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DETERMINING ECOLOGICAL REGIONS IN MICHIGAN BASED ON NATIVE TREE DISTRIBUTION USING GEOGRAPHIC INFORMATION SYSTEMS AND PRINICIPAL COMPONENT ANALYSIS

presented by

Sihui Wang

has been accepted towards fulfillment
of the requirements for the

Master of Arts	degree in	Environmental Design

Major Professor's Signature

27 Sept. 2013

Date

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By

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A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF ARTS

Environmental Design

2010

ABSTRACT

DETERMINING ECOLOGICAL REGIONS IN MICHIGAN BASED ON NATIVE TREE DISTRIBUTION USING GEOGRAPHIC INFORMATION SYSTEMS AND PRINICIPAL COMPONENT ANALYSIS

By

Sihui Wang

Designers, planners, scientists, and government agencies are interested in the organization and classification of the environment. This study derives ecological regions of Michigan based on the natural distribution of tree species native to Michigan by applying Geographic Information System and Principal Component Analysis. The data set includes 51 distribution maps of Michigan native trees. By applying Principal Component Analysis in Statistical Analysis Software, 10 principal dimensions are revealed with 10 accompanying regions explaining 84.9% of the variance. The 10 dimensions are Southern Mixed Vegetation Region, White Oak-NannyBerry Region, Hawthorn Patches, Striped Maple-Black Cherry Region, Tamarack Region, Sumac-Locust Region, Hickory-Honey Locust Region, Elm Region, Oak-Hickory Region, and Oak Mixed Region. Issues related to general landscape planning guidelines and principles for future development are discussed for each region.

Key words: Landscape Ecology, Landscape Architecture, Geography, Regional Science.

ACKNOWLEDGEMENT

I am heartily thankful to my supervisor, Dr. Jon Burley, whose encouragement, guidance and support from the start to the completion enabled me to develop an understanding of the subject. It is also an honor for me to show my gratitude to Dr. Patricia Machemer and Dr. Jiaguo Qi who enlightened me by posing questions and being inspirational in the whole process. I would like to thank teachers and friends both at Michigan State University and Nanjing Forestry University who sincerely helped me to finish all the work. Lastly, the deepest care and support from my parents make this work possible. I truly thank them for their distance support.

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INTRODUCTION

Scholars are interested in the spatial patterns of the environment. It is believed these patterns are important to effectively and efficiently manage and plan the environment.

Investigators have defined regions by using different methods. They often select several variables to classify the landscape. Since Ian Mcharg's "overlay" approach, a variety of spatial classification methods have been developed (Commission for Environmental Coorperation, 1997; Omernik, 1995; Omernik, 1987; Albert *et al*, 1986; Hopkins, 1977; Udvardy, 1975; Hills, 1966). Computer-aided analysis studies and statistical analysis facilitate a more scientific approach is possible. This study embraces statistical analysis combined with geographic information science technology to apply Michigan native tree distribution to derive landscape regions.

Literature review

Modern Era of Landscape Classification

Contemporary landscape classification starts from the beginning of the 20th century. Herbertson (1905) developed major natural regions which also considered human activity as a variable. The method classifies the regions by employing distinct characteristics, thereby, creating areas of relative homogeneity. Manning (1913) is attributed as the first person who interpreted the land data by overlaying the maps (Steinitz *et al*, 1976). Since then, map overlay techniques have been introduced in the landscape profession, with more and more factors being employed for land use analysis (Steinitz *et al*, 1976). In 1975, Udvardy (1975) presented a classification of biogeographical provinces of the world for purpose of conservation. Nelson *et al* (1978) stressed the importance of developing classifications for land and resources. Expressing land capability is often emphasized for developing a unifying and common classification method. Ecoregions have been classified by different scales in North America and United States. For example, Bailey (1976) developed a map of ecoregions of the United States employing climate, potential natural vegetation, soils and land surface forms as controlling factors. Omernik (1987) developed ecoregions of the conterminous United States, and then he processed more ecological network maps for different ecological uses. Denton and Barnes (1988) conducted an ecological climatic classification of Michigan. They focused on the significant variables of tree growth and survival. A unified classification was made combining the climatic information with physiographic patterns. The Commission for Environmental Cooperation (1997) divided North America into major continental regions for better evaluation of nature, conditions and trend of ecosystems. Albert and Denton (1986) developed regional landscape ecosystems of Michigan. At times, these classification systems rely upon the skill and knowledge of the investigator, organizing areas into regions heuristically.

Classification Method

Several methods have been devised to generate regions. Many factors and variables have been examined to construct regions (Bryan, 2003; Mcharg, 1971). Ian Mcharg (1971) noted that overlay maps could lead to more reasonable analysis of land use. He believed this could better achieve the goals of science, nature, aesthetically pleasing and most importantly for human use. Through changing the transparency of maps, "suitability maps" are prepared for integrated analysis. This method was linked the ecology discipline and influenced the direction of land use planning development. Gersmehl (1972) discussed the maps interpretation. In his view, different mapping method lead to different vegetation maps which inevitably cause information loss. Different methods are discussed and suggestions for mapping and classification generation are provided. He emphasized the importance of scales in classification. Back in 1980s, with the advancements in ecology, more and more investigations have been completed defining landscape areas. Bailey *et al* (1978) reviewed the land and resource classification method from the definition and perspective method. Through comparing single factor and multifactor classification, aggregation and subdivision, single level and hierarchical classification, conclusions of single purpose classification could be generated by employing all the related biotic and abiotic factors. Forman and Gordon (1981) defined landscape as a heterogeneous land area composed of a cluster if interactive ecosystems that is repeated in similar form throughout. With more and more research, the study on structure, function and change of the landscape unit define the major characteristics. Both biotic factors and abiotic factors have been examined to determine the ecoregions (Bailey, 2002). Also, Bailey (2002) noted the methods to differentiate other land divisions and ecoregion.

Considering the complexity and changing of a complete landscape, the process of classification is a challenge for all the investigators. Abler *et al* (1971) explored the classification from a geographic view. In his opinion, the spatial organization should be divided into different groups by population, several redundant variables or similar observations. Bailey (1985) explored the influence of different scales of ecosystem mapping. He maintained the idea of developing hierarchical and distinct regions which differs significantly to derive particular management objectives. Also, many other regional ecological land classifications have been investigated (Li and Yeh, 2004; Carter *et al*, 2000; Blankson and Green, 1991).

Midwest Classification Method

Within the Midwest area of the United States, several investigators have attempted to create classification system of homogeneous areas. Denton and Barnes (1988) conducted the ecological climatic classification by using a quantitative approach. They stated they used principal component analysis and cluster analysis. The final product implied that a climatic factors-based classification was significant to the tree growth in State of Michigan. Cleland *et al* (1997) created a hierarchical framework of ecological units based on association of ecological factors on different geographic scales. Categories and scales are discussed to meet human needs. Host *et al* (1996) use Geographic Information System (GIS) and multivariate statistical analysis to integrate the climate, physiographic and edaphic databases to produce the classification of ecological regions in Wisconsin.

In 1930, Marschner (1930) developed his Minnesota classification map depending on the field notes from original land surveys. In 1946, eight different vegetation categories were revealed in this map. In the 1960s, Trygg (1964) produced several ecosystem maps for the Midwest, but by using township plat maps rather than dominant tree species distribution. He studied the land use and natural resources from historical perspective. Barnes *et al* (1982) employed a systematic method: physiographic-soil-vegetation as the main factors to develop forest site classification in Upper Peninsula of Michigan. They indicated that the single factor orientated classification is lacking due to the complex and integration of ecological system. They also developed recommendations for each ecological region. For their physiographic and soil dominant study, vegetation is secondary. Mapping is introduced as the mainstream for generating regions. Albert *et al* (1986) developed regional landscape ecosystems of Michigan. By using the previous Denton's study, Albert succeeded in combining the physiographic information with his generation process. Stefanacci (1997) performed a regional environmental classification map for Michigan by using a set of variables and GIS. She determined the variables should be expressed in three dimensions: climate, general environment, and soil properties. She used these three dimensions to create homogeneous regions. Albert and Comer (2008) tried to interpret the land cover type boundaries and associated forms by plotting information from land surveys. With assistance of GIS, they decided to delineate different types by the dominant tree species and associate land forms. Also, they considered disturbance as a variable. They expressed only 60% confidence for some areas in their map. Santer (1993) developed landscape regions based on political boundaries and he specifically talked about the overlapping zones. He attempted to modernize boundaries for better planning for people life and center city development.

Other Classification Efforts

With the development of mapping technology, the uses of GIS-based landscape classification have become an important part of the assessment of landscape and future landscape management. Brabyn (2009) conducted landscape character classification in New Zealand by using Geographic Information System. Driven by a concern for practical management based on landscape change, Brabyn combined all the physical features on the land and people's perception together. Bastian (2000), concluded that the use of complex reference units, the assessment of numerous and diverse landscape functions, the transformation of natural scientific facts to categories of human society, and the elaboration of environmental goals (landscape visions) are essential characteristics of a genuine holistic approach in landscape ecology. Lioubimtseva and Defourny (1999) generated a terrestrial framework of European Russia; they are more concentrated on the hierarchical categories with a validation of small scale area. Gulinck *et al* (2001) also used GIS-based approach to build a landscape classification. They attempted to evaluate the value of landscape by introducing different variables and characteristics of different regions in Madrid, Spain. Litton (1968) studied the nature of forest landscape as a visual entity. Spatial definitions for different physical landscape features are identified. He categorized the landscape into compositional types from human perspection. Kupfer and Franklin (2000) incorporated data on forest type, soil and topography to identify the ecological units but the results showed that forest type are not randomly associated with soil or topography but with forest dominance species.

Plant Distribution and Mapping

Determining the ecoregions by assessing the natural environmental factors have been studied. The importance of vegetation has been studied by various scholars. Tivy (1971) mentioned that competition and stability are the key factors controlling the shaping of vegetation groups. The distribution of plant communities is determined by a corresponding mosaic of habitats. His view fundamentally established the formation of plants from a biogeographic view. Damman (1979) investigated the role of vegetation analysis in land classification and the habitat. He maintains the perspective of linking vegetation and climate to decide the environmental factors controlling the site classification. Küchler and Zonneveld (1988) studied the vegetation mapping methods. From their perspective, vegetation could reflect the general environment quality. They believed the plant distributions are closely correlated with biotope. Consequently, investigations related to the forest environment have been conducted. Sakai *et al* (1985) studied the succession changes in an aspen forest in Lower Michigan; they maintained spatial patterns of tree species in forested landscapes are regulated by a variety of environmental and disturbance factors. Schwarz *et al* (2003) tried to find the role of neighborhood factors in determining spatial patterns of abundance of dominant tree species, and they suggested that neighborhood factors significantly influence patterns of tree species in forested landscapes such as elevation, disturbance, and species abundance pattern. Fellows and Morse (1991) created and tested models to ascertain the ecoregional distribution of native plant taxa, and the relationships of county boundaries and native plant distribution. Although they tested their models about the taxa and ecoregion boundary fuzziness, they assumed ecoregions are not homogeneous.

In order to better comprehend the correlation of forest distribution and controlling factors, many scholars have developed models and research. Davis (1981) studied the quaternary history and the stability of forest communities. She suggested that forest communities in temperate regions are chance combinations of species without a history. She also suggested the species arrival time which is a clear reflection of regional patterns. Dodge (1989) proved the relationship between buried outwash and upland forest composition for a large area. Tremblay *et al* (2005) studied the tree dynamics after a severe ice storm in the forest ecosystem.

There is several immigration or emigration factors which may influenced the distribution of vegetation. West *et al* (1981) presented general concepts and application of forest succession.

Principal Component Analysis Study

Statistical analysis in the search for homogeneous areas has been used for several decades (Hendrix *et al*, 1988; Castillo, 1988). For my study, Principal Component Analysis (PCA) is the main approach for data analysis and reduction. Since the existing dataset is multidimensional, it is necessary to conduct PCA to investigate the variables. Berry and Horton (1970) employed 60 variables, developed scattered diagrams to investigate the dimensions of urban systems in Britain and India. The emphasis is given on the dimension interpretation which explained most of the variance. Doxiadis (1966) conducted his research in Great Lakes Area by employing PCA as the main method. Since the multivariate analysis is needed, he used as many variables as he could to generate the strongest dimensions. Pielou (1984) stated each step to conduct PCA. Her work is widely employed by others for ecological research. Burley (1995a) employed PCA investigating regions. He plotted all the data and no distinct classes are identified. Zuur *et al* (2007) talked about the "broken stick" role in viewing eigenvalues. Implication and structure could be revealed by employing Principal Component Analysis (Bryan, 2003). Burley *et al* (2009) employed Principal Component Analysis to seek for the latent structure of all the citation resources, revealing thirteen dimensions. In the article, Burley discussed the significance of eigenvalues. Eigenvalues over 1.0 are considered as significant. This study provides a reasonable statistical analysis. Machemer *et al* (2008) studied the model of ideal community, using multivariate statistics to identify the element and preference pattern. In addition, regression analysis is introduced to examine the relationship of variables.

In the GIS field, PCA has been utilized for a while to assess the complexity of landscape. Burley and Brown (1995) combined GIS and Principal Component Analysis together to generate suitability maps to reduce the complexity and define land use probability. Avena *et al* (1999), Li and Yeh (2004) employed PCA analysis and reduce duplication in the remote sensing images. Owen *et al* (2004) employed 27 attributes from land cover data to derive eight significant dimensions for land classification in UK Midland metropolitan area. Similarly, this study also employs gridded land features for quantitative investigations. Cifaldi *et al* (2004) employed 25 variables in landscape pattern metrics to reveal the latent structure of principal component and variables. Eigenvectors over 0.55 or –0.55 are marked as strongly correlated. The relationship between pattern metrics and land cover type is studied. Kliskey (2000) employed PCA and GIS to generate suitability maps for recreation management.

Landscape Ecology Principles in Regional Land Use Planning

This study explores the potential of using trees to define the ecoregion in State of Michigan. For the future application of this study, it is necessary to address the significance of proper landscape ecology principles in a regional scale which will help the land use planning.

Many efforts have covered ecological design and many principles have been put forward. Since the nature process and environmental issue introduced in the landscape and regional planning, Mcharg (1971) revolutionarily developed rational process of landscape design by his model which contained natural process and all the related elements. Since then, concerns about integrated planning and design process began to be popular and more and more similar modes have been introduced into projects. Integrated planning methods have been conducted by many scholars (Bellmann, 2000). Dramstad *et al* (1996) discussed basic landscape ecology concepts and principles, which also introduced several examples to illustrated ecological planning concepts. Dorney and Hoffman (1979) discussed hierarchical biotic or biogeography landscape classification system in varying scales in Ontario, Canada. He simply introduced biotic, abiotic and historic-cultural categories which could employ overlay technique for further research. Bailey *et al* (2002) expanded his own ecoregion theory by combining all the biotic and abiotic factors together. Specifically, he argued management strategies for ignoring ecoregional patterns. Mladenoff *et al* (1994) used GIS and spatial analysis to develop a landscape design for better maintain old forest. Leitão and Ahern (2002), Blaschke (2006) both introduced landscape ecology concepts and metrics into landscape planning and land use analysis.

Recently, ecological planning is more concerned about human actions and natural process (Ndubisi, 2002). Spatial pattern distribution has been taken into consideration in the design process (García-Abad *et al*, 2010; Li and Yeh, 2004; Gunn, 1988). They both brought landscape ecology principles into application.

In Midwest area, comprehensive studies have been conducted for better understanding this area. Lewis (1964) concluded quality corridors in Wisconsin with collaboration from other professions. He pointed out the linear distribution of resources and proposed preservation plan is generated. Lewis (1969) investigated the upper Mississippi River. With phases in process, he found out ecological problems, analyzed the relationship between pattern and corridors, and identified all the landscape characteristics. According to his theory, human impact will have big impact on natural resources, it is crucial to identity all the resource patterns which acting as form determinants. Blank *et al* (1966) conducted research focused on the tourism and recreation management in Michigan's Upper Peninsula. With the identities of regional characteristics and interpretation of growth, he generated region classification maps for better understanding and concepts for management. He successfully interpreted all the distinct eight sub-regions and developed correspondingly guidelines for people recreation use. This is a good approach for resource identification and protection for better land use planning according to the local features. Beyer *et al* (1997) introduced the participation of groups in managing the ecosystem in Eastern Upper Peninsula. Lewis (1996) summed up his study in upper Midwest project. From his point of view, different pattern analysis is the important in planning process. With collective information about the environmental corridors and local personality, the intrinsic desire to protect natural area and rational development strategies will come out. He emphasized the necessity of incorporate human pattern and landscape pattern to achieve the sustainable goal.

Statement of Problems

While in Michigan, a number of investigators have defined regions based upon biophysical data (Albert *et al*, 1986; Stafanacci, 1997). However, no investigator has considered employing the distribution of trees to generate regions and to let the statistical results reveal the structure. I would like to determine if it is possible to generate the regions and examine the revealed spatial patterns based upon Michigan tree distributions by using statistical means. This statistical method may help to view the structure and develop new ideas and issues related to design. I would also like to explore landscape planning issues associated with the findings.

Goals and Objectives

1. Select the tree species which are native to Michigan

a. Examine the tree species which are native to Michigan

b. Convert paper maps to digital maps

2. Statistically analyze the data, use SAS software to select dimensions to define regions.

a. Sample digital maps and export into a text file

b. Convert text file in a SAS dataset and conduct Principal Component Analysis on the whole data set

c. Determine significant dimensions

d. Produce maps based upon significant dimensions

e. Define boundaries of each dimension

3. Define and describe each region

a. Define the boundaries of ecoregions

b. Name the region

c. Describe the regions

4. Discuss the result of the revealed patterns

METHODS

Study Area

The study area I choose is the State of Michigan. Located in the mid-northern part of United States, Michigan is unique for the natural landscape with the influence of the Great Lakes. For my study area, it could represent a fair number of homogeneous landscape areas.

Geography

The Great Lakes influence the surrounding landscape. The Great Lakes bordered two peninsulas forming the State of Michigan. Due to the glacial history, the drained plain occupied large portions of Lower Peninsula (Wood, 1914). From east to west, the Great Lakes that border Michigan are Lake Erie, Lake Huron, Lake Michigan and Lake Superior. Within the Great Lakes area, there are many islands. The Upper Peninsula, is hilly and covered in woodland (Albert *et al*, 1986).

Climate

Because water's heat retention capacity is higher than land, the Great Lakes have a big influence on the climate of Michigan. They generally moderate the temperature of Michigan (Sommers, 1984). They cool the weather in the summer time, reducing the effects of a hot sun; in the winter time, they warm the air, mitigating the effects of a cold winter. With both the warm humid wind from Mexico and cold dry wind from Arctic, Michigan has highly changeable weather. Michigan has four distinct seasons. Also, the humidity from the Great Lakes also brings substantial precipitation in both summer and winter (Schaetzl, 2009). Compared to other environments of the same latitude places, Michigan enjoys a milder climate. In summer, the inner basin of the Lower Peninsula area could benefit the rain fall. While in winter, the moisture from the lakes will create heavy snow in some areas. Lake-effect snow is heaviest on the north west of the Lower Peninsula which receives over 100 inches of snow annually (Davis, 1964). During the winter, the temperature of the lakes continues to drop while keeping the land more warm. Ice frequently covers Lake Erie but seldom fully covers the other lakes.

Short View of Tree History in Michigan

Michigan has a long history of plant immigration history (Davis, 1981). After the glacial era, trees began moving back in Michigan while the weather was getting warm and the ice was melting. When the original American Indians were living in Michigan, most of the land was covered with forests which were great resources for the first settlers and immigrants from Europe. Pine is the most common species. Since 1800s exploitation by French explorers, the logging era started (Santer, 1993). Industries along the river and shore were developed (Schaetzl, 2009). Tree species like white pine were used for railroads and sawmills. Forest fires occurred often, brought significant landscape change in Michigan. A conservation era is followed for preservation (Santer, 1993). Beech maple forest is widely spread in southern Lower Peninsula (Bailey, 1983). Hardwood wetlands include American elm, black ash, red maple and yellow birch occurred primarily in the southern half of Lower Michigan. Dominants with sugar maple, beech (except for western Upper Peninsula), yellow birch, basswood, hemlock and occasionally red maple, red oak, white ash, and white pine are detected in northern half of Lower Michigan and

Upper Michigan; Oak-Hickory Forest with dominants of black, white, and red oaks, shagbark and pignut hickories, and black cherry occurred in the southern half of Lower Michigan; Oak Savanna, Swamp, Marsh and Bog with dominant species of tamarack and black spruce are also present (Barnes and Wagner, 1981).

General Lands Use in Michigan

Currently, the population of Michigan is about 10 million people and a large portion of the residents occupy the southern part of the Lower Peninsula. Since forests arrived after the glacial era, half of the State of Michigan was covered with mature forest and prairies. Still today, forest land is the biggest portion of land. Secondly, agriculture in State of Michigan is a significant land type. In the south, the land is being converted to urban purposes (Michigan Society of Planning Officials, 1995). In northern Michigan, more and more land is used for recreation due to the growing tourism (Blank *et al*, 1966). In 1995, Michigan society of Planning Officials developed a report of land use trends in Michigan (Michigan Society of Planning Officials, 1995).

Data Collection

Gary Hightshoe (1978) presented Native Trees for Urban and Rural America, containing USDA mapping data of each specific tree. These maps were manually entered into Map Factory (MF Works, 2002). This GIS program is a grid cell system. In this study, each cell stands for 1 square kilometer. Fifty-one trees were selected in this study (Table 1). Each tree map contained tree numeric values with the numeral one representing the distribution in State of Michigan. Another value represents the area in

State of Michigan where the tree is not present. The third one stands for the area outside the study. Once the 51 maps were completed (Figure 1), the raster images were sampled (every 400th grid cell) into a numerical format that allowed for more comprehensive data processing.

Figure 1, Tree Distribution Map (*Abies balsamea* (L.) Mill.)

Table 1 Tree List

Variable	Tree
P1	*Abies balsamea* (L.) Mill.
P2	*Abies concolor* (Gordon) Lindley ex Hildebrand
P3	*Acer negundo* Carolus Linnaeus
P4	*Acer pensylvanicum* L.
P5	*Acer saccharinum* L.
P6	*Acer saccharum* Marshall
P7	*Aesculus glabra* Willd.
P8	*Asimina triloba* (Linnaeus) Michel Félix Dunal
P9	*Betula papyrifera* Marsh.
P10	*Carpinus caroliniana* Walter
P11	*Carya alba* (L.) Nutt.
P12	*Carya ovata* (Mill.) K.Koch
P13	*Castanea dentata* (Marsh.) Borkh.
P14	*Celtis occidentalis* Linnaeus
P15	*Cercis canadensis* L.
P16	*Cornus florida* L.
P17	*Crataegus punctata* Jacq.
P18	*Euonymus atropurpureus* Jacq.
P19	*Fagus grandifolia* Ehrh.
P20	*Fraxinus Americana* L.
P21	*Gleditsia triacanthos* L.
P22	*Gymnocladus dioicus* (L.) K. Koch
P23	*Hamamelis virginiana* L.
P24	*Juglans nigra* L.
P25	*Juniperus virginiana* L.

Table 1 Tree List (Continued)

Variable	Tree
P26	*Larix laricina* (Du Roi) K. Koch
P27	*Liriodendron tulipifera* L.
P28	*Nyssa sylvatica* Marsh.
P29	*Ostrya virginiana* (Mill.) K.Koch
P30	*Picea glauca* (Moench) Voss
P31	*Picea mariana* (Mill.) Britton, Sterns & Poggenburg
P32	*Pinus strobes* L.
P33	*Pinus resinosa* Sol. ex Aiton
P34	*Platanus occidentalis* L.
P35	*Populus deltoides* W.Bartram ex Marshall
P36	*Prunus americana* Marsh., 1785[1]
P37	*Prunus serotina* Ehrh.
P38	*Ptelea trifoliate* L., 1753[1]
P39	*Quercus alba* L.
P40	*Quercus ellipsoidalis* E.J.Hill
P41	*Quercus macrocarpa* Michx.
P42	*Quercus bicolor* Willd.
P43	*Rhus typhina* L.
P44	*Rhus copallina* L.
P45	*Salix nigra* Marshall
P46	*Salix discolor* Muhl.
P47	*Sassafras albidum* (Nutt.) Nees
P48	*Thuja occidentalis* L.
P49	*Ulmus americana*L.
P50	*Viburnum lentago* L.
P51	*Zanthoxylum americanum* Mill.

They were sampled because for any one map, there are nearly 1 million data cells. For the statistical analysis, it is better to sample them in a 20 by 20 cell reduction. The sample maps are exported to a text file. Subsequently, it is necessary to format the text file to be imported for the further statistical analysis. In the text file 10 numbers per line were set, with a total of 1183 numbers. The text file was prepared with statistical syntax to be ready by Statistical Analysis Software 9.1 (SAS, 2004). By using the principal component analysis procedure, statistical results are produced, illustrating the relationships of the tree species to each other in the State of Michigan. Statistically this is presented with eigenvalues of the covariance matrix and eigenvectors.

Statistical Analysis

Each variable (a tree distribution map) were standardized to a mean of 0.0, standard deviation of 1.0. Then principal component analysis based upon the covariance matrix (Johnson and Wichern, 1988) was conducted upon the maps. The analysis produced eigenvalues which represent independent dimensions. The eigenvalues show the latent strength correlated to each dimension. Eigenvalues for standardized data with values over 1.0 were considered significant dimensions (Burley and Brown, 1995). Significant dimensions were selected for further analysis by examining the eigenvector coefficients of each dimension. Eigenvector coefficients numerically illustrate the correlation between a variable (tree species) and the dimension. The eigenvector coefficients would range between -1.0 and 1.0. Values near 0 indicate low correlation with the dimension while values near -1.0 and 1.0 indicate strong association. In this study, eigenvector coefficients with a value greater than or equal to 0.400 or less than -0.400 were considered to be strongly associated with the dimension (Burley and Brown, 1995).

Map Generation and Defining Regions

Each principle maps is produced with the coefficient of the eigenvector. For example, each principle map is generated by the following equation: Each Principle map= (Eigenvector Coefficient 1* Map1) + (Eigenvector Coefficient 2* Map2) +...... (Eigenvector Coefficient 51* Map51). Gradient maps are generated as a result of conducting the equations in MF works. Ten composite maps are examined in Adobe Photoshop by using the transparency of each map overlaid with each other. The transparent layers facilitate drawing boundaries and constructing regions.

Results

Summarization of Dataset

This study revealed that there are eight dimensions with eigenvalues greater than 1.0, two dimensions are smaller than 1.0 though near 1.0 (Table 2). Original tree distribution maps and other statistics are used to describe the characteristic of regions.

Table 2 Eigenvalues

Dimension	Eigenvalue	Cumulative
1	22.7208758	0.4939
2	4.7332939	0.5968
3	2.7442247	0.6565
4	1.9511269	0.6989
5	1.5699952	0.733
6	1.3007942	0.7613
7	1.1307666	0.7859
8	1.0071789	0.8078
9	0.9789782	0.8291
10	0.9145375	0.849
11	0.7299992	0.8648
12	0.5183816	0.8761
13	0.5007331	0.887
14	0.4636291	0.8971
15	0.385774	0.9054
16	0.356027	0.9132
17	0.3508642	0.9208
18	0.3265314	0.9279
19	0.3082048	0.9346
20	0.2876939	0.9409
21	0.2668884	0.9467
22	0.2264776	0.9516
23	0.2023373	0.956
24	0.1972509	0.9603
25	0.1842241	0.9643

Table 2 Eigenvalues (Continued)

Dimension	Eigenvalue	Cumulative
26	0.1669631	0.9679
27	0.1531902	0.9712
28	0.1457118	0.9744
29	0.121828	0.9771
30	0.1099728	0.9794
31	0.1023961	0.9817
32	0.0975504	0.9838
33	0.0894844	0.9857
34	0.0804008	0.9875
35	0.0754597	0.9891
36	0.0727294	0.9907
37	0.0678404	0.9922
38	0.0606565	0.9935
39	0.0595757	0.9948
40	0.0495867	0.9959
41	0.0459481	0.9969
42	0.0435468	0.9978
43	0.0386351	0.9987
44	0.0352338	0.9994
45	0.0265016	1
46	0	1
47	0	1
48	0	1
49	0	1
50	0	1
51	0	1

Data Reduction

Eigenvalues which are greater than 1.0 are recognized significant dimension (Burley and Brown, 1995). In this study, dimension 9 and dimension 10 are also selected for future examination.

Table 3: Eigenvectors of Dimension 1-5

Variable	Prin1	Prin2	Prin3	Prin4	Prin5
P1= Abies balsamea	-0.185365	-0.088831	0.159694	-0.027649	0.064628
P2= Abies concolor	-0.156267	-0.209425	-0.006107	0.060227	0.027955
P3=Acer negundo	0.180688	0.112274	-0.137135	0.010307	-0.055991
P4=Acer pensylvanicum	-0.041788	-0.107271	0.010336	0.624431	0.011029
P5=Acer saccharinum	0.177322	0.094488	-0.155594	0.020643	-0.064378
P6=Acer saccharum	0.000000	0.000000	0.000000	0.000000	0.000000
P7=Aesculus glabra	0.078921	-0.160259	0.203554	-0.095415	-0.174251
P8=Asimina triloba	0.172362	-0.181026	0.110089	-0.008079	0.076859
P9=Betula papyrifera	-0.149232	0.187621	-0.164108	0.042462	-0.076907
P10=Carpinus caroliniana	0.000000	0.000000	0.000000	0.000000	0.000000
P11=Carya alba	0.027428	-0.052666	0.080447	-0.031167	-0.215500
P12=Carya ovata	0.189270	0.039481	-0.151153	0.040643	-0.024252
P13=Castanea dentate	0.030716	-0.063949	0.095126	-0.014217	-0.583507
P14=Celtis occidentalis	0.185063	-0.026736	-0.123786	0.052515	0.011114
P15=Cercis canadensis	0.148326	-0.202747	0.160260	-0.067357	0.095685
P16=Cornus florida	0.190007	0.011563	-0.145749	0.048784	-0.012238
P17=Crataegus punctata	0.103533	0.281780	0.288915	0.086745	-0.000583
P18=Euonymus atropurpureus	0.149728	-0.192610	0.171916	-0.028341	0.035561
P19=Fagus grandifolia	0.079174	0.236150	0.271947	0.176118	0.000656
P20=Fraxinus americana	0.101329	0.249111	0.248371	0.284515	0.043681
P21=Gleditsia triacanthos	0.080405	-0.144173	0.153399	-0.088070	0.194276
P22=Gymnocladus dioicus	0.171724	-0.137203	0.062362	0.001809	0.049074
P23=Hamamelis virginiana	0.125699	0.251548	0.207184	-0.118108	0.080171
P24=Juglans nigra	0.191715	-0.012757	-0.133316	0.046041	0.002583
P25=Juniperus virginiana	0.173040	-0.177070	0.092792	-0.005242	0.071003
P26=Larix laricina	-0.027618	0.096169	-0.149041	-0.004832	0.642275

Table 3: Eigenvectors of Dimension 1-5 (Continued)

Variable	Prin1	Prin2	Prin3	Prin4	Prin5
P27=Liriodendron tulipifera	0.180660	-0.046772	-0.070795	0.033054	0.008853
P28=Nyssa sylvatica	0.187839	-0.046162	-0.089927	0.046724	0.027528
P29=Ostrya virginiana	0.000000	0.000000	0.000000	0.000000	0.000000
P30=Picea glauca	-0.156267	-0.209425	-0.006107	0.060227	0.027955
P31=Picea mariana	-0.167603	-0.066796	0.181695	-0.014944	0.055967
P32=Pinus strobus	-0.129323	0.209457	-0.219443	0.042374	0.024741
P33=Pinus resinosa	-0.190310	-0.001485	0.131442	-0.037074	0.006011
P34=Platanus occidentalis	0.179966	0.072591	-0.108658	0.003216	-0.019888
P35=Populus deltoides	0.184028	0.087386	-0.159496	0.026399	-0.064251
P36=Prunus americana	0.156976	-0.160083	0.113686	-0.019359	0.038872
P37=Prunus serotina	0.057120	0.106380	-0.025451	-0.624116	0.015940
P38=Ptelea trifoliata	0.175820	-0.132735	0.032874	0.004592	0.056044
P39=Quercus alba	0.124016	0.283643	0.211480	-0.139581	0.030154
P40=Quercus ellipsoidalis	-0.002048	0.022658	0.153693	0.076685	0.137970
P41=Quercus macrocarpa	0.154508	-0.178772	0.122020	0.010060	0.089191
P42=Quercus bicolor	0.189559	-0.046682	-0.103741	0.052738	0.023086
P43=Rhus typhina	0.000000	0.000000	0.000000	0.000000	0.000000
P44=Rhus copallina	0.076688	-0.034523	0.026078	0.027288	-0.171639
P45=Salix nigra	0.188477	-0.012278	-0.124355	0.042977	0.006576
P46=Salix discolor	0.000000	0.000000	0.000000	0.000000	0.000000
P47=Sassafras albidum	0.177834	0.028376	-0.071661	0.010328	0.004351
P48=Thuja occidentalis	-0.168049	0.153982	-0.069020	0.010643	-0.073591
P49=Ulmus americana	0.012088	0.034247	0.040472	0.054046	0.001367
P50=Viburnum lentago	0.105298	0.282933	0.282193	0.046161	-0.001879
P51=Zanthoxylum americanum	0.179663	0.083880	-0.133542	0.022037	-0.054734

Table 4 Eigenvectors of Dimension 6-10

Variable	Prin6	Prin7	Prin8	Prin9	Prin10
P1= Abies balsamea	0.044186	0.055741	-0.009551	0.009864	0.165670
P2= Abies concolor	0.054460	0.076526	-0.030087	0.053531	0.245054
P3=Acer negundo	-0.069840	-0.042189	0.012753	-0.012129	-0.161056
P4=Acer pensylvanicum	-0.029414	0.018199	0.012293	0.072133	-0.172517
P5=Acer saccharinum	-0.056716	-0.060484	0.020009	-0.016688	-0.191511
P6=Acer saccharum	0.000000	0.000000	0.000000	0.000000	0.000000
P7=Aesculus glabra	-0.462253	-0.077429	0.011365	0.264152	-0.099725
P8=Asimina triloba	0.148221	0.005866	-0.001343	-0.100836	0.003216
P9=Betula papyrifera	-0.098224	0.183799	-0.003841	0.108558	0.060587
P10=Carpinus caroliniana	0.000000	0.000000	0.000000	0.000000	0.000000
P11=Carya alba	-0.237101	0.594636	0.010288	-0.485791	-0.268586
P12=Carya ovata	-0.032901	0.054065	-0.002411	0.061179	0.017381
P13=Castanea dentate	0.208645	-0.165477	0.004516	0.243448	0.129348
P14=Celtis occidentalis	0.010179	0.027149	-0.017761	0.108519	0.191110
P15=Cercis canadensis	-0.059467	-0.087650	-0.005393	-0.184701	0.016484
P16=Cornus florida	-0.012952	0.063640	-0.008044	0.073287	0.067565
P17=Crataegus punctata	0.001952	-0.012399	-0.017162	-0.038606	0.139298
P18=Euonymus atropurpureus	0.009415	0.020331	0.012861	0.026082	-0.137105
P19=Fagus grandifolia	-0.023511	-0.033394	-0.207032	-0.060390	0.163099
P20=Fraxinus americana	-0.046734	-0.047399	0.002598	-0.042007	-0.000935
P21=Gleditsia triacanthos	-0.403567	-0.316775	0.009453	0.264121	-0.134007
P22=Gymnocladus dioicus	0.103953	-0.014325	-0.003182	-0.125888	0.009878
P23=Hamamelis virginiana	0.022142	0.098272	0.013645	0.068154	0.079906
P24=Juglans nigra	0.015154	0.094552	-0.012480	0.074809	0.127801
P25=Juniperus virginiana	0.121370	0.004413	-0.007730	-0.114708	0.068461

Table 4 Eigenvectors of Dimension 6-10 (Continued)

Variable	Prin6	Prin7	Prin8	Prin9	Prin10
P26=Larix laricina	0.022295	-0.109755	0.007584	-0.061787	-0.107985
P27=Liriodendron tulipifera	0.045223	0.034003	-0.008301	0.020873	0.047812
P28=Nyssa sylvatica	0.033241	0.115315	-0.013138	0.063148	0.155981
P29=Ostrya virginiana	0.000000	0.000000	0.000000	0.000000	0.000000
P30=Picea glauca	0.054460	0.076526	-0.030087	0.053531	0.245054
P31=Picea mariana	0.113586	0.130928	0.009451	-0.032331	-0.058427
P32=Pinus strobus	0.142061	-0.063005	-0.015566	-0.103742	0.139491
P33=Pinus resinosa	0.004223	-0.064956	0.007279	-0.051573	-0.067997
P34=Platanus occidentalis	-0.059376	0.026229	0.008032	0.008235	-0.054270
P35=Populus deltoides	-0.042251	-0.050919	0.007496	-0.004475	-0.146955
P36=Prunus americana	0.018045	0.064100	0.000339	-0.061885	0.025489
P37=Prunus serotina	0.139379	0.090103	0.020593	0.084240	-0.014703
P38=Ptelea trifoliata	0.071191	0.048460	-0.010918	-0.067797	0.118295
P39=Quercus alba	0.052574	0.029700	0.013797	0.024696	0.014259
P40=Quercus ellipsoidalis	0.369136	0.402440	0.047978	0.566037	-0.413310
P41=Quercus macrocarpa	0.118817	0.050618	0.007383	-0.055437	0.013349
P42=Quercus bicolor	0.030571	0.114329	-0.015949	0.082564	0.174063
P43=Rhus typhina	0.000000	0.000000	0.000000	0.000000	0.000000
P44=Rhus copallina	0.462948	-0.395766	0.015239	-0.222926	-0.337393
P45=Salix nigra	-0.000787	0.107108	-0.012361	0.086620	0.134753
P46=Salix discolor	0.000000	0.000000	0.000000	0.000000	0.000000
P47=Sassafras albidum	-0.010926	0.021225	0.001603	-0.011421	0.000622
P48=Thuja occidentalis	-0.069622	0.004948	0.008852	-0.027652	-0.132235
P49=Ulmus americana	-0.012338	-0.012253	0.973654	-0.035703	0.117997
P50=Viburnum lentago	0.010979	-0.005629	-0.014621	-0.032328	0.137269
P51=Zanthoxylum americanum	-0.027407	-0.056691	0.006022	-0.018147	-0.129339

Table 3 and Table 4 show the results of eigenvector coefficients of fifty-one variables in ten selected dimensions. The eigenvector ranges from -1.0 to 1.0. Values near 0 indicate strong correlation exists between the variable and dimension while value near -1.0 or 1.0 means weak correlation. In this study, eigenvectors greater than or equal to 0.4 or -0.4 are signed for significant association. When one subject employs more than one significant eigenvector coefficients, a cross-dimension analysis is suggested. Weak association eigenvectors ranges either from -0.4 to 0.27 or 0.27 to 0.4.

The first ten dimensions explain approximately 84.9% variance of the data set, and dimension one explained 49% of variances. The first three dimensions did not produce the large group of associated variables. No significant eigenvector coefficients are detected. The fourth dimension is strongly associated variable 4 (*Acer pensylvanicum*) and variable 37 (*Prunus serotina*). Dimension five contains variable 13 (*Castanea dentata*) and variable 26 (*Larix laricina*). The sixth dimension contains variable 7 (*Aesculus glabra*), variable 21 (*Gleditsia triacanthos*) and variable 44 (*Rhus copallina*). The seventh dimension contains variable 11 (*Carya alba*) and variable 40 (*Quercus ellipsoidalis*). The eighth dimension contains solely variable 49 (*Ulmus americana*). The ninth dimension contains variable 11 (*Carya alba*) and variable 40 (*Quercus ellipsoidalis*). The tenth dimension comprises primary variable 40 (*Quercus ellipsoidalis*). Variable 40 is detected as a cross-dimension variable of dimension seven, nine and ten. Variables which are not showing correlations are identified as independent variables in each dimension. Weak correlation exists in dimension two with variable 17 (*Crataegus punctata*), 39 (*Quercus alba*) and 50 (*Viburnum lentago*). Dimension three contains weak association with variable 17 (*Crataegus punctata*) and variable 19 (*Fagus grandifolia*).

Dimension four contains variable 20 (*Fraxinus americana*)for weak correlation. Seventh dimension contains variable 21 (*Gleditsia triacanthos*) and 44 (*Rhus copallina*). Dimension nine contains variable 48 (*Thuja occidentalis*). Dimension ten contains variable 44 (*Rhus copallina*). In weak correlation recognition, variable 14 span dimension 2 and 3. Variable 44 span dimension seven and ten.

DISCUSSION

Region Location and Description

This study employed GIS-based map generating techniques and quantitative analysis to generate ecologically similar regions for the State of Michigan. The analysis was designed to examine native Michigan tree distributions, revealing the latent dimensions formed by the tree distributions. The results indicate 10 significant dimensions. This discussion interprets the findings of these ten dimensions when produced as maps in Michigan.

Figure 2, Dimension 1- Southern Mixed Vegetation Region

Dimension 1-Southern Mixed Vegetation Region

The eigenvalue of this dimension is 22.7 and explains 49.39% of variance. The area of this dimension is 34776 square kilometers and occupies 23.37% of the whole state. This continuous area is located in the southern part of Lower Peninsula. In order to derive the characteristics of environment, correlation between variables and dimension are investigated. Since there is no direct strong or weak correlation has been recognized, influences of variables are examined for their strength related to dimension. The eigenvector coefficients are divided into three main categories: Near to 1.0, near to -1.0 and near to 0. Near to 1.0 indicates positively association with dimension while -1.0 indicates negatively associates the region. Eigenvectors which are equal or near to 0 means the variable has little influence on the formation of region. The same category method is employed for other dimensions. Once the variables are recognized, the results could reflect the general environment factors in this area.

Table 5 Eigenvectors of Dimension 1

Variable	Eigenvector	Correlation
P1= Abies balsamea	-0.185365	-
P2= Abies concolor	-0.156267	-
P3=Acer negundo	0.180688	+
P4=Acer pensylvanicum	-0.041788	0
P5=Acer saccharinum	0.177322	+
P6=Acer saccharum	0.000000	0
P7=Aesculus glabra	0.078921	0
P8=Asimina triloba	0.172362	+
P9=Betula papyrifera	-0.149232	-
P10=Carpinus caroliniana	0.000000	0
P11=Carya alba	0.027428	0
P12=Carya ovata	0.189270	+
P13=Castanea dentata	0.030716	0
P14=Celtis occidentalis	0.185063	+
P15=Cercis canadensis	0.148326	+
P16=Cornus florida	0.190007	+
P17=Crataegus punctata	0.103533	+
P18=Euonymus atropurpureus	0.149728	+
P19=Fagus grandifolia	0.079174	0
P20=Fraxinus americana	0.101329	+
P21=Gleditsia triacanthos	0.080405	0
P22=Gymnocladus dioicus	0.171724	+
P23=Hamamelis virginiana	0.125699	+
P24=Juglans nigra	0.191715	+
P25=Juniperus virginiana	0.173040	+

Table 5 Eigenvectors of Dimension 1(Continued)

Variable	Eigenvector	Correlation
P26=Larix laricina	-0.027618	0
P27=Liriodendron tulipifera	0.180660	+
P28=Nyssa sylvatica	0.187839	+
P29=Ostrya virginiana	0.000000	0
P30=Picea glauca	-0.156267	-
P31=Picea mariana	-0.167603	-
P32=Pinus strobus	-0.129323	-
P33=Pinus resinosa	-0.190310	-
P34=Platanus occidentalis	0.179966	+
P35=Populus deltoides	0.184028	+
P36=Prunus americana	0.156976	+
P37=Prunus serotina	0.057120	0
P38=Ptelea trifoliata	0.175820	+
P39=Quercus alba	0.124016	+
P40=Quercus ellipsoidalis	-0.002048	0
P41=Quercus macrocarpa	0.154508	+
P42=Quercus bicolor	0.189559	+
P43=Rhus typhina	0.000000	0
P44=Rhus copallina	0.076688	0
P45=Salix nigra	0.188477	+
P46=Salix discolor	0.000000	0
P47=Sassafras albidum	0.177834	+
P48=Thuja occidentalis	-0.168049	-
P49=Ulmus americana	0.012088	0
P50=Viburnum lentago	0.105298	+
P51=Zanthoxylum americanum	0.179663	+

Table 5 shows the new category of eigenvectors. From the chart we could imply positively associated tree spices and negatively associated trees. Trees of Genus *Abies, Picea, Pinus* tend to grow in the northern area which are negatively associated. By examining the habitat of distributed trees, knowledge of this region is gained. Geographically, this area is located in the most southern part of Michigan, enjoys warm climate. Based on all the observation dataset, it is not easy to generate a united region with dominated species; it is more like a mixed region. The land use of this region is mainly for agriculture, which could date back to the history of pre-settlement (Santer, 1993). It is worth mentioning that the east side of this region has a large proportion of urban areas which has the most human activity (Stefanacci, 1997).

Figure 3, Dimension 2-White Oak-Nannyberry Region

Dimension 2: White Oak-Nanny Berry Region

The eigenvalue of this dimension is 4.73, explains 10.29% of the variables: The area of this dimension is 19644 square kilometers and it occupies 13.2% of the whole state. This dimension is located northern than the first dimension with scattered patches north of the boundaries. Two weak positive correlations are detected by Variable 39 (*Quercus alba*) and 50 (*Viburnum lentago*). Genus *Quercus* are common in drier climate and sandy loam soil, and no shade-tolerance. Genus *Viburnum* is often growing in wet soil at the border of forest. Several patches north of the main matrix also comprise portions of this dimension (Barnes and Wagner, 1981).

Table 6 Eigenvectors of Dimension 2

Variable	Eigenvector	Correlation
P1= Abies balsamea	-0.088831	0
P2= Abies concolor	-0.209425	-
P3=Acer negundo	0.112274	+
P4=Acer pensylvanicum	-0.107271	-
P5=Acer saccharinum	0.094488	0
P6=Acer saccharum	0.000000	0
P7=Aesculus glabra	-0.160259	-
P8=Asimina triloba	-0.181026	-
P9=Betula papyrifera	0.187621	+
P10=Carpinus caroliniana	0.000000	0
P11=Carya alba	-0.052666	0
P12=Carya ovata	0.039481	0
P13=Castanea dentata	-0.063949	0
P14=Celtis occidentalis	-0.026736	0
P15=Cercis canadensis	-0.202747	-
P16=Cornus florida	0.011563	0
P17=Crataegus punctata	0.281780	+
P18=Euonymus atropurpureus	-0.192610	-
P19=Fagus grandifolia	0.236150	+
P20=Fraxinus americana	0.249111	+
P21=Gleditsia triacanthos	-0.144173	-
P22=Gymnocladus dioicus	-0.137203	-
P23=Hamamelis virginiana	0.251548	+
P24=Juglans nigra	-0.012757	0
P25=Juniperus virginiana	-0.177070	-

Table 6 Eigenvectors of Dimension 2 (Continued)

Variable	Eigenvector	Correlation
P26=Larix laricina	0.096169	0
P27=Liriodendron tulipifera	-0.046772	0
P28=Nyssa sylvatica	-0.046162	0
P29=Ostrya virginiana	0.000000	0
P30=Picea glauca	-0.209425	-
P31=Picea mariana	-0.066796	0
P32=Pinus strobus	0.209457	+
P33=Pinus resinosa	-0.001485	0
P34=Platanus occidentalis	0.072591	0
P35=Populus deltoides	0.087386	0
P36=Prunus americana	-0.160083	-
P37= Prunus serotina	0.106380	+
P38=Ptelea trifoliata	-0.132735	-
P39=Quercus alba	0.283643	+
P40=Quercus ellipsoidalis	0.022658	0
P41=Quercus macrocarpa	-0.178772	-
P42=Quercus bicolor	-0.046682	0
P43=Rhus typhina	0.000000	0
P44=Rhus copallina	-0.034523	0
P45=Salix nigra	-0.012278	0
P46=Salix discolor	0.000000	0
P47=Sassafras albidum	0.028376	0
P48=Thuja occidentalis	0.153982	+
P49=Ulmus americana	0.034247	0
P50=Viburnum lentago	0.282933	+
P51=Zanthoxylum americanum	0.083880	0

Variable 3 (*Acer negundo*), 9 (*Betula papyrifera*), 17 (*Crataegus punctata*), 19 (*Fagus grandifolia*), 20 (*Fraxinus americana*), 23 (*Hamamelis virginiana*), 32 (*Pinus strobus*), 48 (*Thuja occidentalis*) also show positive correlation to this dimension. Variable 2 (*Abies concolor*), 4 (*Acer pensylvanicum*), 7 (*Aesculus glabra*), 8 (*Asimna triloba*), 15 (*Cercis canadensis*), 18 (*Euonymus atropurpureus*), 21 (*Gleditsia triacanthos*), 22 (*Gymnocladus dioicus*), 25 (*Juniperus virginiana*), 30 (*Picea glauca*), 36 (*Prunus americana*), 38 (*Ptelea trifoliata*), 41 (*Quercus macrocarpa*) are negatively associated with this dimension. This region could be treated as a transition or mixed region. Mixed land use and human activity placed strong influence on this part and this area show mixed forest type.

Figure 4, Dimension 3- Hawthorn Patches

Dimension 3- Hawthorn Patches

The eigenvalue of this dimension is 2.74, explains 5.97% of the variance. The area of this dimension is 2031 square kilometers and it occupies 1.36% of the whole state. With weak correlations from variable 17 (*Crataegus punctata*), 19 (*Fagus grandifolia*), and 50 (*Viburnum lentago*), this dimension doesn't show strong direct correlation with any variables. And surprisingly, the area is shaped as small separated patches. Two are located in the southeast corner while the other one is isolated in the central area of Lower Peninsula. It is worthy to think about the existence of such small area and whether these patches could be connected by some kind of controlling factor. Barnes and Wagner (1981) described the habitat of *Crataegus punctata*. They are characteristic of open and disturbed area which is intolerant of shade. The distribution of *Fagus grandifolia* and *Viburnum lentago* are in the Upper Peninsula, not southern part, so this positive association is perplexing.

Table 7 Eigenvectors of Dimension 3

Variable	Eigenvector	Correlation
P1= Abies balsamea	0.159694	+
P2= Abies concolor	-0.006107	0
P3=Acer negundo	-0.137135	-
P4=Acer pensylvanicum	0.010336	0
P5=Acer saccharinum	-0.155594	-
P6=Acer saccharum	0.000000	0
P7=Aesculus glabra	0.203554	+
P8=Asimina triloba	0.110089	+
P9=Betula papyrifera	-0.164108	-
P10=Carpinus caroliniana	0.000000	0
P11=Carya alba	0.080447	0
P12=Carya ovata	-0.151153	-
P13=Castanea dentata	0.095126	0
P14=Celtis occidentalis	-0.123786	-
P15=Cercis canadensis	0.160260	+
P16=Cornus florida	-0.145749	-
P17= Crataegus punctata	0.288915	+
P18=Euonymus atropurpureus	0.171916	+
P19=Fagus grandifolia	0.271947	+
P20=Fraxinus americana	0.248371	+
P21=Gleditsia triacanthos	0.153399	+
P22=Gymnocladus dioicus	0.062362	0
P23=Hamamelis virginiana	0.207184	+
P24=Juglans nigra	-0.133316	-
P25=Juniperus virginiana	0.092792	0

Table 7 Eigenvectors of Dimension 3(Continued)

Variable	Eigenvector	Correlation
P26=Larix laricina	-0.149041	-
P27=Liriodendron tulipifera	-0.070795	0
P28=Nyssa sylvatica	-0.089927	0
P29=Ostrya virginiana	0.000000	0
P30=Picea glauca	-0.006107	0
P31=Picea mariana	0.181695	+
P32=Pinus strobus	-0.219443	-
P33=Pinus resinosa	0.131442	+
P34=Platanus occidentalis	-0.108658	-
P35=Populus deltoids	-0.159496	-
P36=Prunus americana	0.113686	+
P37= Prunus serotina	-0.025451	0
P38=Ptelea trifoliata	0.032874	0
P39=Quercus alba	0.211480	+
P40=Quercus ellipsoidalis	0.153693	+
P41=Quercus macrocarpa	0.122020	+
P42=Quercus bicolor	-0.103741	-
P43=Rhus typhina	0.000000	0
P44=Rhus copallina	0.026078	0
P45=Salix nigra	-0.124355	-
P46=Salix discolor	0.000000	0
P47=Sassafras albidum	-0.071661	0
P48=Thuja Occidentalis	-0.069020	0
P49=Ulmus americana	0.040472	0
P50=Viburnum lentago	0.282193	+
P51=Zanthoxylum americanum	-0.133542	-

Quercus ellipsoidalis, Prunus americana, Gleditsia triacanthos, Aesculus glabra and *Abies balsamea* turn out to be related to this patch's distribution. For these isolated patches, agriculture is still the main land use.

Figure 5, Dimension 4- Striped Maple-Black Cherry Region

Dimension 4: Striped Maple-Black Cherry Region

The eigenvalue of dimension 4 is 1.95, explains 4.24% of the variance. The area of this dimension is 37703 square kilometers and it occupies 25.34% of the whole state. Surprisingly, this area has separated two independent areas and scattered patches. Part of this dimension is located in the east side of Upper Peninsula, and the other main area is the southern Lower Peninsula. This dimension is negatively and strongly correlated with Variable 37 (*Prunus serotina*) with an eigenvector of -0.624116 and positive strong correlation with Variable 4 (*Acer pensylvanicum*), weak correlation with Variable 28 (*Fraxinus americana*) with a eigenvector 0.284515. Tree distribution map of *Prunus serotina* is exactly the same area in Upper Peninsula as it depicted in this dimension, while *Fraxinus americana* is the west part of Upper Peninsula. Both of these two trees are distributed in Upper Peninsula, so this southern region is the opposite of *Fraxinus americana*. For Tree *Acer pensylvanicum*, it covered large portion of State of Michigan except for east Upper Peninsula.

Table 8 Eigenvectors of Dimension 4

Variable	Eigenvector	Correlation
P1= Abies balsamea	-0.027649	0
P2= Abies concolor	0.060227	0
P3=Acer negundo	0.010307	0
P4=Acer pensylvanicum	0.624431	+
P5=Acer saccharinum	0.020643	0
P6=Acer saccharum	0.000000	0
P7=Aesculus glabra	-0.095415	0
P8=Asimina triloba	-0.008079	0
P9=Betula papyrifera	0.042462	0
P10=Carpinus caroliniana	0.000000	0
P11=Carya alba	-0.031167	0
P12=Carya ovata	0.040643	0
P13=Castanea dentata	-0.014217	0
P14=Celtis occidentalis	0.052515	0
P15=Cercis canadensis	-0.067357	0
P16=Cornus florida	0.048784	0
P17=Crataegus punctata	0.086745	0
P18=Euonymus atropurpureus	-0.028341	0
P19=Fagus grandifolia	0.176118	+
P20=Fraxinus americana	0.284515	+
P21=Gleditsia triacanthos	-0.088070	0
P22=Gymnocladus dioicus	0.001809	0
P23=Hamamelis virginiana	-0.118108	-
P24=Juglans nigra	0.046041	0
P25=Juniperus virginiana	-0.005242	0

Table 8 Eigenvectors of Dimension 4 (Continued)

Variable	Eigenvector	Correlation
P26=Larix laricina	-0.004832	0
P27=Liriodendron tulipifera	0.033054	0
P28=Nyssa sylvatica	0.046724	0
P29=Ostrya virginiana	0.000000	0
P30=Picea glauca	0.060227	0
P31=Picea mariana	-0.014944	0
P32=Pinus strobus	0.042374	0
P33=Pinus resinosa	-0.037074	0
P34=Platanus occidentalis	0.003216	0
P35=Populus deltoides	0.026399	0
P36=Prunus americana	-0.019359	0
P37= Prunus serotina	-0.624116	-
P38=Ptelea trifoliata	0.004592	0
P39=Quercus alba	-0.139581	-
P40=Quercus ellipsoidalis	0.076685	0
P41=Quercus macrocarpa	0.010060	0
P42=Quercus bicolor	0.052738	0
P43=Rhus typhina	0.000000	0
P44=Rhus copallina	0.027288	0
P45=Salix nigra	0.042977	0
P46=Salix discolor	0.000000	0
P47=Sassafras albidum	0.010328	0
P48=Thuja occidentalis	0.010643	0
P49=Ulmus americana	0.054046	0
P50=Viburnum lentago	0.046161	0
P51=Zanthoxylum americanum	0.022037	0

From the dimension (Table 8), it is obvious to see the strength of association between tree distribution and dimension. *Fagus grandifolia* is also positively associated with this dimension, while *Quercus alba* and *Hamamelis virginiana* are still negatively associated with this dimension. Striped maple is a species easily adapted in Michigan with its highly shade-tolerant characteristics (Barnes and Wagner, 1981). *Prunus serotina* is common in southern half of Lower Peninsula.

Figure 6, Dimension 5- Tamarack Region

Dimension 5: Tamarack Region

The eigenvalue of this dimension is 1.56 which explains 3.41% of variance. The area of this dimension is 108101 square kilometer, occupies 72.65% of the whole state. This dimension covers almost the whole Upper Peninsula. In the Lower Peninsula, the northern part and southern part are covered. Negatively strong correlation between Variable 13 (*Castanea dentata*) and dimension with eigenvector of -0.583507, positively strong correlation of Variable 26 (*Larix laricina*) with eigenvector of 0.642275 are detected. *Larix laricina* is adaptive species which span all over Michigan. *Castanea dentata* is almost extinct (Barnes and Wagner, 1981).

Table 9 Eigenvectors of Dimension 5

Variable	Eigenvector	Correlation
P1= Abies balsamea	0.064628	0
P2= Abies concolor	0.027955	0
P3=Acer negundo	-0.055991	0
P4=Acer pensylvanicum	0.011029	0
P5=Acer saccharinum	-0.064378	0
P6=Acer saccharum	0.000000	0
P7=Aesculus glabra	-0.174251	-
P8=Asimina triloba	0.076859	0
P9=Betula papyrifera	-0.076907	0
P10=Carpinus caroliniana	0.000000	0
P11=Carya alba	-0.215500	-
P12=Carya ovata	-0.024252	0
P13=Castanea dentata	-0.583507	-
P14=Celtis occidentalis	0.011114	0
P15=Cercis canadensis	0.095685	0
P16=Cornus florida	-0.012238	0
P17=Crataegus punctata	-0.000583	0
P18=Euonymus atropurpureus	0.035561	0
P19=Fagus grandifolia	0.000656	0
P20=Fraxinus americana	0.043681	0
P21=Gleditsia triacanthos	0.194276	+
P22=Gymnocladus dioicus	0.049074	0
P23=Hamamelis virginiana	0.080171	0
P24=Juglans nigra	0.002583	0
P25=Juniperus virginiana	0.071003	0

Table 9 Eigenvectors of Dimension 5 (Continued)

Variable	Eigenvector	Correlation
P26=Larix laricina	0.642275	+
P27=Liriodendron tulipifera	0.008853	0
P28=Nyssa sylvatica	0.027528	0
P29=Ostrya virginiana	0.000000	0
P30=Picea glauca	0.027955	0
P31=Picea mariana	0.055967	0
P32=Pinus strobus	0.024741	0
P33=Pinus resinosa	0.006011	0
P34=Platanus occidentalis	-0.019888	0
P35=Populus deltoides	-0.064251	0
P36=Prunus americana	0.038872	0
P37= Prunus serotina	0.015940	0
P38=Ptelea trifoliata	0.056044	0
P39=Quercus alba	0.030154	0
P40=Quercus ellipsoidalis	0.137970	+
P41=Quercus macrocarpa	0.089191	0
P42=Quercus bicolor	0.023086	0
P43=Rhus typhina	0.000000	0
P44=Rhus copallina	-0.171639	-
P45=Salix nigra	0.006576	0
P46=Salix discolor	0.000000	0
P47=Sassafras albidum	0.004351	0
P48=Thuja occidentalis	-0.073591	0
P49=Ulmus americana	0.001367	0
P50=Viburnum lentago	-0.001879	0
P51=Zanthoxylum americanum	-0.054734	0

Table 9 shows the new category of correlations for all the eigenvector efficient. Variable 21 (*Gleditsia triacanthos*) and variable 40 (*Quercus ellipsoidalis*) also show positive correlation except *Larix laricina. Gleditsia triacanthos* is tending to grow in the most southern part of Lower Peninsula and this could explain the distribution depicted in the map above. *Quercus ellipsoidalis* prefers drained sites and sandy soils, but it's shade-intolerant (Barnes and Wagner, 1986). Variable 7 (*Aesculus glabra*), variable 11

(*Carya alba*) and variable 44 (*Rhus copallina*) also indicated weak association with dimension. *Aesculus glabra* is rare in the southern Lower Peninsula with its limit southern Michigan and they prefer floodplain. *Carya alba* is occasional in the southern half of the Lower Peninsula. *Rhus copallina* tends to live on the eastern shoreline of southern Lower Peninsula. This uncontinuous shape show stong correlation between Lower Peninsula and Upper Peninsula. It is unexpected that this two separated land could be classified as one in this dimension.

Figure 7, Dimension 6- Sumac-Locust Region

Dimension 6: Sumac-Locust Region

The eigenvalue of this dimension is 1.3 and explains 2.83% of the variance. The area of this dimension is 22490 square kilometer, occupies 15.11%of the whole state. In this dimensional map, striped southern area and scattered patches are identified. Variable 21 (*Gleditsia triacanthos*) and variable 44 (*Rhus copallina*) have strong correlation with this dimension. Variable 40 (*Quercus ellipsoidalis)* has weak correlation with an eigenvector showing 0.369. Also, Variable 8 (*Asimna triloba*), Variable 13 *(Castanea dentata),* Variable 22 *(Gymnocladus dioicus)* Variable 25 *(Juniperus virginiana)* Variable 31 (*Picea mariana*), Variable 32 *(Pinus strobes),* Variable 37*(Prunus serotina),* Variable 41 *(Quercus macrocarpa)* have positive correlation with dimension six.

Table 10 Eigenvectors of Dimension 6

Variable	Eigenvector	Correlation
P1= Abies balsamea	0.044186	0
P2= Abies concolor	0.054460	0
P3=Acer negundo	-0.069840	0
P4=Acer pensylvanicum	-0.029414	0
P5=Acer saccharinum	-0.056716	0
P6=Acer saccharum	0.000000	0
P7=Aesculus glabra	-0.462253	-
P8=Asimina triloba	0.148221	+
P9=Betula papyrifera	-0.098224	0
P10=Carpinus caroliniana	0.000000	0
P11=Carya alba	-0.237101	-
P12=Carya ovata	-0.032901	0
P13=Castanea dentata	0.208645	+
P14=Celtis occidentalis	0.010179	0
P15=Cercis canadensis	-0.059467	0
P16=Cornus florida	-0.012952	0
P17=Crataegus punctata	0.001952	0
P18=Euonymus atropurpureus	0.009415	0
P19=Fagus grandifolia	-0.023511	0
P20=Fraxinus americana	-0.046734	0
P21=Gleditsia triacanthos	-0.403567	-
P22=Gymnocladus dioicus	0.103953	+
P23=Hamamelis virginiana	0.022142	0
P24=Juglans nigra	0.015154	0
P25=Juniperus virginiana	0.121370	+

Table 10 Eigenvectors of Dimension 6(Continued)

Variable	Eigenvector	Correlation
P26=Larix laricina	0.022295	0
P27=Liriodendron tulipifera	0.045223	0
P28=Nyssa sylvatica	0.033241	0
P29=Ostrya virginiana	0.000000	0
P30=Picea glauca	0.054460	0
P31=Picea mariana	0.113586	+
P32=Pinus strobus	0.142061	+
P33=Pinus resinosa	0.004223	0
P34=Platanus occidentalis	-0.059376	0
P35=Populus deltoides	-0.042251	0
P36=Prunus americana	0.018045	0
P37= Prunus serotina	0.139379	+
P38=Ptelea trifoliata	0.071191	0
P39=Quercus alba	0.052574	0
P40=Quercus ellipsoidalis	0.369136	+
P41=Quercus macrocarpa	0.118817	+
P42=Quercus bicolor	0.030571	0
P43=Rhus typhina	0.000000	0
P44=Rhus copallina	0.462948	+
P45=Salix nigra	-0.000787	0
P46=Salix discolor	0.000000	0
P47=Sassafras albidum	-0.010926	0
P48=Thuja occidentalis	-0.069622	0
P49=Ulmus americana	-0.012338	0
P50=Viburnum lentago	0.010979	0
P51=Zanthoxylum americanum	-0.027407	0

Varible 44 (*Rhus copallina*) is positively associated with this dimension. For this unusual shape of distributed area, it is believed this island area shares distinct landscape characteristics. Referring to Albert *et al* (1986), the precipitation in the northern patch is higher than other areas in northern Lowe Peninsula which could explain the distribution of *Rhus copallina.* Reviewing the habitat and distribution of *Gleditsia triacanthos* could imply the opposite result of variable 44. Honey Locust prefers moist soil of river valleys, and southern Lower Peninsula is suitable for the growing (Barnes and Wagner, 1986). With horse or cattle dispersing their seeds, it could implied that the higher human disturbance or agricultural activities.

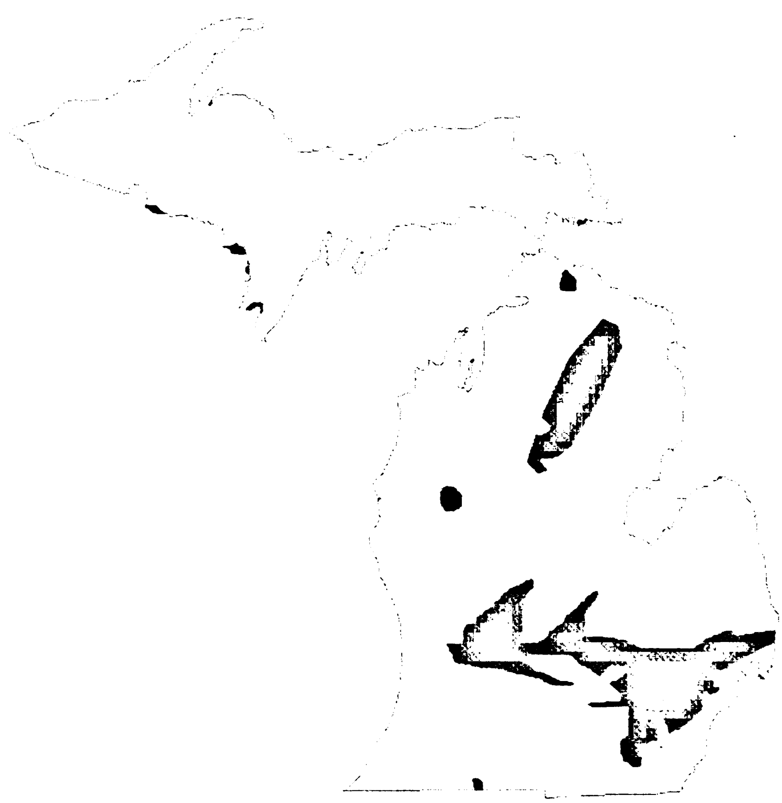

Figure 8, Dimension 7- Hickory-Honey Locust Region

Dimension 7: Hickory-Honey Locust Region

The eigenvalue of this dimension is 1.13 which is still assumed as significant dimension since it's over 1.0. It explains 2.46% of the total variance. The area of this dimension is 17041 square kilometer, occupies 11.45% of the whole state. This dimension shows scattered patches in Lower Peninsula with distinct shapes. A stick-shaped inland patch shares the same boundary with dimension 6. A continuous area is identified in the southern central area of Lower Peninsula. Small patches are found both in Lower Peninsula and Upper Peninsula.

Table 11 Eigenvectors of Dimension 7

Variable	Eigenvector	Correlation
P1= Abies balsamea	0.055741	0
P2= Abies concolor	0.076526	0
P3=Acer negundo	-0.042189	0
P4=Acer pensylvanicum	0.018199	0
P5=Acer saccharinum	-0.060484	0
P6=Acer saccharum	0.000000	0
P7=Aesculus glabra	-0.077429	0
P8=Asimina triloba	0.005866	0
P9=Betula papyrifera	0.183799	+
P10=Carpinus caroliniana	0.000000	0
P11=Carya alba	0.594636	+
P12=Carya ovata	0.054065	0
P13=Castanea dentata	-0.165477	-
P14=Celtis occidentalis	0.027149	0
P15=Cercis canadensis	-0.087650	0
P16=Cornus florida	0.063640	0
P17=Crataegus punctata	-0.012399	0
P18=Euonymus atropurpureus	0.020331	0
P19=Fagus grandifolia	-0.033394	0
P20=Fraxinus americana	-0.047399	0
P21=Gleditsia triacanthos	-0.316775	-
P22=Gymnocladus dioicus	-0.014325	0
P23=Hamamelis virginiana	0.098272	0
P24=Juglans nigra	0.094552	0
P25=Juniperus virginiana	0.004413	0

Table 11 Eigenvectors of Dimension 7 (Continued)

Variable	Eigenvector	Correlation
P26=Larix laricina	-0.109755	-
P27=Liriodendron tulipifera	0.034003	0
P28=Nyssa sylvatica	0.115315	+
P29=Ostrya virginiana	0.000000	0
P30=Picea glauca	0.076526	0
P31=Picea mariana	0.130928	+
P32=Pinus strobus	-0.063005	0
P33=Pinus resinosa	-0.064956	0
P34=Platanus occidentalis	0.026229	0
P35=Populus deltoides	-0.050919	0
P36=Prunus americana	0.064100	0
P37= Prunus serotina	0.090103	0
P38=Ptelea trifoliata	0.048460	0
P39=Quercus alba	0.029700	0
P40=Quercus ellipsoidalis	0.402440	+
P41=Quercus macrocarpa	0.050618	0
P42=Quercus bicolor	0.114329	0
P43=Rhus typhina	0.000000	0
P44=Rhus copallina	-0.395766	-
P45=Salix nigra	0.107108	+
P46=Salix discolor	0.000000	0
P47=Sassafras albidum	0.021225	0
P48=Thuja occidentalis	0.004948	0
P49=Ulmus americana	-0.012253	0
P50=Viburnum lentago	-0.005629	0
P51=Zanthoxylum americanum	-0.056691	0

Table 11 showed variable 11 *(Carya alba)* is strongly and positively associated with this dimension with an eigenvector of 0.59, while Variable 21 *(Gleditsia triacanthos)* and Variable 44 *(Rhus copallina)* show negative weak correlation with this dimension. Reviewing the habitat of *Carya alba*, it is occasional in the southern half of Lower Peninsula. From the tree distribution maps, *Gleditsia triacanthos* is rare in the northern part of the Lower Peninsula. *Rhus copallina* tends to live in the eastern shoreline of southern Lower Peninsula. Also, variable 9 (*Betula papyrifera*), variable 28 (*Nyssa sylvatica)* and variable 45 *(Salix nigra)* are positive correlated with this dimension. *Betula papyrifera* is common from Upper Peninsula through most of the Lower Peninsula with an limit on the southern Lower Peninsula. Genus *Salix* is shade-intolerant and they are common in southern half of Lower Peninsula and rare in Upper Peninsula (Barnes and Wagner, 1986). *Nyssa sylvatica* is common in southern Lower Peninsula.

Figure 9, Dimension 8- Elm Region

Dimension 8: Elm Region

The Eigenvalue for this dimension is 1.01, accounts for 2.19% of variance. The area of this dimension is 147034 square kilometer, occupies 98.81% of the whole state. This dimension is the last dimension with eigenvalue over 1.0. The shape of this dimension is almost the whole area of Michigan except for small striped area along the edge of eastern Lower Peninsula and northern Upper Peninsula. This continuous area could be treated as an important dimension as it span over the whole state.

Table 12 Eigenvectors of Dimension 8

Variable	Eigenvector	Correlation
P1= Abies balsamea	-0.009551	0
P2= Abies concolor	-0.030087	0
P3=Acer negundo	0.012753	0
P4=Acer pensylvanicum	0.012293	0
P5=Acer saccharinum	0.020009	0
P6=Acer saccharum	0.000000	0
P7=Aesculus glabra	0.011365	0
P8=Asimina triloba	-0.001343	0
P9=Betula papyrifera	-0.003841	0
P10=Carpinus caroliniana	0.000000	0
P11=Carya alba	0.010288	0
P12=Carya ovata	-0.002411	0
P13=Castanea dentata	0.004516	0
P14=Celtis occidentalis	-0.017761	0
P15=Cercis canadensis	-0.005393	0
P16=Cornus florida	-0.008044	0
P17=Crataegus punctata	-0.017162	0
P18=Euonymus atropurpureus	0.012861	0
P19=Fagus grandifolia	-0.207032	-
P20=Fraxinus americana	0.002598	0
P21=Gleditsia triacanthos	0.009453	0
P22=Gymnocladus dioicus	-0.003182	0
P23=Hamamelis virginiana	0.013645	0
P24=Juglans nigra	-0.012480	0
P25=Juniperus virginiana	-0.007730	0

Table 12 Eigenvectors of Dimension 8 (Continued)

Variable	Eigenvector	Correlation
P26=Larix laricina	0.007584	0
P27=Liriodendron tulipifera	-0.008301	0
P28=Nyssa sylvatica	-0.013138	0
P29=Ostrya virginiana	0.000000	0
P30=Picea glauca	-0.030087	0
P31=Picea mariana	0.009451	0
P32=Pinus strobus	-0.015566	0
P33=Pinus resinosa	0.007279	0
P34=Platanus occidentalis	0.008032	0
P35=Populus deltoides	0.007496	0
P36=Prunus americana	0.000339	0
P37= Prunus serotina	0.020593	0
P38=Ptelea trifoliata	-0.010918	0
P39=Quercus alba	0.013797	0
P40=Quercus ellipsoidalis	0.047978	0
P41=Quercus macrocarpa	0.007383	0
P42=Quercus bicolor	-0.015949	0
P43=Rhus typhina	0.000000	0
P44=Rhus copallina	0.015239	0
P45=Salix nigra	-0.012361	0
P46=Salix discolor	0.000000	0
P47=Sassafras albidum	0.001603	0
P48=Thuja occidentalis	0.008852	0
P49=Ulmus americana	0.973654	+
P50=Viburnum lentago	-0.014621	0
P51=Zanthoxylum americanum	0.006022	0

Variable 49 (*Ulmus americana*) shows positively strong correlation with this dimension with eigenvector of 0.973654. Variable 19 (*Fagus grandifolia*) negatively associated with this dimension with eigenvector of -0.20. According to the atlas of United States Trees, American elm is distributed around Eastern continent since early 1900s (Little, 1971). Referring to the habitat of American elm, they grow in southern Michigan river flood plains, disturbed open pastures, in northern Upper Peninsula; they grow with hardwood forests associated with beech (Barnes and Wagner, 1981). So if Michigan is divided into regions based on this dimension, the entire Michigan could be treated as an entire ecological region.

Figure 10, Dimension 9- Oak-Hickory Region

Dimension 9: Oak Hickory Region

This dimension shares an eigenvalue of 0.97, explains 2.13% of variance. The area of this dimension is 36463 square kilometer, occupies 56.48% of the whole state. Although its eigenvalue is smaller than 1.0 (Burley and Brown, 1995), this dimension is still detected for further analysis as it's really close to 1.0. In this dimension, one piece of continuous area appeared in the southern Lower Peninsula, while scattered patches are distributed in northern Lower Peninsula and western Upper Peninsula.

Table 13 Eigenvectors of Dimension 9

Variable	Eigenvector	Correlation
P1= Abies balsamea	0.009864	0
P2= Abies concolor	0.053531	0
P3=Acer negundo	-0.012129	0
P4=Acer pensylvanicum	0.072133	0
P5=Acer saccharinum	-0.016688	0
P6=Acer saccharum	0.000000	0
P7=Aesculus glabra	0.264152	+
P8=Asimina triloba	-0.100836	-
P9=Betula papyrifera	0.108558	+
P10=Carpinus caroliniana	0.000000	0
P11=Carya alba	-0.485791	-
P12=Carya ovata	0.061179	0
P13=Castanea dentata	0.243448	+
P14=Celtis occidentalis	0.108519	+
P15=Cercis canadensis	-0.184701	-
P16=Cornus florida	0.073287	0
P17=Crataegus punctata	-0.038606	0
P18=Euonymus atropurpureus	0.026082	0
P19=Fagus grandifolia	-0.060390	0
P20=Fraxinus americana	-0.042007	0
P21=Gleditsia triacanthos	0.264121	+
P22=Gymnocladus dioicus	-0.125888	-
P23=Hamamelis virginiana	0.068154	0
P24=Juglans nigra	0.074809	0
P25=Juniperus virginiana	-0.114708	-

Table 13 Eigenvectors of Dimension 9 (Continued)

Variable	Eigenvector	Correlation
P26=Larix laricina	-0.061787	0
P27=Liriodendron tulipifera	0.020873	0
P28=Nyssa sylvatica	0.063148	0
P29=Ostrya virginiana	0.000000	0
P30=Picea glauca	0.053531	0
P31=Picea mariana	-0.032331	0
P32=Pinus strobus	-0.103742	-
P33=Pinus resinosa	-0.051573	0
P34=Platanus occidentalis	0.008235	0
P35=Populus deltoides	-0.004475	0
P36=Prunus americana	-0.061885	0
P37= Prunus serotina	0.084240	0
P38=Ptelea trifoliata	-0.067797	0
P39=Quercus alba	0.024696	0
P40=Quercus ellipsoidalis	0.566037	+
P41=Quercus macrocarpa	-0.055437	0
P42=Quercus bicolor	0.082564	0
P43=Rhus typhina	0.000000	0
P44=Rhus copallina	-0.222926	-
P45=Salix nigra	0.086620	0
P46=Salix discolor	0.000000	0
P47=Sassafras albidum	-0.011421	0
P48=Thuja occidentalis	-0.027652	0
P49=Ulmus americana	-0.035703	0
P50=Viburnum lentago	-0.032328	0
P51=Zanthoxylum americanum	-0.018147	0

Reviewing the eigenvectors in Table 13, associative variables are collected. Positively, Variable 40 *(Quercus ellipsoidalis)* is strongly correlated with dimension with eigenvector of 0.56, Variable 7 (*Aesculus glabra*), Variable 13 (*Castanea dentata*) and Variable 21 (*Gleditsia triacanthos*) are weakly correlation with eigenvectors smaller than 0.27. Negatively, Variable 11 (*Carya alba*) is strongly correlated with this dimension with eigenvector of -0.48. Variable 15 (*Cercis canadensis*), variable 25 (*Juniperus virginiana*), variable 32 (*Pinus strobus*) and variable 44 (*Rhus copallina*) are weakly correlated with this dimension.

With the review of distribution of *Quercus ellipsoidalis,* they are occasional in the southern part of Lower Peninsula, locally common in northern Lower Peninsula, rare in Upper Peninsula (Barnes and Wagner, 1981). They prefer sandy and well-drained soils, associated with other oaks and aspen, red pines in southern Lower Peninsula. At this point, Northern Pin Oak is the dominant species in this dimension.

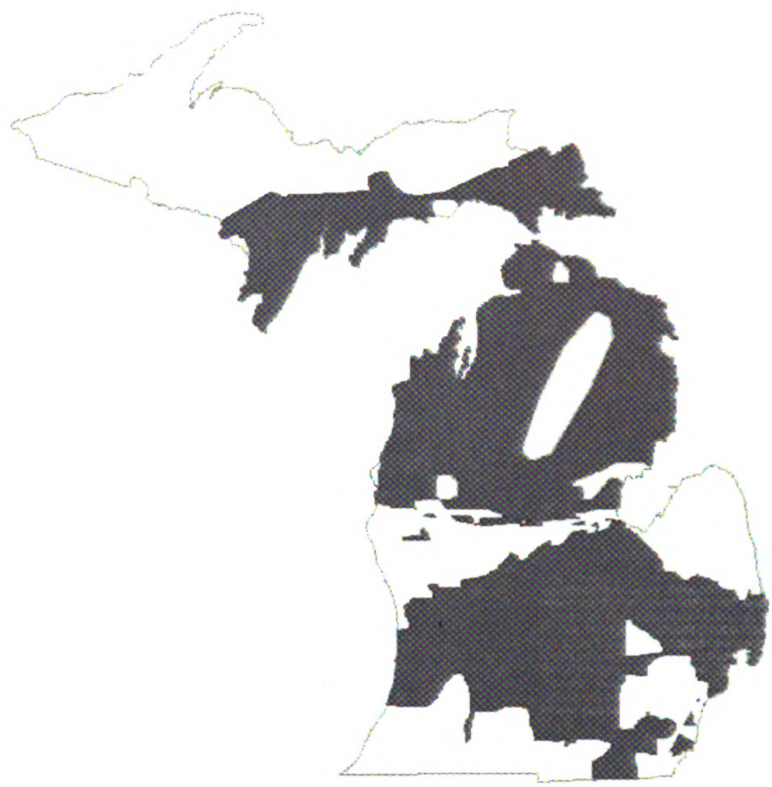

Figure 11, Dimension 10- Oak Mixed Region

Dimension 10: Oak Mixed Region

The eigenvalue of this component is 0.91, explains 1.99% of the variance. The area of this dimension is 84064 square kilometers and occupies 56.48% of the whole area. This figure shows non-continuous areas across Michigan. From north to south they are southern east Upper Peninsula, northern Lower Peninsula and central Lower Peninsula. Small independent land areas are detected and braced by this dimension distributed area. For this separated area, island effect and tree distribution needs deeper investigation for its distinct shape of absent area which share the same boundary with dimension 6,7 and 9.

Table 14 Eigenvectors of Dimension 10

Variable	Eigenvector	Correlation
P1= Abies balsamea	0.165670	+
P2= Abies concolor	0.245054	+
P3=Acer negundo	-0.161056	-
P4=Acer pensylvanicum	-0.172517	-
P5=Acer saccharinum	-0.191511	-
P6=Acer saccharum	0.000000	0
P7=Aesculus glabra	-0.099725	0
P8=Asimina triloba	0.003216	0
P9=Betula papyrifera	0.060587	0
P10=Carpinus caroliniana	0.000000	0
P11=Carya alba	-0.268586	-
P12=Carya ovata	0.017381	0
P13=Castanea dentata	0.129348	+
P14=Celtis occidentalis	0.191110	+
P15=Cercis canadensis	0.016484	0
P16=Cornus florida	0.067565	0
P17=Crataegus punctata	0.139298	+
P18=Euonymus atropurpureus	-0.137105	-
P19=Fagus grandifolia	0.163099	+
P20=Fraxinus americana	-0.000935	0
P21=Gleditsia triacanthos	-0.134007	-
P22=Gymnocladus dioicus	0.009878	0
P23=Hamamelis virginiana	0.079906	0
P24=Juglans nigra	0.127801	+
P25=Juniperus virginiana	0.068461	0

Table 14 Eigenvectors of Dimension 10 (Continued)

Variable	Eigenvector	Correlation
P26=Larix laricina	-0.107985	-
P27=Liriodendron tulipifera	0.047812	0
P28=Nyssa sylvatica	0.155981	+
P29=Ostrya virginiana	0.000000	0
P30=Picea glauca	0.245054	+
P31=Picea mariana	-0.058427	0
P32=Pinus strobus	0.139491	+
P33=Pinus resinosa	-0.067997	0
P34=Platanus occidentalis	-0.054270	0
P35=Populus deltoides	-0.146955	-
P36=Prunus americana	0.025489	0
P37= Prunus serotina	-0.014703	0
P38=Ptelea trifoliata	0.118295	+
P39=Quercus alba	0.014259	0
P40=Quercus ellipsoidalis	-0.413310	-
P41=Quercus macrocarpa	0.013349	0
P42=Quercus bicolor	0.174063	+
P43=Rhus typhina	0.000000	0
P44=Rhus copallina	-0.337393	-
P45=Salix nigra	0.134753	+
P46=Salix discolor	0.000000	0
P47=Sassafras albidum	0.000622	0
P48=Thuja occidentalis	-0.132235	-
P49=Ulmus americana	0.117997	+
P50=Viburnum lentago	0.137269	+
P51=Zanthoxylum americanum	-0.129339	-

One significant correlation is identified as Variable 40 (*Quercus ellipsoidalis*) with eigenvector of -0.41. Both negative and positive weak correlations are revealed. Positively, Variable 1 (*Abies balsamea*), Variable 2 (*Abies concolor*), Variable 13 (*Castanea dentata*) Variable 14 (*Celtis occidentalis*), Variable 17 (*Crataegus punctata*), Variable 19 (*Fagus grandifolia*), Variable 24 (*Fagus grandifolia*), Variable 28 (*Nyssa sylvatica*), Variable 30 (*Picea glauca*), Variable 32(*Pinus strobus*), Variable 38 (*Ptelea trifoliata*), Variable 42 (*Quercus bicolor*), Variable 45 (*Salix nigra*), Variable 49 (*Ulmus americana*)and Variable 50 (*Viburnum lentago*) are correlated with this dimension.

Negatively, Variable 3 (*Acer negundo*), Variable 4 (*Acer pensylvanicum*), Variable 5(*Acer saccharinum*), Variable 11 (*Carya alba*), Variable 18(*Euonymus atropurpureus*), Variable 21 (*Gleditsia triacanthos*), Variable 26 (*Larix laricina*), Variable 35 (*Populus deltoides*), Variable 44 (*Rhus copallina*), Variable 48 (*Thuja occidentalis*) and Variable 51 (*Zanthoxylum americanum*) are associated with this dimension.

Map Synthesis of 10 Regions

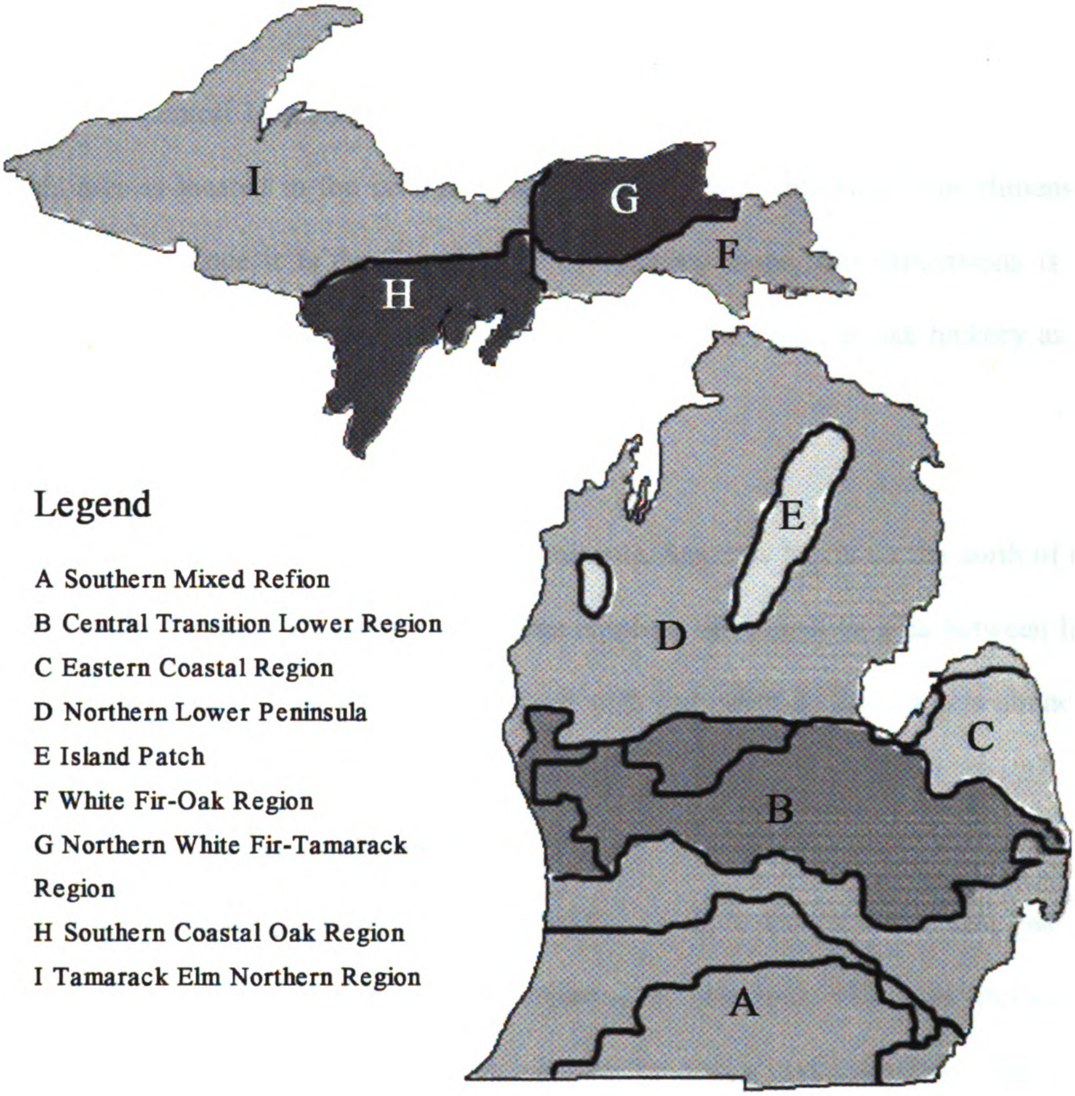

Figure 12, Ecological Regions of Michigan

These regions are generated by examining all ten significant dimension maps. Ten regions are developed for their distinct characteristics (Figure 12).

Region A Southern Mixed Region

This area is influenced by the first and second dimension. As dimension 1 share the biggest eigenvalue dimension, I assign the boundary mainly based on this dimension.

After examining all the eigenvectors in dimension 1 and 2, no significant variable is detected, yet many plant types are positively affiliated with this area- a mixed vegetation zone.

Region B Central Transition Lower Region

This area is located in the central Lower Peninsula with influence from dimension 2,5,7,9 and 10. Since it is developed from overlapping maps, this dimensions is not simple to delineate, so I suggest this a transition area. This area has oak-hickory as the dominant tree species.

Region C Eastern Coastal Region

This area is on the thumb of the Lower Peninsula. Saginaw bay is on the north of this area, rivers flow to the Lake Huron. This area employs the transition area between land and water. Floodplains area founded there and with the effect of lake, it gets abundant precipitation.

Region D Northern Lower Peninsula

I assign the boundary based on the dimension 1, 2, 5, 9, and 10. Tamarack, oak and elm from the analysis are dominant tree species in this area. This area enjoys big influences from the Great Lakes. The climate is cooler than southern part, and precipitation is abundant. Pine-oak forest is settled in the pre-settlement era. Forest is the main land type in this area, still, wetlands, swamp are found in this area.

Region E Inland Island Patch

As two distinct inland patches embraced by northern Lower Peninsula, these small region are generated from dimension 6, 7, 9 and 10. This larger unexpected patch located in the center of northern Lower Peninsula was derived from dimensions 6, 7 and 9, 10. It became a distinct inland patch. The shape of this patch is affected mostly by the precipitation and elevation. At the same time, the Great Lakes have influence on this area. The precipitation tends to decrease from the western lake side to eastern shoreline and these 2 patches are located in the changing area. The vegetation of this area is mainly oak, elm and hickory.

Region F Striped Maple Southern Region

The formation of this region is affected by dimension 4 and dimension 10. These 2 dimensions revealed that striped maple span over eastern Upper Peninsula and northern Lower Peninsula. The northern Location of this area provides with cooler climate and significant lake effect.

Region G White Spruce Northern Region

In this area, dimension 4 and 10 affected the formation. Striped maple showed negative association with dimension 10 while white spruce is distributed in this area. Considering the decreasing temperature and growing precipitation, the ecology of white spruce is reflected the landscape.

Region H Southern Coastal Region

Dimension 10 and dimension 4 affected the formation of this dimension. The precipitation is less than the inner area of Upper Peninsula and with the temperature is higher than northern part. With strong lake effect, tamarack, striped maple are occasionally to be observed.

Region I Northern Tamarack Elm Region

Dimension 4, 8, and 10 define the region. Tamarack and Elm are the dominant defining species in this area. Precipitation increases at the southern part of the area and with the cold climate, hardwoods plant are less dominant. Evergreen trees which can bear the extreme weather grow in that area.

Region J Elm Region

This region is the whole State of Michigan based on dimension 8. Elm is almost everywhere in Michigan, and this could be treated as a whole.

Concerns and Comparisons

Because I used a statistical approach and let the data reveal the structure of the regions, this approach facilitated questions and issues concerning the construction of regions. Albert (1986) developed 4 general regions in State of Michigan. Stefannaci (1997) collected a physical environment dataset to decide the number of broad regions and inner districts and patches. My analysis developed a different set of regions.

Based on the analysis of dimensions and their relationships with variables in this study, there are 16 impacted tree variables which strongly related to the 10 basic dimensions. Considering the complexity of dimension maps in my analysis, the result was a blending of areas and borders. Under such a blending condition, it is hard to create a simple map to show the regions. I suggest that the regions in Michigan may not be so distinct nor always clear. At the same time, the analysis suggests that Michigan could be part of just one region. For example, for eighth dimension, strong correlation between variable 49 (*Ulmus americana*) and dimension 8 is detected. In this case, with *Ulmus americana*all over Michigan, the State of Michigan could be viewed as one united region.

Blank *et al* (1966) developed 8 regions in Upper Peninsula, Bailey (1983) developed 2 regions in the previous work, Omernik (1987) developed 5 regions. Kuchler (1964) developed 3 units by employing integrated ecosystem. Albert (1986) employed all the possible physical characteristics and climate data to incorporate with the region generation. Stefannaci (1997) developed 4 regions with districts and urban area. In my study, I illustrate there may be more than 4 regions in Michigan or even just possibly one super region.

My analysis suggests that the actual size of regions is a concern. Albert *et al* (1986) and Stefannaci (1997) generated somewhat equally sized regions. My study suggests the regions could range from small patches to larger-the whole state. Different dimensions suggest different shapes of regions. Some of them are lonely small patches, some of them are united continuous areas.

The third difference from other studies is there are lots of blended areas. Former studies derived distinct regions. Scholars selected important variables that they thought divided the boundaries of homogenous regions. In this study, blended areas are common to observe. For example, dimension 2 and dimension 9 share some common areas but also, the boundaries of them are a little distinct. To investigate the relationships between fuzzy spaces and clear spaces, the areas may require more study.

The fourth issue is the homogeneity of landscape areas. Some investigators have divided the state into distinctive regions. In my study, the landscape may be much more heterogeneous. Landscape heterogeneity is the fundamental issue in landscape ecology. Pickett and Cadenasso (1995) noted that lots of ecological phenomenon is sensitive to spatial heterogeneity and flow of different mosaics. They also suggested the examination of dynamics of a certain landscape unit. Gustafson and Gardner (1996) stressed the importance of landscape heterogeneity on the colonization of patches. In this way, scattered sites could be interpreted and organized. Bailey (1983) talked about to defining similar sites by employing similar vegetation and soils. But in reality, each parcel and space may be unique and the landscape is heterogeneous.

The fifth issue is the existence of inland patches within patches. Small patches are intended to scatter inside a specific broader region. Stefanacci (1997) investigated the northern Lower Peninsula, she divided the whole area into inland patches and coastal areas. In my study, inland patches within patches are also detected in northern Lower Peninsula. In Lower Peninsula, patches are easy to identify while regions in Upper Peninsula tends to be without patches. The scattered island patches can play an important role. But still, other factors should be evaluated for understanding and eliminate the fuzziness of boundaries. Discontinuous small patches are also recognized in the study. The size, location and number are tending to change depends on the dimension and with this problem, maybe we should not see regions in an old way but still, they are connected by certain controlling factors.

The last concern about this study is discontinuous regions appeared which are affected by the same dimension. It is unexpected to see separated areas in the same dimension since geographically Upper Peninsula and Lower Peninsula are bordered by the Great Lakes. Traditionally, regions have been physically connected.

Gunn's Upper Peninsula Resource Management Classification

Based upon identification of regional characteristics, seeking for reasonable resource management and tourism creation strategies, Blank *et al* (1966) conducted an investigation and subregional interpretation in Upper Peninsula of Michigan (Figure 13).

A series of criteria are employed for this study and eight independent subregions are recommended for tourism and recreation. From one point, his study combined the natural characteristics and human activity. Connection to local community, transportation, existing land form are included for deriving a theme for each subregion and potential area for further development are identified.

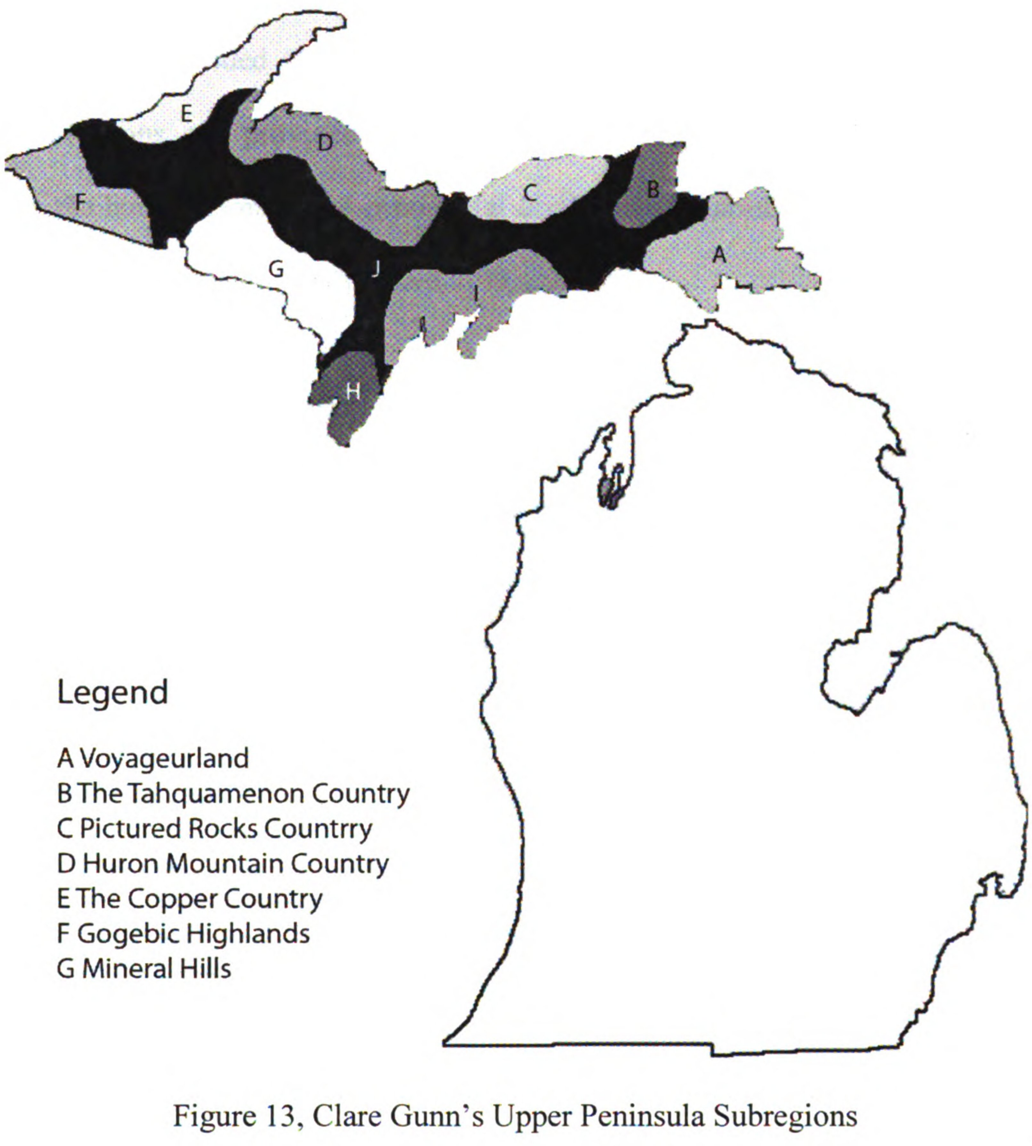

Figure 13, Clare Gunn's Upper Peninsula Subregions

One of the important features of this study is it provided a good concept development and implication for management. Transportation planning for different usage in different natural area and historical appeal are considered. Gunn's study is considered good example for development management. However, still, independent regions are generated for recreation planning from coastal areas to inland areas. The results on my study and Gunn's look quite different. Gunn's regions are expert derived not statistically derived like my regions.

Bailey's Ecoregion of the United States

Bailey (1983) divided the entire United States into hierarchical ecoregions by domains, divisions and provinces. Viewing the State of Michigan (Figure 14), it is located in the humid domain, hot continental division and marine division. Specifically, two provinces dominated the entire State of Michigan.

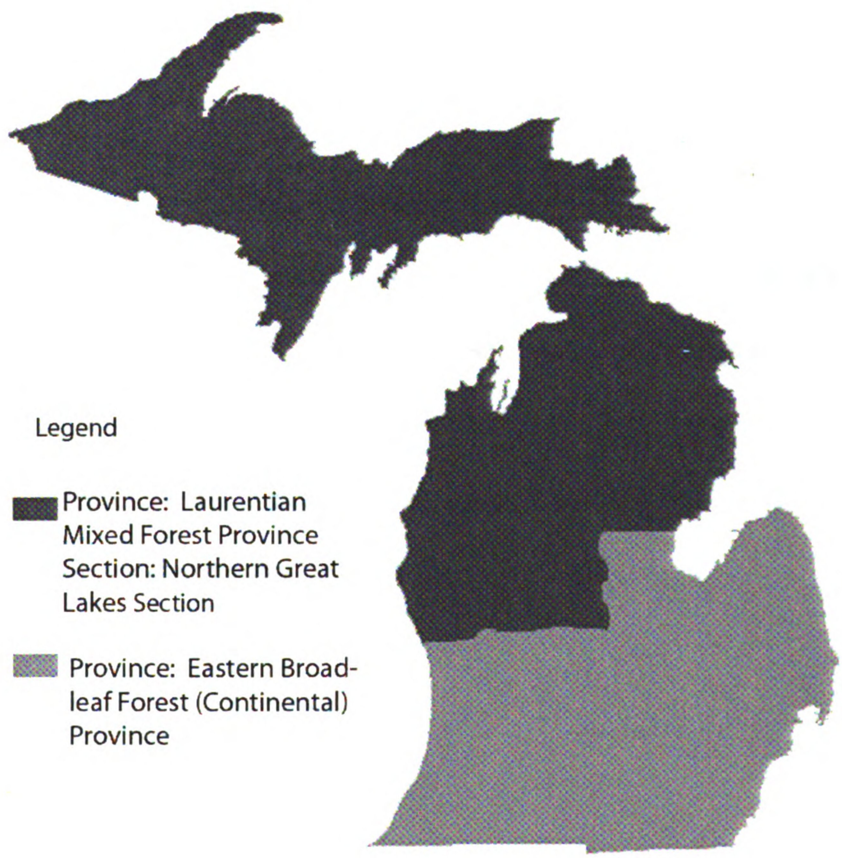

Figure 14, Bailey's Ecoregion Map-Michigan

In his work, land surface form, climate, vegetation, soil and fauna are studied. The Southern Broad leaf region employs oak and hickory as the dominant tree species, beech and maple forest increase near the northern boundary of this region. The precipitation decrease as the distance to lake increases. The Northern Great Lakes Section has a mixed forest. Pine and hemlock are dominant species for the northern part and mixed deciduous forest like beech-maple are more used to in warmer places. It is worth mentioning that Bailey's hierarchical method concluded the general approach for classifying regions in a large scale. But, there is no obvious evidence showing that the boundary he drew exactly reflect the existing landscape condition. For example, there could be the same lake effect on different places which are physically far from each other but still on the eastern shoreline. The tree species that area important to Bailey are determined not to be important in my statistical analysis.

Omernik ecoregions of Continuous United States

Omernik (1987) incorporated human development into his delineation of ecoregions. Factors include climate, vegetation, mineral availability and physiography. Simply from the names he gave, it is easy to tell the land form and forest type for each region. Similar forest types are represented as in Bailey's ecoregion. Also, transitional area of northern central hardwood forests is identified (Figure 15).

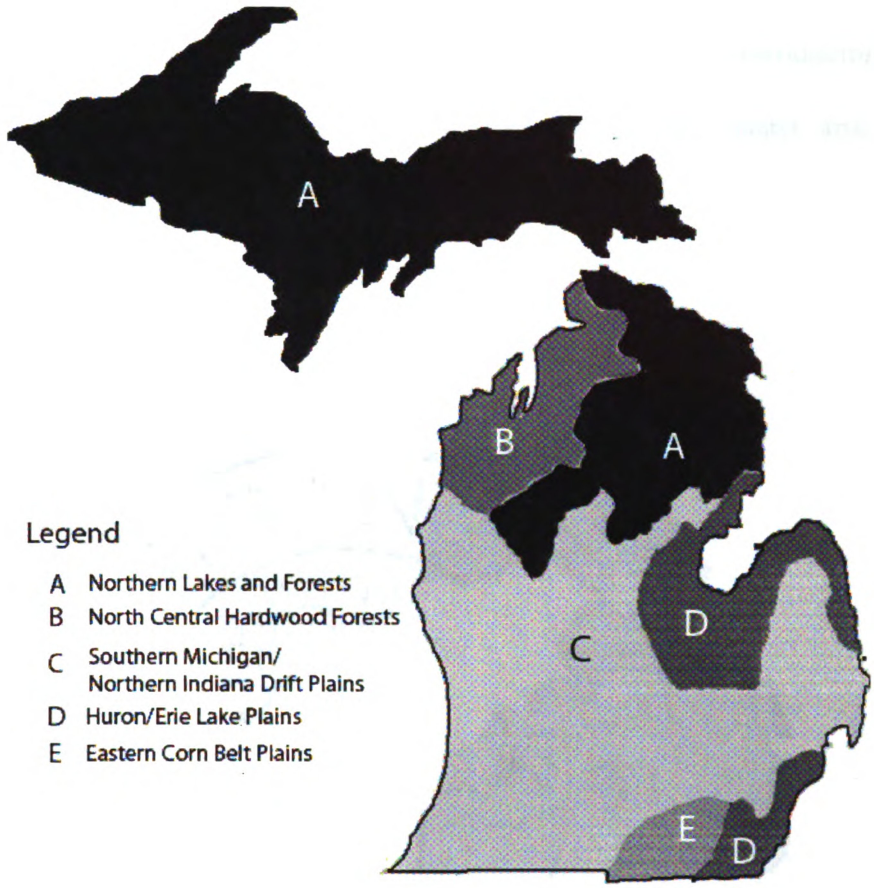

Figure 15, Omernik's Ecoregion- Michigan

His work is recognized as mapping homogeneous areas by employing mixed factors and this map implied further landscape management developing for better resource preservation. The blending problem arises when he delineates the boundaries. He used subjective decision to define regions. He did not provide specific reasons for delineating, which causes doubt in system. His Lower Peninsula regions look different than mine-inland patches are not found in this area. His classification also treated the Upper Peninsula as a whole region which is different from mine.

Albert's Regional Landscape Ecosystems of Michigan

Albert (1986) developed landscape ecosystems of Michigan by introducing climate, soil and physiographic factors. Statistical analysis of PCA and cluster analysis area conducted to help the forming of ecological units boundaries.

Figure 16, Albert's Landscape Ecosystem of Michigan

By employing climate, soil and physiographic factors, four major regions are identified-Southern Lower Peninsula, Northern Lower Peninsula, Eastern Upper

Peninsula and Western Upper Peninsula (Figure 16). Also, hierarchical districts are detected for further analysis. Districts are named by their major locations. Combining physical environment and biotic community of plants and animals makes this study more accurate. Upon conclusion, plant communities are stated within each location.

This study classified Michigan into 4 major regions and the size of each region are physically tends to be similar. My study implies that the sizes of regions can be different, range from small patches to the whole and still, blending area arises between regions so there may be no distinct regions.

Stefanacci's Environmental Regions of Michigan

GIS and quantitative methods have been introduced in the classification of homogeneous regions. Stefanacci (1997) employed a set of variables and PCA to generate four broad regions which share similar climate, soil, topography and land use.

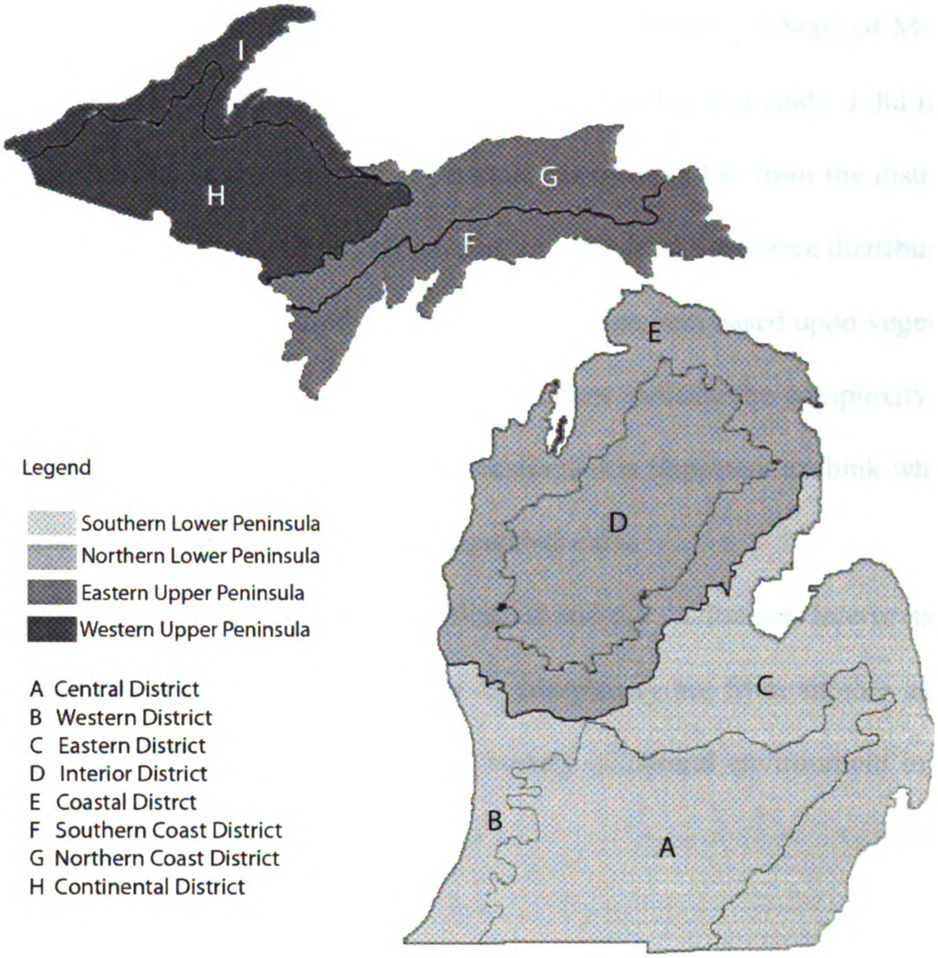

Figure 17, Stefanacci's Environmental Regions of Michigan

She divided each region into districts to illustrate the diversity in different locations (Figure 17). Multi-factor analysis and statistical analysis made this study an accurate data based study mapping. She was successful in finding an inland patch as it is depicted in the northern Lower Peninsula. Integrated interpretation of each district is clarified and for this point, this work is somewhat similar with Albert's classification (1986). Although neither Stefanacci, Albert, nor my studies are in agreement concerning the spatial arrangement of regions.

Conclusions and Implications in Land Use Planning

My intention for this study is to develop ecological regions for State of Michigan, which could repeated statistical analysis and GIS mapping. For this study, I did not start with preconceived shapes and lines from personal perspective but from the distribution maps of native trees. With this study, which employs single variable-tree distributions, it could lead to a classification method for landscape management based upon vegetation.

The unexpected shapes of 10 significant dimensions indicate the complexity of this environment, with the revelation of these dimensions, it is important to think why these non-continuous shapes appear and why these patches exist.

My study suggests the areas are quite blended and not so distinct. Interpretation of each dimension could be challenging due to its complexity but from another aspect, it shows the diversity of landscape types and a variety of natural environment in spatial forest structure.

Possibility of Diverse Landscape

In Stefanacci (1997)'s work, she did not exclude urban area, but the location of all the regions indicate the human disturbance and alteration. For better landscape management, knowing the existence of natural resource is not sufficient, incorporating the human activity are more reasonable. Hills (1966) categorized the land into several levels for land use application. In recent years, constructing better environment based upon understandings of site is widely accepted by more and more scholars. Comprehensive analysis would be conducted before the planning process. However, people are more inclined to simplify or classify distinctive areas for different potential usage or for preservation. It is believed that this concept is not necessarily new for planners; however, it is worth rethinking that if this is the right way to develop the most suitable maps for site. If we think in another way, considering the diversity of landscape features, the diversity of landscape ecosystems or the diversity of forest types, then it will reflect the importance and uniqueness of natural area and the transition areas between city and rural region. People are striving for conducting corridors or stepping stones to link two areas together for energy flow and species exchange. From a planner's view, this may be more sympathetic to natural process and build a variety of visual landscape. In that case, the planning for city and rural areas should be specified with more concerns on the transition areas. The pace of urban sprawl is often quickening with the development of industry and human activity, rural or sub-urban areas tends to be "invaded" by the urban spatial features, thus, forest or other landscape types are facing the challenging of transforming for residential or other urban landscape types. Although this study presents an example of delineating boundaries of overlapping area, the results of all dimension maps inspired me of thinking building more diverse environmental in certain landscape types. For example, dimension eight almost covers the whole State of Michigan. It could be illustrated that Michigan could be treated as a whole region because it grows American elm everywhere; this homogeneous unit could be used as a significant reference for regional planning. Similarly, each type of landscape could build diverse landscape for meet people's different preferences. Open landscape, enclosed landscape, all landscape features could be build based upon the knowledge of tree distribution. Emerging new trend of landscape urbanism (Waldheim, 2006), which emphasized the urban ecology and urban geography also put forward a new challenging issue for landscape architects. In this case, I would like to suggest that treating each parcel of land as unique in a compositional way for better resource management and built environment.

Applied Plant-Based Regional Planning

Fifty-one Michigan native tree maps show the spatial distribution of tree species in Michigan. But as Davis (1981) indicated, the migration or tree species is still ongoing. Thus any regions defined in a study using plant distribution data may still be in flux. These regions may have some importance is the planning, design, and management of spaces, but it is not yet clear what these regions might mean and if they have a clear connection to a regional plan. Grant Jones (Jones and Amidon, 2007) developed Intrinsic Landscape Aesthetic Resource Information System to do regional planning. They combined GIS technique to build models, evaluate each region, make decisions based on the weighting of the whole environment. To some extent, this method employed natural factors and human impact. For my study, plant-based regional planning is possible when time and effort are employed by people.

Incorporating Regional Plan with Site Plan

Surprisingly, this study shows scattered patches in some dimensions. Viewing previous study, transition areas or independent central areas are identified by investigators (Albert *et al*, 1986; Stefanacci, 1997). For a regional scale, small areas of inland could be merged into larger local region. In this study, I paid attention to these islands; examinations and comparison are conducted for further analysis. Some of them could be merged but some could not. For example, for Dimension 6, 7, 9, and 10, they share the same boundaries in striped areas of northern Lower Peninsula. Dimension 6 and 7 occupied the same area while dimension 9 and 10 left it blank. With such obvious difference, this inland patch could not be merged into northern Lower Peninsula area. The complexity of plants cannot be displayed by rough maps, and through statistical analysis as a main approach, this potential area is detected and cannot be ignored for its specialness. In land use planning process, we could draw rough lines of certain areas, therefore, there could be mixed area excluded for the specific physical factors controlling. In that way, incorporating site plan into regional planning is a possible way to make unexpected and more complete results. Treat each parcel of land as unique could make site plan more suitable and applicable. For this study, rough distribution of each tree has been delineated, but, inside each specific area, the composition and structure could be studied to discuss the influence on land formation. That is saying ecoregions developed in this study could help us find associated trees and be prepared for more detection of ecological uses.

Greenway Planning in Regional Scale

In order to link rural and urban areas, corridors of greenway are highlighted for further design. However, building and maintaining a network of greenways need collaboration of other professions (Burley, 1995b). The objective of this study is to generate spatial patterns within State of Michigan and from the result I got, the situation calls for private or open spaces for building greenways. Generally speaking, greenways design and development require the observation of balancing preservation and development in certain areas. Building greenways could lead to linking these two types of land. For its enormous benefits, ecologically, greenway plays an important role as a strongly positive corridor. Linking fragmented spatial patterns could bring more edge effect, foster the inner growing of species, strengthen the exchange rate and make the ecosystem more stable for its diversity. From this point, greenway is strongly recommended for environmental issues. Therefore, knowing tree species distribution could help planners solve this problem. Besides, understanding the location of trees could result in view of spatial green system. Urban green system has been incorporated within city design since Emerald Necklace in Boston (Daniels, 2009). With the detection of forest system in Michigan, future greenway concept could be put forward and guide the land planning.

Limitation

Quantitative analysis has been introduced in this study and with its particular strength; the interpretation of the results in this study is not completed. From statistical aspect, there can be more analysis to be done. For the variable selection, hedges, shrubs and prairie could be employed for further studies as variables. For the data analysis method, although PCA is good in eliminating the variables, regression analysis could be done to see more results. Biophysical factors could predict the region by regression. To increase the accuracy of data analysis, all the eigenvectors could be plotted and further examination could be done by simply see the pattern of data set and their correlation with each dimension. In that case, the data reduction will take more effort but could indicate more accurate and reasonable clusters. Also, quantitative analysis could be employed in other studies related to the landscape planning, for example, to see the water feature area data and employing this single factor to reveal the classification.

Another implication of this research is the further use of this ecological region map. Since there are lots of previous work of landscape classification and land use planning, this different research effort could be prepared for further comparison and utilization. Ecological region classification is not only based on the tree distribution, it reflects environment for nature and people. How people could use this for professions like resources management, tourism planning, land use planning, urban geography, urban-rural forest management could be developed. Solely from this study, investigators could raise problems for deeper research. But conclusions from this study are general guidelines for developing balance for preservation and development. Mainly, these regions could represent the natural landscape of Michigan.

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