ulmus has a low overall degree of affinity with all genera. In every matrix it is associated persistently with tilia and acer and compared with the other tree types has some association with black ash. This may be explained by the fact that ulmus can tolerate the moister soils.

vi) Fagus, quercus and to a lesser extent acer, would appear to be most closely associated with pinus. It is, perhaps, one of the most gregarious of tree types.

vii) Ostrya is a very shade-tolerant species and it may be largely for this reason that it shows affinity to such genera as quercus, acer and tilia.

viii) Carya, one of the less common types shows a more or less uniform pattern of low indices of similarity, but ulmus and tilia show the highest degree of association with it.

ix) Populus shows a definite affinity to pinus. This association with pinus may be explained by the fact that both genera are tolerant of sandy soils. They also seem to occur together frequently as secondary growth in the windfall areas. Populus, owing to its ability to reproduce vegetatively, is usually one of the first trees to recolonise an area (16).

x) Fraxinus nigra)
)
xi) Larix Laricina) Both types, particularly larix laricina were confined to swamp lands of which most other trees are intolerant. According to the survey notes, under conditions of poor drainage they appear to form pure stands. It may be that the surveyor ignored any other species, such as salix spp. and betula spp. and included them in the fraxinus nigra or larix laricina swamp community.

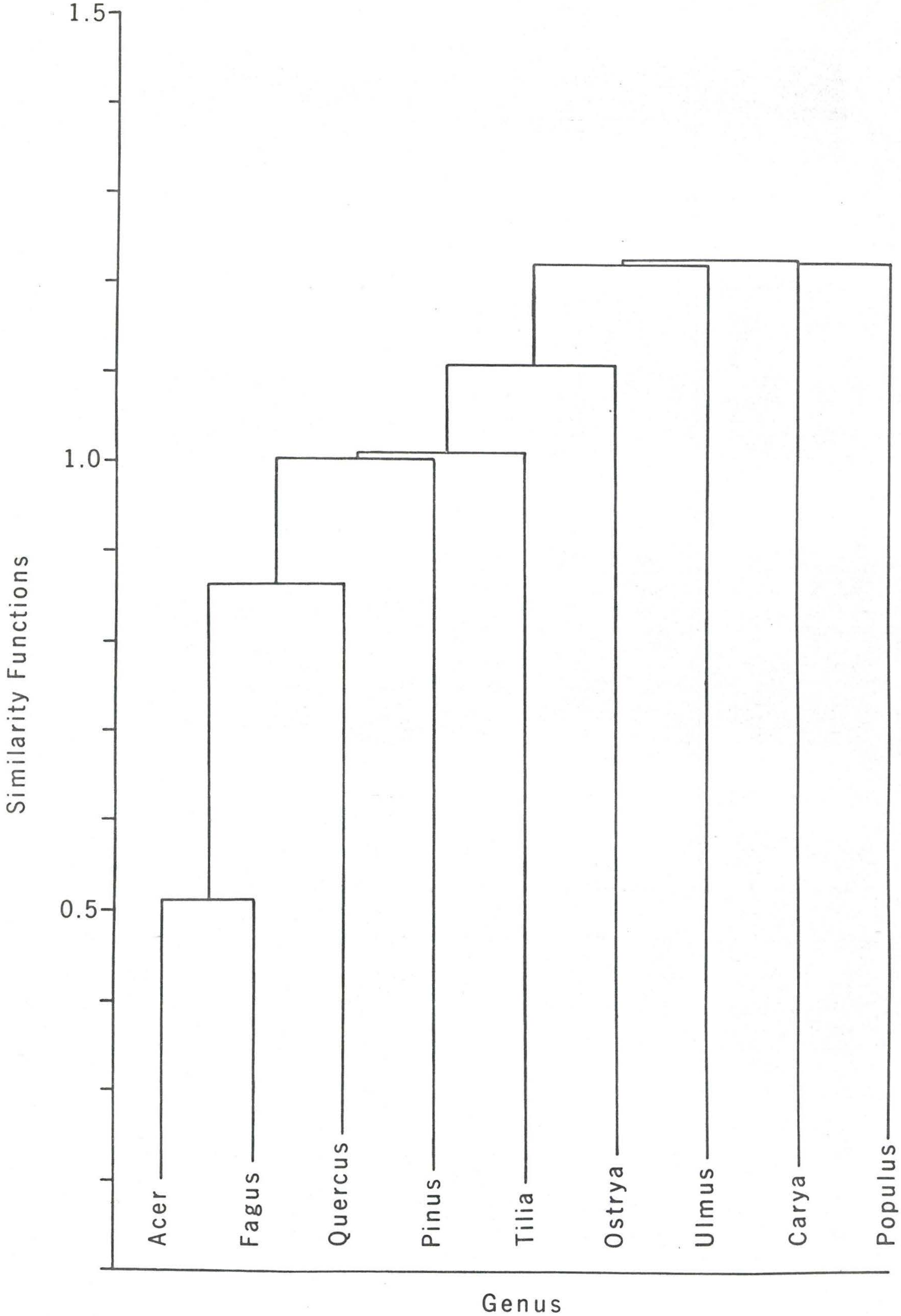
Establishing the main associations.

The next step in establishing vegetation associations found in Tuscarora is the use of some device which groups the associated pairs of tree types, established by the various similarity coefficients, into fewer composite groups. The first method attempted - cluster analysis - is of a statistical nature. A cluster is defined as a group of inter-correlated variables (association indices of the genera) such that the level of correlation between all possible pairs of variables which are members of the group is greater than or equal to some arbitratily selected level of correlation (19). A hierarchy of interrelationships of tree types computed from linkages - correlation values satisfying an arbitrary level of correlation - between all the pairs of variables is thus developed. Several methods of cluster analysis are available, the technicalities of which will be omitted suffice to say that they vary according to the criteria for the admission of an individual into a cluster.

The first variation of cluster analysis attempted was Tyrone's modification of Holzinger and Harmans' B coefficient (26), a variation of the complete linkage method of cluster grouping. This technique requires that a given variable joining a cluster at a certain level of similarity, must have relations at that level or above with every member of the cluster. Thus, single bonds with just one member of the cluster would not be sufficient to effect the juncture. It is for this reason that the Tuscarora data failed to produce clusters of interlinked tree types, for some of the less abundant genera were completely unrelated to other tree types; that is, they seldom or never occurred in the same observation with certain tree types. Clustering by average linkage which bases the admission of any individual into a cluster on the average of the similarities of that individual with the members of the cluster, was also attempted (27). The results of this method are expressed in diagrammatic form in the dendrogram (Fig. 14) showing the inter-relationships of 9 genera only. Black ash and tamarack communities were not accepted into this cluster since values of their similarity functions were both zero. Although this method was theoretically successful, it could not be applied for defining associations.

Consequent on the failure of Cluster Analysis to produce successful association groups in terms of suitability for mapping, another, less quantitative method was devised, based on the presence of either hardwoods or conifers or a combination of both types in any one area. The results may be summarised as follows:-

1. <u>HARDWOOD ASSOCIATIONS</u>
   - a) 'Major' hardwoods
   - b) 'Mixed' hardwoods
   - c) Swamp hardwoods
2. <u>HARDWOOD - CONIFER ASSOCIATIONS</u>
   - a) 'Major' hardwood - conifer
   - b) 'Mixed' hardwood - conifer
3. <u>CONIFER - HARDWOOD ASSOCIATIONS</u>
   - a) Conifer - 'Major' hardwoods
   - b) Conifer - 'Mixed' hardwoods
4. <u>CONIFER ASSOCIATIONS</u>
   - a) Conifers
   - b) Coniferous swamp



DENDROGRAM OF RELATIONSHIPS AMONG NINE GENERA

Fig. 14

1. Hardwood Associations.

Examination of the various similarity coefficients showed the only 'high' correlation values between genera were those expressing the relationships between acer, fagus and quercus. The other 5 hardwood genera mentioned by the surveyor: tilia, ostrya, carya, ulmus and populus were neither correlated highly within the 3 members of the first group, nor with themselves. Thus, according to the survey note data there are no distinct separate hardwood associations such as quercus - carya (oak - hickory), apart from the predominant and easily recognisable acer, fagus - guercus association. Yet the presence of the other five hardwoods cannot be ignored. Some, particularly tilia and ostrya have significant degrees of affinity with one or other of the acer - fagus - quercus group. On the basis of these two subdivisions were devised. The term '<u>major</u>' was applied to the trees - acer, fagus, quercus since they were undoubtedly the most abundant hardwoods in the township. The term 'dominant' could not be used with validity as it was not possible to prove statistically that these trees were dominant in the ecological sense. The less abundant - tilia, ulmus, ostrya, populus and carya were named '<u>minor</u>' tree types. On this differentiation any lot in which acer, quercus, fagus occurred for over 50% of the total chainage of the vegetation cover, either individually or in any combination, was assigned the term 'Major Hardwoods' (class 1A). When any one of the 5 'minor' genera co-occurred in the same observation with any combination of the so-called 'major hardwoods', for more than 50% of the total lot chainage, this grouping was classified 'mixed' hardwood association (class 1B). The third subdivision, swamp hardwood, is applied to the distinctive black-ash swamp community. The surveyor himself, appears to consider this type as an association in its own right. The distinction between the three classes will be clarified if the examples below are examined.

TABLE 8a

<u>Actual examples of association allocation to lots</u>

1A - 'Major' hardwood association Concession 1 Lot 35

+ Denotes Presence

Chns.	Acer	Querc.	Fagus	Tilia	Ulmus	Pinus	Ost.	Carya	Pop.	Swamp Frax. Nigra	Swamp Larix Laric.
4.40										+	
3.30	+	+	+								
4.30	+	+	+								
2.90	+	+	+								
1.20										+	
3.90	+		+								

TABLE 8b

1B - 'Mixed' hardwood association Concession 1 Lot 5

Chns.	Acer	Querc.	Fagus	Tilia	Ulmus	Pinus	Ost.	Carya	Pop.	Swamp Frax. Nigra	Swamp Larix Laric.
1.40	+	+									
1.40											
2.80										+	
1.80	+	+									
1.00	+	+		+			+				
10.00	+	+		+			+				

TABLE 8c

1C - Swamp hardwood association   Concession 1   Lot 31

Chns.	Acer	Querc.	Fagus	Tilia	Ulmus	Pinus	Ost.	Carya	Pop.	Frax. Nigra	Swamp Larix Laric.
2.50										+	
7.50										+	
3.80		Cleared									
3.70		+	+								
1.00										+	
1.30		+	+								

2. Hardwood Conifer Associations.

Apart from tamarack (larix laricina), pine (pinus shobus) is the only other conifer mentioned by the surveyor for the township, in 1842. When the hardwoods constitute 50% or more of the lot chainage but pinus occurring with them for a significant length, the vegetation of the lot is categorised as 'Two'. Allocation of a lot into the (A) and (B) divisions of this class is dependent upon the type of hardwood grouping. If it is mainly, acer, fagus, quercus then it is assigned to the 'major hardwood-conifer' class (sA). On the other hand, it falls into category (2B) when any or a combination of the so-called minor tree genera are present in every observation. (Table 8c)

TABLE 8d

Examples of Association Allocation

2A - 'Major' hardwood-conifer association   Concession 1   Lot 27

Chns.	Acer	Querc.	Fagus	Tilia	Ulmus	Pinus	Ost.	Carya	Pop.	Frax. Nigra	Larix Laric.
7.00	+		+			+					
7.55	+	+	+			+					
0.50	Pond										
2.30	+	+	+								
2.30										+	

TABLE 8e

2B - 'Mixed' hardwood-conifer association Concession 2 Lot 10

Chns.	Acer	Querc.	Fagus	Tilia	Ulmus	Pinus	Ost.	Carya	Pop.	Frax. Nigra	Larix Laric.
6.00	+		+		+						
5.00	+		+		+	+					
4.00	+		+	+	+	+					
5.00	+	+	+	+	+	+					

3. <u>Conifer-Hardwood Associations.</u>

The difference between categories 2 and 3 is that the latter is assigned to lots in which conifers predominate over hardwoods in the overall vegetation cover. In other words pinus still co-occurring with hardwoods must occupy 50% or more of the lot's forest cover. As in the preceding classes, allocation of vegetation into sub-divisions (A) and (B) depends on the type of hardwoods with which pinus is associated.

TABLE 8f

<u>Examples of Association Allocation</u>

3A - Conifer - 'Major' Hardwood Concession 4 Lot 19

Chns.	Acer	Querc.	Fagus	Tilia	Ulmus	Pinus	Ost.	Carya	Pop.	Frax. Nigra	Larix Laric.
1.00	McKenzie Creek										
2.05	Low Flats										
3.25	Cleared										
4.50											
6.00	+		+			Dominant +					
6.00						+					

TABLE 8g

3B - Conifer - 'mixed' hardwood Concession 5 Lot 2

Chns.	Acer	Querc.	Fagus	Tilia	Ulmus	Pinus	Ost.	Carya	Pop.	Frax. Nigra	Larix Laric.
9.00		+				+					
6.00						+	+				
5.00						Dominant +	+				

4. <u>Conifer Associations.</u>

In a few areas it may safely be assumed that pine is found in pure stands since the surveyor refers to it alone in a lot and mentions no other genera. In this case it belongs to category 4A. Sub-division 4B refers to the tamarack swamp association which, like the black ash community, the surveyor considers as a distinct entity.

TABLE 8h

<u>Examples of Association Allocation</u>

4A - Conifer association Concession Broken Front Lot 5

Chns.	Acer	Querc.	Fagus	Tilia	Ulmus	Pinus	Ost.	Carya	Pop.	Frax. Nigra	Larix Laric.
0.50											+
4.50											+
6.80		+				+					
5.90											+
2.30		+	+			+					

It must be stressed that although the similarity coefficients, expressing the degree of association, were not directly used in this particular classification of tree types into associations, as they would have been, had the cluster analysis technique been successful, they were by no means superfluous. They provided a firm foundation upon which ideas and assumptions arrived at in this classification could be based.

Admittedly, this method is more subjective than the others proposed but there is no reason why other investigators could not apply it to the survey records of their study area.

Mapping Associations

Lots in which vegetation occurred were allocated the appropriate association class. The compilation of this map (Fig. 15) was based on the same principles as those of the Importance Map (Fig. 13), therefore they will not be repeated. It is sufficient to note that only one class was assigned to each lot so that there was no superimposition of symbols as in the 'Importance' map.

The symbols of the Association map were designed so as to differentiate readily between the two broad classes of vegetation:

i) associations dominated by hardwood types

ii) associations dominated by conifers

Varying thicknesses of horizontal and vertical lines are used to represent the former while conifer dominated associations are designated by dots which vary in size according to the 'strength' of occurrence of the conifer type.

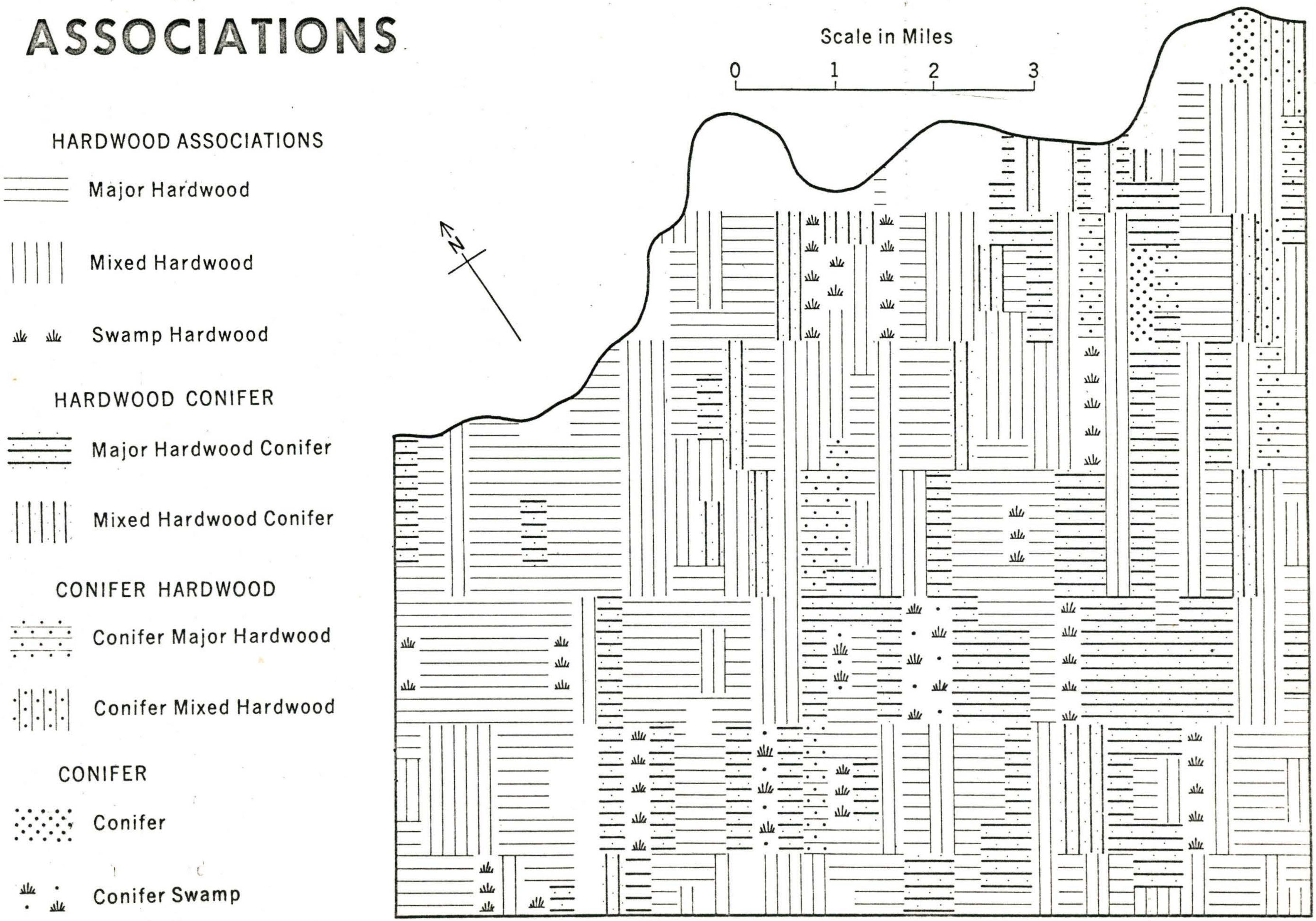

ASSOCIATIONS
HARDWOOD ASSOCIATIONS
Major Hardwood
Mixed Hardwood
Swamp Hardwood
HARDWOOD CONIFER
Major Hardwood Conifer
Mixed Hardwood Conifer
CONIFER HARDWOOD
Conifer Major Hardwood
Conifer Mixed Hardwood
CONIFER
Conifer
Conifer Swamp
N
Scale in Miles
0
1
2
3

Fig. 15

2.6 EVALUATION OF MAPS

Results

As far as the aerial representation of vegetation distribution is concerned the maps have the following common characteristics:-

1. All, except for the trend surface maps in which clearings were not considered, show a tendency for clearings to be located on the margins of the township, particularly in the north along the Grand River and in the south west.
2. The widespread occurrence of acer, fagus and quercus is immediately apparent throughout Tuscarora.
3. Pinus tends to be clustered in certain areas, noteably the north-east sector of Tuscarora, near the Grand River.
4. Species such as tilia americana and ostrya virginiana show a scattered distribution pattern but nowhere do they obtain the ecological status of the acer, fagus, quercus combination.
5. The general dispersion of swamp vegetation throughout the area is evident but the more extensive swamps appear to be located in the south centre of the township.

Explanations of these patterns will be suggested in Part III.

Comparative assessment of mapping methods

The trend surfaces complicate comparison with other methods of aerial representation since they are statistically compiled. However, this very property provides them with certain advantages, the most important of which is that they provide a satisfactory solution to the difficult problem of interpolation of vegetation between the survey grid. Another advantage in this context is that values can be predicted in the areas of data absence, i.e., the cleared Broken Front lots, from the data available in adjacent areas. This method is useful also, in that it allows an assessment of the ecological standing of a single tree type within the area. They may be used to identify 'trends' in genus or species distribution at any scale of area and with certain modifications of the basic data manipulation procedure, surfaces could be produced to assess the importance of various vegetation associations in an area. The major limitation of trend surface analysis in the township in question, is that its success is dependent upon the amount and properties of the data so that some genera produce neither a valid nor significant surface.

A major criticism of both the '<u>Importance</u>' and '<u>Association</u>' maps is that interpolation between survey lines necessitated the assumption that vegetation encountered along the survey lines extended for 50 chains (half the length of a concession) on either side. This was highly unlikely to be the case but since complete coverage of the map was preferred rather than a grid pattern dictated by the survey lines, the assumption could not be avoided. Although the tree types denoted on the map represent the most important at any one location in that their combined values were 50% and over, where two or three genera are superimposed the magnitude of importance of each genus cannot be gauged. This could be shown, however, by 'strengthening' the symbol representing the tree type with the highest 'Importance' value. Owing to the nature of the calculations from which the values were derived, the 'Importance' standing of certain genera may be over-emphasised. To recap, the value obtained by a genus in a lot was dependent not only on its chainage but also upon the number of other genera occurring in the same observations. This means that the more gregarious types such as pinus and to a lesser extent, quercus, which are the only trees noted in an observation, will attain high values. A hypothetical example will serve to clarify the issue:-

Chainage	Acer	Tilia	Ulmus	Pinus	Ostrya
10.50	Present	Absent	Absent	Present	Absent
1.00	Present	Absent	Absent	Present	Absent
3.50	Absent	Absent	Absent	Present	Absent
6.00	Present	Present	Present	Absent	Present

In this lot, although acer is recorded for 17.50 chains and pinus for only 15.00, the latter will have a higher Importance value. The same situation arises with black ash swamp for this is a community in itself and is invariably the only tree type mentioned in an observation.

As with the trend surfaces, this method could be used for much larger areas than a township. Instead of calculating values at the lot level, the basic unit for calculations could be one square mile or greater, depending on the dimensions of the study area.

The divided circle method is merely a technique for summarising the 'Importance' value data. All tree types with a value exceeding 3% are represented by a segment proportional to their percentage value. Types with a value of less than 3% are combined and classified as 'Others' since the segments produced would otherwise be impractical to construct and differentiate successfully by symbols. This method does take into consideration the chainage occupied by vegetation cover (as opposed to clearings) since the circles are proportional to the length of forest cover per 6 lots. Bar graphs could have been used in an alternative form of graphic representation but they did not have the same compactness and ease of construction as the divided circles.

In the 'Association Map', Fig. 15, there is no superimposition of symbols as in the Importance Map, Fig. 13, since the vegetation of each lot can be allocated only one category such as 1A or 3B. This map is perhaps not as specific as that produced by the Importance Method since the particular genus combination constituting the associations is not shown.

In concluding, no one of the above methods can represent a complete record of all ecological parameters. All the maps produced are essentially predictions of forest cover patterns based on the surveyor's attempts at obtaining an approximation of existing vegetation comditions. No one method can be proved to be any more accurate or reliable than another since there is no satisfactory means of estimating the probability of error inherent in the maps produced as there are no original forest stands remaining on Tuscarora. Examination of secondary growth is of very little value in this respect.

PART III: AN ANALYSIS OF FACTORS CONTROLLING FOREST COVER FORM AND DISTRIBUTION

3.1 Introduction

So far the objectives of this study have been to devise methods of reconstructing, as objectively as possible, the forest vegetation of Tuscarora as it existed at a time when man's influence upon it was minimal. It is now the intention to account for the distribution pattern arrived at by the proposed methods, in terms of influencing factors operating at that time. Obviously, the controls of vegetation composition and distribution of any area, will be of a complex nature, involving not only the interaction of ecological factors such as local climate, soil pH and depth, but also the physiological and phytosociological characteristics of the plants themselves. However, in the present investigation, these influencing factors will be limited to those extrapolated from the information provided by the survey records and will, therefore, be of a fundamental nature. It must not be forgotten that in any attempt to interpret the composition and distribution of the vegetation, so much depends upon the surveyor and his ability to provide an accurate assessment of existing conditions. It cannot be over-emphasised that throughout this section the survey records will provide the principle source of material. Any other reference source will be used either to check the surveyor's data or to substantiate the main arguments. As with Part II the ultimate aim of this section will be to show how the survey records may be used to maximum capacity to provide a reliable assessment of the physical and cultural landscape of the period, through an analysis of the existing vegetation. At the same time it is hoped that the advantages and weaknesses of the survey note information will be illuminated.

3.2 An Assessment of the influence of physical environmental factors upon the vegetation of Tuscarora as established by survey record information.

As mentioned briefly in the introduction to Part III, any modern study of the vegetation and environmental relationships of Tuscarora would involve an examination of the influence of micro-climate or of edaphic factors upon tree distribution. Incorporated in the latter would be the analysis of soil properties such as water retaining capacity, acidity and nutrient status. Research has already been carried out on this subject, most of which is contained in a paper by P. F. Maycock (1963) (15). In a phytosociological analysis of the forested areas of the region south of the Goderich - Toronto line, Maycock presents an ordination of forest stands in relation to site moisture characteristics, thus contributing towards an overall appreciation of the ecological tolerance of the individual tree species of Southern Ontario. As well as measuring the capacity of a particular soil to hold moisture he also examines the pH and 'important' element contents - calcium, potassium, phosphorus and magnesium - of the A 1 horizon in the stands examined.

It would be beyond the scope of this thesis, to carry out such an analysis on Tuscarora since it is with environmental conditions drawn from the survey records with which this particular section is concerned. Factors which may be examined under these terms are therefore limited but may be viewed as follows:-

1. <u>Rôle of landforms</u>

The effect of landform on tree pattern will be examined in relation to its direct influences, i.e., upon terrain type and indirect influences, i.e., surface drainage.

a) <u>Terrain type</u>

Since surveyor's information pertaining to topographic features is restricted to remarks such as: 'Ascending' or 'Descending'; 'low flats', 'gully', this particular analysis was carried out with the aid of a 1:50,000 scale topographic map of the area. Much of the township is of a level or undulating nature, occasionally cut into by shallow gullies. In such an area, soil is to be presumed of uniform depth so that the main controlling factor would be soil drainage conditions. Two exceptions were noted however, to the generalised relief just described. (i) the area on the western boundary of Tuscarora (see physical map, page 21) drained by a small tributary of the Grand River. The surveyor's description "Very rough, broken Land" (Concession 3, line between lots 36/37) provides some indication of the nature of terrain without pre-examination of the topographic sheet. The vegetation of this gullied land is principally fagus and pinus, pinus predominating in the gully bottoms over considerable distances. (ii) In concession 5 the surveyor remarks 'soil getting stoney, long grass and other indicators of stone'. This is thought to be the edge of the Onondaga escarpment impinging into Tuscarora from Oneida township to the east. Here the limestone bed rock is presumably near the surface and the forest vegetation of this area is composed of those tree types which show a preference for dryer sites, i.e., quercus, carya and pinus.

It can be seen that the areas directly controlled by terrain type are limited in consequence of the uniform physiography of the township.

b) Surface Drainage

As may be judged from the frequency of occurrence of black ash swamps, over much of the area the water table is either at or close to the ground surface. It was presumed that at any location referred to by the surveyor as: 'swaley', 'flats', 'lowland' or 'marshy' a high water table was present. Thus, in order to examine the existence possibility of any relationship between these areas and tree types, a list was drawn up of the number of occurrences of each genus in areas of high water table. Black ash and tamarack were excluded in the analysis since it is readily apparent that these species are associated with 'moist' sites. Relative Frequency values were also calculated, defined in this case as the number of occurrences of one tree type in areas of high water table as a percentage of the total number of occurrences of all other tree types occurring in such locations. The results are tabulated overleaf:

TABLE 9. Relative Frequency Values of Tree Occurrence on moist sites

Genus	No. of occurrences in areas of high water table	Relative Frequency	Overall Relative Frequency (values for whole twp.)
Acer	37	23.88%	22.5%
Tilia	36	23.22%	8.3%
Ulmus	30	19.35%	2.5%
Fagus	21	13.55%	22.5%
Pinus	12	7.45%	11.9%
Ostrya	10	6.45%	5.0%
Quercus	7	4.51%	15.7%
Carya	1	0.65%	0.8%
Populus	1	0.65%	0.5%

Total occurrences = 155

Total number of locations with a high water table = 64

Some indication of the moisture tolerance of the individual tree types may be gained if the relative frequency values of occurence on 'moist' cites are compared with frequency values for the whole township. However, it may be argued that the high frequency of acer in areas with a high water table are a function of its high overall frequency. Similarly the low overall frequency values of carya and populus mean that there will be less probability of them occurring often in moist locations. However, this argument does not hold true for the other tree types. Quercus and fagus, for instance, occupy third and second positions in the values for the whole township but have comparatively few occurrences in areas with a high water table while the reverse is true of ulmus and tilia. A definite relationship, therefore, may be said to exist between tree type and site moisture characteristics and this may be substantiated if the above results are compared with those of Maycock's moisture tolerance findings. Maycock divided forest stands into five categories - dry; dry mesic; mesic; wet mesic; wet, differentiated on the basis of the water retaining capacity of their soils. Species were allocated to one of the 5 'moisture segments' according to the number and 'importance' of occurrences in the 5 stand classes. Maycock's categorisation for each of the 9 tree types mentioned in the above list is as follows:-

Tree species	Moisture segment
Acer rubrum	Wet
Acer saccharum	Mesic
Tilia Americana	Wet - Mesic
Ulmus Americana	Wet
Fagus grandifolia	Dry - Mesic
Ostrya virginiana	Dry - Mesic
Pinus strobus	Dry
Quercus alba	Dry
Quercus rubra	Dry - Mesic
Quercus velutina	Dry
Carya ovata	Dry
Populus grandidentata	Dry
Populus tremuloides	Wet

There appears to be a close correspondence between these 'moisture tolerance' results and those indicated by the relative frequencies calculated from the survey records. For instance, Ulmus and Tilia, which have a relatively high number of occurrences on moist sites in Tuscarora, have been placed by Maycock into the Wet and Wet-mesic segments respectively. Ostrya and fagus occupy intermediate positions in both lists, while all three species of oak most commonly encountered in Tuscarora favour, according to Maycock, dry sites, which coincides with the results obtained for the township.

It became apparent when totalling the occurrences of the various tree types on areas of high water table that a definite acer, tilia, ulmus (maple, bass, elm) association existed, for acer occurred with either tilia or ulmus or both for 30 out of its 37 occurrences. No effective method was devised for comparing the floristic composition of the vegetation of the well-drained areas with that of the poorly-drained locations since the former were not so readily definable in terms of extent of area.

2. Rôle of Soil Texture

The term 'texture' as used here and by the surveyor applies to the very broad classes of sand and clay. As such it is the only information available from the survey records pertaining to soil, apart from indirect remarks such as 'good land' or 'very handsome land'. The distinction between sand and clay is obviously very vague since it was presumably done on the basis of touch and appearance. In spite of this, it has validity for after plotting the location on the survey grid of the two texture classes (Fig. 16) it was compared with a modern soil survey map. It was noted that the incidence of 'sandy' soil, interpolated from the surveyor's observations, coincided closely in extent to the area described as 'Berrien sandy loam' on the modern soil survey map. A portion of the northerly extension of the Norfolk sand plain, this sand is the coarsest textured of the 8 soil types found within the township. A mechanical analysis was carried out on samples of Berrien sandy loam and Brantford clay loam. The particle size content of each are shown in Table 10.

TABLE 10. Results of Mechanical Analysis of Soils (Hydrometer Method)

Soil Texture Class	Depth of Sample	Percentage Sand content	Percentage Silt	Percentage Clay
Sand	6"	93.4	3.5	3.1
Sand	18"	96.3	1.1	2.6
Clay loam	6"	51.8	7.1	41.1
Clay loam	18"	61.0	12.1	26.9

In spite of these differences in particle size, the moisture content of both textural classes was relatively high, that of the Berrien sandy loam remaining constant to a depth of at least 18 inches.

In order to test for any relationship between tree type and soil 'texture' class the number of occurrences of each genus on sand and clay sites (survey data) were totalled.

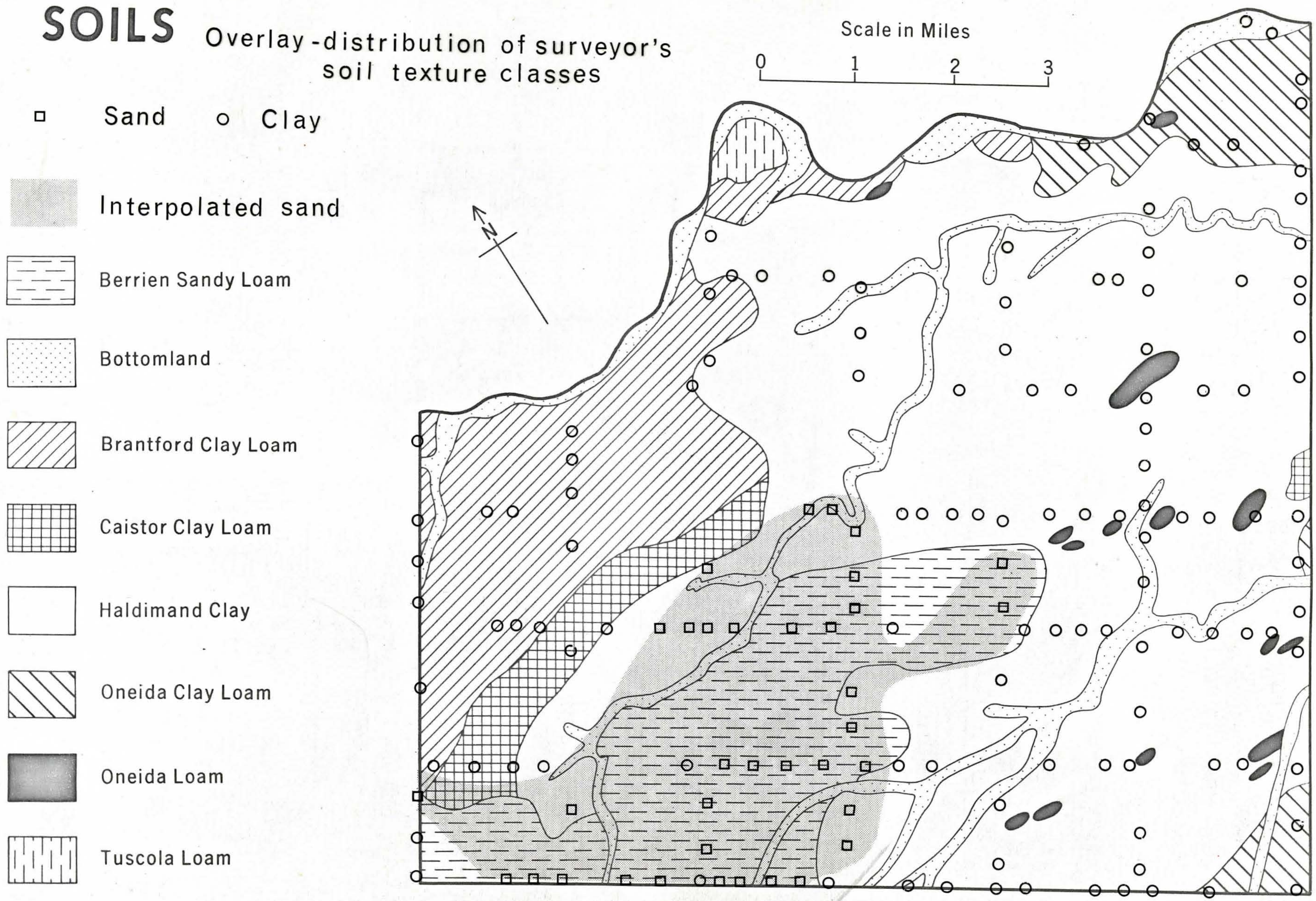

SOILS
Overlay-distribution of surveyor's soil texture classes
Sand
Clay
Interpolated sand
Berrien Sandy Loam
Bottomland
Brantford Clay Loam
Caistor Clay Loam
Haldimand Clay
Oneida Clay Loam
Oneida Loam
Tuscola Loam
N
Scale in Miles
0
1
2
3

Fig. 16

TABLE 11. Distribution of Generic Groups on the surveyor's soil texture classes

Tree Type	No. of occurrences on clay	No. of occurrences on sand
Acer	125	27
Fagus	115	48
Quercus	84	29
Tilia	39	5
Ulmus	12	-
Pinus	52	24
Ostrya	28	9
Carya	7	-
Populus	1	4

Total no. of clay sites = 151

Total no. of sand sites = 54

A Null hypothesis was formulated stating that there is no relationship between soil 'texture' and tree type. Using the data of Table 11 and on the basis of the following contingency table a chi-square test was carried out for each generic group whose values exceeded five (27). Ulmus, carya and populus were therefore omitted on the grounds of low sample size.

TABLE 12. Contingency table (Pinus data) for calculation of X^2

	Soil Type	Present	Absent	Total
Observed Values	Clay	52	99	151
	Sand	24	30	54
	Total	76	129	205

The results show that in only two cases (Fagus and Acer) is there a significant relationship between soil texture type and tree type. In these two cases, fagus occurs most frequently on the coarser-textured soils, while acer is associated with the clay areas. Generally, texture plays an important part in controlling soil moisture content and it is in this context that it may be considered an indirect factor in contolling vegetation patterns. However, on the township it was noted that there was by no means a marked absence of swamps in the area of 'sandy' soil. According to the soil survey notes and moisture content analysis the Berrien sandy loam has imperfect to poor drainage owing to the presence of clay at a depth of three to six feet. Differences in soil texture at or near the ground surface are not, therefore, directly responsible for the composition of forest vegetation at any one location.

3. Rôle of other physical environmental phenomena

It was observed that the vegetation of areas ravaged by strong winds differed somewhat not only in composition but also in its form. In all, the surveyor made 133 observations of vegetation assemblages occurring in these so-called 'windfalls'. The genus content was as follows:

TABLE 13. Relative Frequency values of tree occurrences on windfalls

Genus	No. of occurrences in windfalls	Relative Frequency	Overall Frequency
Fagus	103	27.4%	22.5%
Pinus	93	24.8%	11.9%
Acer	88	23.4%	22.5%
Quercus	46	12.2%	15.7%
Tilia	27	7.2%	8.3%
Populus	7	1.8%	0.5%
Ulmus	6	1.6%	2.5%
Ostrya	5	1.3%	5.0%
Carya	-	-	-

If the frequency values are correlated with those of overall frequency, certain deviations are apparent. However, it is difficult to make deductions concerning the nature of the vegetation of these areas since it is not known whether the trees observed by the surveyor are those which have remained standing, those which have been uprooted, or both. It was noted that windfalls were frequently accompanied by the term 'thick brush' indicating secondary growth. Sometimes specific trees were observed to occur as brush. This applies especially, to pinus and populus which were either re-establishing themselves after disturbance or were colonising from adjacent areas owing to the lack of competition from the more aggressive hardwoods such as acer and quercus.

3.3 An Assessment of the effects of anthropogenic influence on the vegetation of 1842 in Tuscarora

The effect of settlement in the township with its concomitant disturbance of the existing vegetation was manifest in three main ways: a) vegetation clearance

b) drainage of certain areas

c) damming of the Grand River in several areas (28).

Only the first mentioned factor will be discussed here since it obviously has the most widespread implications. At the same time, almost all of the information pertaining to this subject may be extracted from the survey records whereas there is no direct mention at all of the other two matters. The influence of clearance on the overall pattern of vegetation may be viewed in two sections, the one dealing with wholesale clearance and the other with selective cutting.

Wholesale clearing

Much of the clearing recorded in the survey records had occurred prior to the influx of the Six Nations Indians from other parts of the Grand River Tract when it was suggested by the Government of the time that the Indians would benefit if they surrendered all their remaining land to the Crown with the exception of a tract of 20,000 acres. The problem at hand had been one of encroachment of white settlers onto Indian land. The tract chosen as the future Reserve covered the present township of Tuscarora which was laid out as such in the survey at present under study. From descriptions taken from the Land Inspection Returns of 1844 (29) much settlement had taken place between 1842 and 1844. The people largely responsible for the clearings observed by the surveyor were mainly squatters who had moved into the area between 1835 and 1842.

From the survey notes the following factors may be extrapolated concerning the nature of clearing:-

1. Extent - is generally recorded in chains along the survey grid in the same manner as forest vegetation. Occasionally, however, Walker noted the approximate acreage of clearing, as for instance, in Concession 6, Lot 17: 'Derry's clearing, 12 acres, half on either side of the line'.

2. Type of clearing - Walker differentiated between an area in the first stages of clearing in which the trees had been felled and left either to decay or to await removal for construction or saw-mill purposes. This was referred to as 'chopping' whenever it was encountered. He used the term 'clearing' for an area which had presumably been largely depleted of the original timber.

3. General condition of clearing - Frequently the surveyor referred to old choppings or old clearings which had become overgrown with briars and thorns. Sometimes a clearing may have been occupied by &brush' indicating that regeneration of vegetation was taking place.

With the above observations at hand a reliable impression of vegetation clearance in the area can be made. As can be seen from the maps (Figs. 13 and 15) the vegetation most reduced by clearance was that on the periphery of the township and to a certain extent that along the largest creeks traversing the area, eg., McKenzie Creek. The Grand River tract (Broken Front lots) was particularly susceptible to clearing owing to the greater fertility of its soil (predominantly light alluvium) and to its accessibility by water. In some cases, especially in the west central area, the vegetation within one mile of the river had been completely removed. In the eastern sector of the Broken Front many lots were observed to be 'half-cleared'. It is unfortunate that this area had been depleted of vegetation to such an extent since it probably had possessed some of the floristically rarer elements within its tree types owing to the more suitable habitat conditions. It is significant in this context that the only record of black walnut (juglans nigra) and butternut (juglans cinerea) - as identification trees - were obtained in this area. As with settlement, the distribution of clearing in Tuscarora was of a dispersed nature. Nowhere was it concentrated round a nodal point except perhaps in the extreme wouth where a saw-mill had been built on the Sal Jaques Creek (Boston Creek) where rapids occurred (now named Victoria Mills). There appears to be a lack of clearance along the eastern boundary at this date for the area seems to have been broached from the west and south.

Where wholesale clearance took place it obviously drastically affected the vegetation by its very removal but noticeable effects would be the rise and spread of secondary growth with any coincidental changes in vegetation composition that this might encrue, eg., an increase in populus species. When an area was to be cultivated all trees, no matter what their economic value, were considered to be nothing more than weeds, so where wholesale clearance was in operation all trees suffered the same fate (29). In terms of area however, the effect of this type of clearing was small.

Selective Cutting

While the survey records provide an adequate basis upon which assumptions concerning the effects of clearance upon the existing vegetation may be founded, they only provide a hint of the occurrence of selective cutting. It is definitely known, however, that selective cutting of at least one tree type - pine, took place for the surveyor mentions the phenomenon on two occasions:-

Concession 1, Lot 29 he remarks: 'windfall, in a kind of pine slashing caused chiefly by getting out saw logs'.

Broken Front, line between lots 60/61: 'Best of pines being taken for sawlogs'.

A few chains further North: 'Ascending; a great number of saw logs'.

Pine (pinus strobus) was much in demand at that time as it is at the present day since it is one of the most valuable of Canada's soft-wood timbers (16). In the first mentioned example above, the wood is almost certainly taken to Smith's and Roger's sawmill on the Sal Jaques Creek. Those cut in the more northerly lots are either processed at this mill too or are transported to Brantford in the adjacent township to the west. In areas near these examples there is a noted scarcity of pine and that which does occur is in the form of 'brush' indicating that it has already begun regenerating. However, over much of the area (as may be noted from the maps) it constitutes one of the most important tree types. Indeed, in the extreme north east section of the township it occurs in almost pure stands and it is thought to be dominant in the rough gully country along the north west boundary of Tuscarora. Of course, the surveyor may have tended to over-emphasise the status of pine in view of its conspicuous character and its economic value. It would seem then, that owing to its overall widespread occurrence within Tuscarora, the selective cutting of pine was of local importance only in 1842.

There is no evidence in the survey records of selective cutting of any other tree species. If there had been it is more than likely that the hard maple (acer saccharum) and white oak (quercus alba) both renowned for their durability and resistance, would have fallen victim to the axe (16). However, both of these trees are abundant throughout the township.

More concrete information to substantiate the surveyor's information and to strengthen personal deductions could not be found in the usual sources (Appendices to the Journal of the Legislative Assembly) for Tuscarora. This is presumably because the area is classified as an Indian Reserve rather than as Crown Land.

3.4 An Assessment of the Subjectivity of the surveyor's observations and its influence on the determination of forest cover.

The reliability of the description of the composition and distribution of the forest vegetation of Tuscarora is wholly dependent upon the surveyor's integrity and aptitude for making accurate detailed vegetation records. The notes for the other townships surveyed by Walker - Oneida, Brantford, Dumfries and Wellesley, were all presented in the same detailed, methodical manner. There is no reason to believe that Walker presents an unreliable or fraudulant assessment of the arboreal vegetation of Tuscarora. However, in the course of working with the survey records, certain factors pertaining to the composition and distribution of the forest types have come to light which point to a certain amount of bias and subjective judgement only to be expected in a survey procedure of this nature.

The first point is the virtual absence of trees which are normally far from insignificant members of a plant community as found on Tuscarora. Such a tree is white ash (Fraxinus Americana) which is recorded only once in the surveyor's observed vegetation assemblages. This low figure can not really be explained by rareness for according to the findings of P. Maycock (1963) it has the highest constancy value[1] of 62 tree species occurring in extreme Southern Ontario (15). One explanation may be that white ash has increased in numbers since 1842 in the area. However, as an identification tree it occurs to a far greater extent than carya and populus, Table 7, which are considered

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[1]Constancy - frequency (totalled over all stands of a group and expressed as a percentage). It indicates the reliability of finding a tree in woods chosen at random in the area.

in the main vegetation assemblages. Its paucity cannot be attributed to the absence of suitable edaphic conditions since it will thrive on a wide variety of habitats but makes its best growth on a deep, well drained soil, along streams (16); of which there is no dearth on Tuscarora. It is too, as easily identifiable as any of the other forest trees as it is one of the statliest trees of the mixed hardwood region, with a straight, tall, unbranched trunk. Lack of information then, concerning the presence of this tree, in the main observations can only be due to selectivity of the surveyor. Likewise, trees such as cherry (prunus spp); butternut (juglans cinerea) and black walnut (juglans nigra) which admittedly are far less common than fraxinus americana only figure once or twice as identification trees (Table 7) in spite of the fact that Tuscarora is well within the range of these species (32). It may be that these particular trees favoured the more fertile soils along the Grand River, an area lacking in records owing to clearing prior to the survey in 1942. Other surveyors note the rarer species such as juglans, tulip tree (liriodendron tulipfera) and sassafras (sassafras albidum), for instance McDonald and Mount when surveying Stephen township and Moore township respectively, in Lambton County (31). Many also include the blue beech (carpinus caroliniana) a commonly occurring tree.

It is probable also, that the importance of some types was over-emphasised. Pine may well have been such a tree owing to its conspicuous appearance (particularly if the survey was carried out in winter) and its uniqueness in being the only commonly occurring conifer amongst the deciduous trees. The fact that it was an economically valuable tree may be of importance in this respect. There is no means of substantiating these suppositions, however.

Walker recorded swamp vegetation in terms of either black ash or tamarack, yet there were undoubtedly other arboreal types present, especially in the black ash areas. Such trees were salix spp., alnus spp. and betula spp. which are mentioned very infrequently as identification trees (Table 7). He obviously considers the swamp vegetation as a well defined community named after the dominant species.

It is doubtful whether the trees selected as identification trees represent a random sample - whether they actually are the nearest to the lot corners and were chosen without regard to species, condition, size or durability. The greater frequencies (Table 7) of acer and fagus may be explained by their overall greater abundance, as established from the main observations, in which case there will be a greater probability of them occurring at the corners of lot lines. The greater frequency of fagus may be attributed to its smooth bark facilitating the scribing of any identification mark. The high frequency of ostrya cannot really be due to its abundance but may be explained by its reputation for durability. The same is true of carpinus, which although a small tree is used not infrequently for corner identification. Although pine is long-lived and easily recognisable the surveyor may have not used it as frequently as an identification post since it was likely to be one of the first trees to be cut by settlers.

Impartial selection of witness trees is therefore not very likely, all going to show that the interpretation of the composition of the original vegetation of Tuscarora or indeed of any township, was governed to a considerable extent by the surveyor. This section has served to show that the investigator's own assumptions must be made with the unavoidable subjectivity of the surveyor's methods constantly in mind. It must be remembered that the surveyor was not a forester or ecologist bent on providing a detailed description of species composition and distribution but perhaps an 'amateur' botanist whose aim was to provide a rough guide as to the characteristics and capabilities of the land in the area through a broad appreciation of its forest vegetation. In view of the hardships imposed by the elements, insects and other such factors, while undertaking these surveys, he fulfilled these aims extremely well.

Conclusions - Part III

The amount of direct and indirect information extracted from the survey records alone, is sufficient to provide a fundamental explanation of certain causal factors operating on the vegetation pattern of 1842. Human influence upon forest composition, that is, species content of Tuscarora, can be deemed virtually insignificant in that selective cutting, as far as can be proved from the evidence used, had only minor importance. In terms of the distribution of vegetation cover, human interference was significant in view of the fact that local clearance had taken place prior to the survey. However this, as drastic as it was, remained restricted to the Broken Front Lots (River Range) and certain peripheral locations.

It would seem that surface and soil drainage conditions are major factors in determining the species content of the woodlands of the township itself, as well as the distribution of tree types at any one location. On the whole, apart from certain anomalies, already discussed, terrain type, in terms of degree of slope and soil depth is nowhere unfavourable for forest growth; nor does terrain type vary considerably, the greatest contrast being between the hummocky drumlin areas and the level lake plain in the centre of the township. Drainage would appear to be directly responsible for the acer - tilia - ulmus association found in the moister areas not otherwise occupied by black ash or tamarack swamp.

Obviously, the surveyor's reports do not supply any direct information concerning the nature of the surveyor's bias and its influence on determination of forest cover in Tuscarora. Therefore, deductions made pertaining to selective observations were based on the occurrence of certain anomalies, such as the paucity or absence of certain arboreal species.

A more quantitative correlation of both cultural and physical environmental factors and tree types may have been theoretically possible. Using tree types as the independent variables and factors such as distance from habitation, distance from saw-mill, terrain type and surface drainage conditions as dependent variables, a form of factor analysis could have been carried out. However, it was felt that the data was not concrete enough to produce valid results in a sophisticated statistical analysis of such a nature. It must be noted that all of the 'methods' used in the correlation of environmental factors and vegetation cover were very basic in character owing to the type of information supplied by the surveyor's notes.

It has been shown in this section that while the survey records may be useful in an analysis of the presence of certain causal factors operating on forest cover, they could not provide sufficient evidence for the strict testing of hypotheses pertaining to the exact nature or relative influence of these causal factors.

SUMMARY AND CONCLUSIONS

In the present investigation into the application of early land survey records in the analysis of 'original' vegetation, the intention has been to devise methods of reconstruction which remain objective but succeed in extracting the maximum of valid information pertaining to the nature and distribution of forest cover in a given area. In this way it is hoped that the proposed techniques may be applied to any area laid out and described in the same type of procedure as that of Tuscarora, the township selected amongst other criteria as a representative sample of the Southern Ontario surveys carried out in the period 1780 - 1850.

The introductory chapter, specifically the review of literature and summary comparison of American and Canadian survey procedures, stresses that a different approach is required from previous methodological studies since these were of relevance to areas surveyed on the American system which lends itself more readily to quantitative analysis. Thus, the same methods of data manipulation used by U.S. botanists could not aid directly in the analyses of the majority of Ontario surveys.

The vegetation reconstruction process presents a two-fold problem. In the first place, the composition of the vegetation of any one location must be summarised; in other words, some method of classification of the vegetation assemblages at the 'lot' level must be devised. The second problem is one of devising techniques to express the aerial differentiations of forest cover composition and is, therefore, essentially cartographic in nature as opposed to the statistically orientated character of the first aspect. The most sophisticated potential solution to both problems is that of Trend Surface Analysis by which computerised contour maps, each predicting the 'Importance' value of one tree type within the township, were produced. The 'z' values of the trend surface computations represent the chainage occupied by one tree type per lot, relative to that occupied by the other observed tree types within the lot. Although this can provide a valuable method of vegetation reconstruction its major limitation is that its degree of usefulness is controlled largely by the type of data array of 'z' values of the individual generic groups. The so-called 'Importance' map is based on the same parameter as the 'z' values of the trend surfaces but whereas in the latter the aerial distribution of the 'Importance' values were determined and mapped by computerised, statistical operations, those of the 'Importance' map were interpolated manually either as a type of choropleth map or as divided circles. The second principle method of data manipulation, a loose form of Association analysis, is based on the degree of relationship between 'major' and 'minor' hardwoods; and between coniferous species and these two hardwood types within each lot. In an evaluation of these methods of reconstruction it was concluded that no single map can ever be devised which will represent a complete picture of the vegetation cover established by survey procedure and that there is no means whereby either the accuracy of the surveyor's observations or of the maps produced from these observations, may be checked.

In the third part of the study an analysis of both cultural and physical environmental influences upon forest cover was carried out, the survey records providing the primary source of information. This analysis served to show the potentials of survey records for determining the causal factors operating on the form and distribution of the forest cover at a particular point in time. Although the information they contain is sufficient to provide knowledge of the existence of certain relationships between edaphic or cultural factors, for instance, it is inadequate for the successful testing of rigid hypotheses concerned with the relative influence of controlling factors on vegetation distribution. This inadequacy stems from the lack of detail pertaining not only to the nature of the vegetation itself, concerning actual species records or diameters of trees as well as to factors such as soils and the exact extent and nature of clearing. That the surveyor was not an ecologist helps to explain this lack of detail. An assessment of the subjectivity of the surveyor's observations pertaining to forest cover shows the ways in which the completed reconstruction may deviate from reality. Much of this third major section is essentially a verbal analysis and any quantitative techniques used such as the chi-squared test, had to be basic owing to the restricted nature of the data.

Initially, it was hoped that this study might help towards some form of standardisation of methods used in analysing Ontario survey record data. However, it is a matter of opinion whether standardisation is desirable or even possible, for a rational approach to vegetation analysis and reconstruction can be taken only within the context of a specific problem. Naturally, the most successful reconstruction is that which throws most light on the individual research worker's own investigations. Each investigator will organise the survey record information so as to extract the maximum information of relevance to his particular problem, whether it is concerned with the natural ranges of species or with forest history or with forest cover/ environmental relationships. In some instances, therefore, a straightforward verbal analysis may be adequate. However, if the investigator wishes to ascertain the general overall trend and pattern of vegetation within an area, as has been established for Tuscarora, then methods of carrying out this aim are limited owing to the restricted type of general investigation, provided they are modified according to the scale of area involved in the study and the amount of detail available in the survey records.

No matter whether the proposed methods are employed in future work which entails a knowledge of past vegetation form or distribution, it is hoped that the present study has provided some insight into the potentials of the Southern Ontario survey records for both quantitative and qualitative analyses of a landscape through its vegetation cover. There is little doubt that these surveyor's notebooks are useful documents provided they are used with constant recourse to their limitations for they constitute a definite sample of forest cover at a known date in the past and were written on the spot according to some pre-arranged plan.

APPENDIX

ASSOCIATION ANALYSIS - RESULTS OF ASSOCIATION INDICES

TABLE 1 'POINT DATA'

TOTAL OCCURRENCES OF EACH GENUS

873.	611.	872.	321.	96.	464.	194.	33.	22.	370.	19.

1a MATRIX OF OCCURRENCES

	Acer	Quercus	Fagus	Tilia	Ulmus	Pinus	Ostrya	Carya	Populus	Fraxinus Nigra	Larix Laricina
Acer	873.	424.	684.	277.	82.	248.	149.	26.	5.	12.	0.
Quercus	424.	611.	427.	134.	21.	226.	117.	16.	7.	5.	0.
Fagus	684.	427.	872.	202.	43.	306.	119.	22.	4.	7.	0.
Tilia	277.	134.	202.	321.	56.	55.	72.	10.	5.	6.	0.
Ulmus	82.	21.	43.	56.	96.	14.	4.	5.	2.	5.	0.
Pinus	248.	226.	306.	55.	14.	464.	40.	1.	18.	11.	0.
Ostrya	149.	117.	119.	72.	4.	40.	194.	6.	3.	1.	0.
Carya	26.	16.	22.	10.	5.	1.	6.	33.	0.	0.	0.
Populus	5.	7.	4.	5.	2.	18.	3.	0.	22.	3.	0.
Frax. N.	12.	5.	7.	6.	5.	11.	1.	0.	3.	370.	1.
Larix Lar.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.	19.

1b MATRIX OF OCCURRENCES - DICE'S ASSOCIATION INDEX

	Acer	Quercus	Fagus	Tilia	Ulmus	Pinus	Ostrya	Carya	Populus	Fraxinus Nigra	Larix Laricina
Acer	1.00	0.49	0.78	0.32	0.09	0.28	0.17	0.03	0.01	0.01	0.00
Quercus	0.69	1.00	0.70	0.22	0.03	0.37	0.19	0.03	0.01	0.01	0.00
Fagus	0.78	0.49	1.00	0.23	0.05	0.35	0.14	0.03	0.00	0.01	0.00
Tilia	0.86	0.42	0.63	1.00	0.17	0.17	0.22	0.03	0.02	0.02	0.00
Ulmus	0.85	0.22	0.45	0.58	1.00	0.15	0.04	0.05	0.02	0.05	0.00
Pinus	0.53	0.49	0.66	0.12	0.03	1.00	0.09	0.00	0.04	0.02	0.00
Ostrya	0.77	0.60	0.61	0.37	0.02	0.21	1.00	0.03	0.02	0.01	0.00
Carya	0.79	0.48	0.67	0.30	0.15	0.03	0.18	1.00	0.00	0.00	0.00
Populus	0.23	0.32	0.18	0.23	0.09	0.82	0.14	0.00	1.00	0.14	0.00
Frax. N.	0.03	0.01	0.02	0.02	0.01	0.03	0.00	0.00	0.01	1.00	0.00
Larix Lar.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	1.00

1c MATRIX OF OCCURRENCES - DICE'S COINCIDENCE INDEX

	Acer	Quercus	Fagus	Tilia	Ulmus	Pinus	Ostrya	Carya	Populus	Fraxinus Nigra	Larix Laricina
Acer	1.00	0.57	0.78	0.46	0.17	0.37	0.28	0.06	0.01	0.02	0.00
Quercus	0.57	1.00	0.58	0.29	0.06	0.42	0.29	0.05	0.02	0.01	0.00
Fagus	0.78	0.58	1.00	0.34	0.09	0.46	0.22	0.05	0.01	0.01	0.00
Tilia	0.46	0.29	0.34	1.00	0.27	0.14	0.28	0.06	0.03	0.02	0.00
Ulmus	0.17	0.06	0.09	0.27	1.00	0.05	0.03	0.08	0.03	0.02	0.00
Pinus	0.37	0.42	0.46	0.14	0.05	1.00	0.12	0.00	0.07	0.03	0.00
Ostrya	0.28	0.29	0.22	0.28	0.03	0.12	1.00	0.05	0.03	0.00	0.00
Carya	0.06	0.05	0.05	0.06	0.08	0.00	0.05	1.00	0.00	0.00	0.00
Populus	0.01	0.02	0.01	0.03	0.03	0.07	0.03	0.00	1.00	0.02	0.00
Frax. N.	0.02	0.01	0.01	0.02	0.02	0.03	0.00	0.00	0.02	1.00	0.01
Larix Lar.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	1.00

1d MATRIX OF OCCURRENCES - SNEATH'S SIMPLE MATCHING COEFFICIENT

	Acer	Quercus	Fagus	Tilia	Ulmus	Pinus	Ostrya	Carya	Populus	Fraxinus Nigra	Larix Laricina
Acer	1.00	0.40	0.64	0.30	0.09	0.23	0.16	0.03	0.01	0.01	0.00
Quercus	0.40	1.00	0.40	0.17	0.03	0.27	0.17	0.03	0.01	0.01	0.00
Fagus	0.64	0.40	1.00	0.20	0.05	0.30	0.13	0.02	0.00	0.01	0.00
Tilia	0.30	0.17	0.20	1.00	0.16	0.08	0.16	0.03	0.01	0.01	0.00
Ulmus	0.09	0.03	0.05	0.16	1.00	0.03	0.01	0.04	0.02	0.01	0.00
Pinus	0.23	0.27	0.30	0.08	0.03	1.00	0.06	0.00	0.04	0.01	0.00
Ostrya	0.16	0.17	0.13	0.16	0.01	0.06	1.00	0.03	0.01	0.00	0.00
Carya	0.03	0.03	0.02	0.03	0.04	0.00	0.03	1.00	0.00	0.00	0.00
Populus	0.01	0.01	0.00	0.01	0.02	0.04	0.01	0.00	1.00	0.01	0.00
Frax. N.	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.01	1.00	0.00
Larix Lar.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00

1e MATRIX OF OCCURRENCES - WILLIAMS AND LAMBERT'S COEFFICIENT

	Acer	Quercus	Fagus	Tilia	Ulmus	Pinus	Ostrya	Carya	Populus	Fraxinus Nigra	Larix Laricina
Acer	5.996	80.715	62.108	16.934	6.641	131.887	19.800	3.432	15.723	565.809	24.695
Quercus	80.715	17.637	78.033	28.108	24.143	27.094	1.318	0.988	2.870	297.662	12.476
Fagus	62.108	78.033	5.873	60.450	36.157	74.379	39.886	5.740	17.723	587.664	24.630
Tilia	16.934	28.108	60.450	133.600	17.959	58.102	2.479	0.129	0.090	110.662	5.012
Ulmus	6.641	24.143	36.157	17.959	298.184	16.874	7.238	2.871	0.171	21.332	1.267
Pinus	131.887	27.094	74.379	58.102	16.874	62.882	23.081	12.040	4.082	174.980	8.196
Ostrya	19.800	1.318	39.886	2.479	7.238	23.081	218.484	0.242	0.009	66.806	2.746
Carya	3.432	0.988	5.740	0.129	2.871	12.040	0.242	355.951	0.484	10.545	0.418
Populus	15.723	2.870	17.723	0.090	0.171	4.082	0.009	0.484	366.562	1.978	0.276
Frax. N.	565.809	297.662	587.664	110.662	21.332	174.980	66.806	10.545	1.978	106.402	3.961
Larix L.	24.695	12.476	24.630	5.012	1.267	8.196	2.746	0.418	0.276	3.961	369.482

ASSOCIATION ANALYSIS - RESULTS OF ASSOCIATION INDICES

TABLE 2 'WEIGHTED DATA'

TOTAL OCCURRENCES OF EACH GENUS

4628.	3320.	4570.	1799.	458.	2339.	1102.	204.	120.	1078.	87.

2a MATRIX OF OCCURRENCES

	Acer	Quercus	Fagus	Tilia	Ulmus	Pinus	Ostrya	Carya	Populus	Fraxinus Nigra	Larix Laricina
Acer	4628.	2386.	3665.	1557.	393.	1325.	863.	174.	47.	54.	0.
Quercus	2386.	3320.	2327.	845.	125.	1198.	659.	104.	48.	39.	0.
Fagus	3665.	2327.	4570.	1188.	242.	1567.	685.	127.	26.	27.	0.
Tilia	1557.	845.	1188.	1799.	247.	306.	447.	79.	28.	41.	0.
Ulmus	393.	125.	242.	247.	458.	81.	16.	24.	10.	19.	0.
Pinus	1325.	1198.	1567.	306.	81.	2339.	232.	4.	100.	44.	0.
Ostrya	863.	659.	685.	447.	16.	232.	1102.	49.	9.	4.	0.
Carya	174.	104.	127.	79.	24.	4.	49.	204.	0.	0.	0.
Populus	47.	48.	26.	28.	10.	100.	9.	0.	120.	6.	0.
Frax. N.	54.	39.	27.	41.	19.	44.	4.	0.	6.	1078.	5.
Larix Lar.	0.	0.	0.	0.	0.	0.	0.	0.	0.	5.	87.

2b MATRIX OF OCCURRENCES - DICE'S ASSOCIATION INDEX

	Acer	Quercus	Fagus	Tilia	Ulmus	Pinus	Ostrya	Carya	Populous	Fraxinus Nigra	Larix Laricina
Acer	1.00	0.52	0.79	0.34	0.08	0.29	0.19	0.04	0.01	0.01	0.00
Quercus	0.72	1.00	0.70	0.25	0.04	0.36	0.20	0.03	0.01	0.01	0.00
Fagus	0.80	0.51	1.00	0.26	0.05	0.34	0.15	0.03	0.01	0.01	0.00
Tilia	0.87	0.47	0.66	1.00	0.14	0.17	0.25	0.04	0.02	0.02	0.00
Ulmus	0.86	0.27	0.53	0.54	1.00	0.18	0.03	0.05	0.02	0.04	0.00
Pinus	0.57	0.51	0.67	0.13	0.03	1.00	0.10	0.00	0.04	0.02	0.00
Ostrya	0.78	0.60	0.62	0.41	0.01	0.21	1.00	0.04	0.01	0.00	0.00
Carya	0.85	0.51	0.62	0.39	0.12	0.02	0.24	1.00	0.00	0.00	0.00
Populous	0.39	0.40	0.22	0.24	0.08	0.84	0.07	0.00	1.00	0.05	0.00
Frax. N.	0.05	0.04	0.02	0.04	0.02	0.04	0.00	0.00	0.01	1.00	0.00
Larix Lar.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	1.00

2c MATRIX OF OCCURRENCES - DICE'S COINCIDENCE INDEX

	Acer	Quercus	Fagus	Tilia	Ulmus	Pinus	Ostrya	Carya	Populous	Fraxinus Nigra	Larix Laricina
Acer	1.00	0.60	0.80	0.48	0.15	0.38	0.30	0.07	0.02	0.02	0.00
Quercus	0.60	1.00	0.59	0.33	0.07	0.42	0.30	0.06	0.03	0.02	0.00
Fagus	0.80	0.59	1.00	0.37	0.10	0.45	0.24	0.05	0.01	0.01	0.00
Tilia	0.48	0.33	0.37	1.00	0.22	0.15	0.31	0.08	0.03	0.03	0.00
Ulmus	0.15	0.07	0.10	0.22	1.00	0.06	0.02	0.07	0.03	0.03	0.00
Pinus	0.38	0.42	0.45	0.15	0.06	1.00	0.13	0.00	0.08	0.03	0.00
Ostrya	0.30	0.30	0.24	0.31	0.02	0.13	1.00	0.07	0.01	0.00	0.00
Carya	0.07	0.06	0.05	0.08	0.07	0.00	0.07	1.00	0.00	0.00	0.00
Populous	0.02	0.03	0.01	0.03	0.03	0.08	0.01	0.00	1.00	0.01	0.00
Frax. N.	0.02	0.02	0.01	0.03	0.03	0.03	0.00	0.00	0.01	1.00	0.01
Larix Lar.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	1.00

2d MATRIX OF OCCURRENCES - SNEATH'S SIMPLE MATCHING COEFFICIENT

	Acer	Quercus	Fagus	Tilia	Ulmus	Pinus	Ostrya	Carya	Populous	Fraxinus Nigra	Larix Laricina
Acer	1.00	0.43	0.66	0.32	0.08	0.23	0.18	0.04	0.01	0.01	0.00
Quercus	0.43	1.00	0.42	0.20	0.03	0.27	0.18	0.03	0.01	0.01	0.00
Fagus	0.66	0.42	1.00	0.23	0.05	0.29	0.14	0.03	0.01	0.00	0.00
Tilia	0.32	0.20	0.23	1.00	0.12	0.08	0.18	0.04	0.02	0.01	0.00
Ulmus	0.08	0.03	0.05	0.12	1.00	0.03	0.01	0.04	0.02	0.01	0.00
Pinus	0.23	0.27	0.29	0.08	0.03	1.00	0.07	0.00	0.04	0.01	0.00
Ostrya	0.18	0.18	0.14	0.18	0.01	0.07	1.00	0.04	0.01	0.00	0.00
Carya	0.04	0.03	0.03	0.04	0.04	0.00	0.04	1.00	0.00	0.00	0.00
Populous	0.01	0.01	0.01	0.02	0.02	0.04	0.01	0.00	1.00	0.01	0.00
Frax. N.	0.01	0.01	0.00	0.01	0.01	0.01	0.00	0.00	0.01	1.00	0.00
Larix Lar.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00

2e MATRIX OF OCCURRENCES - WILLIAMS AND LAMBERT'S COEFFICIENT

	Acer	Quercus	Fagus	Tilia	Ulmus	Pinus	Ostrya	Carya	Populous	Fraxinus Nigra	Larix Laricina
Acer	148.827	766.999	612.501	269.908	103.971	1058.800	267.990	52.123	94.789	2025.274	159.242
Quercus	766.999	10.376	781.933	273.889	152.794	298.017	65.931	20.168	21.294	959.058	75.626
Fagus	612.501	781.933	132.545	568.699	244.794	679.429	425.533	88.194	132.406	2082.270	153.743
Tilia	269.908	273.889	568.699	447.994	26.202	445.211	0.980	0.885	2.889	323.430	29.407
Ulmus	103.971	152.794	244.794	26.202	1367.771	83.082	57.298	5.803	0.158	48.864	5.997
Pinus	1058.800	298.017	679.429	445.211	83.082	218.888	179.025	91.729	15.660	495.552	42.496
Ostrya	267.990	65.931	425.533	0.980	57.298	179.025	864.021	2.417	7.720	220.086	15.942
Carya	52.123	20.168	88.194	0.885	5.803	91.729	2.417	1598.097	3.569	37.155	2.579
Populous	94.789	21.294	132.406	2.889	0.158	15.660	7.720	3.569	1678.908	10.594	1.493
Frax. N.	2025.274	959.058	2082.270	323.430	48.864	495.552	220.086	37.155	10.594	880.135	6.465
Larix Lar.	159.242	75.626	153.743	29.407	5.997	42.496	15.942	2.579	1.493	6.465	1710.803

GLOSSARY

List of botanical names and English equivalents of arboreal species and generic groups referred to in the text.

Acer	Maple
Alnus	Alder
Betula	Birch
Carpinus	Blue Beech
Carya	Hickory
Cornus	Dogwood
Fagus	Beech
Fraxinus Americana	White Ash
" Nigra	Black Ash
Juglans	Walnut
Larix	Tamarack
Ostrya	Ironwood
Pinus	Pine
Populus	Poplar or Aspen
Prunus	Cherry
Quercus	Oak
Salix	Willow
Tilia	Basswood
Ulmus	Elm

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FIGURE 2: Potzger J. E., M. E. Potzger and J. McCormick, 1956. The Forest Primaeval of Indiana as recorded in the original U.S. Land Surveys and an evaluation of Indiana Vegetation. Butler University Botanical Studies, Vol. XIII, Figure 2, Page 98.

FIGURE 3: E. Bourdo Jr., A Validation of Methods used in Analysing Original Forest Cover. Doctoral Dissertation Series. Publication No. 11,252, Figure 20, Page 165.

FIGURE 4: Adapted from cadastral map of County of Brant, Dept. of Highways. Drawn by Hunting Survey Corp. Ltd., 1963.

FIGURE 5: Adapted from National Topographic Series, Brantford, Ontario, Street No. 40 p/1, East Half, 3rd Edition.

FIGURE 6 and 16 (underlay): Soil map of Brant County, Soil Survey by Dept. of Chemistry, O.A.C., Guelph, assisted by Central Experimental Farms Branch, Ottawa.

All other maps and diagrams are original.