PRE-EUROPEAN SETTLEMENT VEGETATION OF LAKE COUNTY, ILLINOIS

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Summary

We mapped and analyzed the landscape pattern and composition of vegetation described by the U. S. Public Land Survey (PLS) of Lake County, Illinois, which was conducted between 1833 and 1839. Lake County was mapped by the PLS as 29 % prairie, 50 % timber, 13 % scattering timber and less than 1 % barrens. Prairie occurred primarily in the south central part of the county, while scattering timber was most predominant in the north and timber was widespread. Based on measures of tree density, areas mapped by the PLS as timber were over 65 % savanna, averaged less than 60 trees/ha, and were dominated by white oak. Areas mapped as scattering timber were over 90 % savanna, averaged less than 30 trees/ha, and were dominated by bur oak. Black oak, red oak and hickory were important secondary species in both types, with white pine and jack pine also important in scattering timber on the sand plain of Lake Michigan. Forest and woodland, represented by > 100 trees/ha and 50-100 trees/ha, respectively, were far less common than savanna, representing about 30 % of the areas mapped as timber and 10 % of the areas mapped as scattering timber. They were concentrated on the east flank of the DesPlaines River and on morainal bluffs along Lake Michigan. They also differed from savanna by dominance of white oak over bur oak and by greater abundance of mesophytic species, including ash, basswood, Hill's oak, elm, sugar maple and aspen. The landscape pattern of this vegetation indicates that fire processes played a significant role in shaping the presettlement vegetation pattern of Lake Co. .

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INTRODUCTION

At the time of European settlement (*ca.* 1820), northeastern Illinois was a broad mosaic of prairie and oak (*Quercus*)-dominated savanna, which comprised the northeasterly transition from tallgrass prairie to eastern deciduous forests (Davis 1977, Anderson 1983, Anderson & Bowles 1999). This pattern was climatically induced and controlled by fires set by lightning and by indigenous people, with timber persisting on the lee sides of fire barriers such as topographic relief and water courses (Gleason 1913, Moran 1978, 1980, Grimm 1983, 1984, Anderson 1991, Leitner *et al.* 1991, Bowles *et al.* 1994, McBride & Bowles 2001). Most of this original vegetation has been lost because of wide-scale fragmentation by agriculture and urbanization, while remnants have deteriorated from fire suppression and overgrazing (Cottam 1949, McCune & Cottam 1985, Anderson 1991, Stearns 1991, Robertson & Schwartz 1994, Schwartz 1997, Bowles & McBride 1998). Consequently, management and restoration of this vegetation represents an important challenge (Apfelbaum & Haney 1991, Leach & Ross 1995, Shore 1997, Bowles & McBride 1998). Conservationists need an understanding of the composition, structure, and dynamic processes of pre-European settlement (traditionally termed "pre-settlement") vegetation so as to better manage and restore its original biodiversity. Ecological models that apply presettlement processes to vegetation pattern, composition, and structure will best meet these needs (Leach & Ross 1995). In this report on the presettlement vegetation of Lake County, we interpret landscape vegetation pattern, structure and composition in relation to landscape features and fire processes and make management and restoration recommendations.

The Public Land Survey

A powerful approach to understanding the landscape pattern and structure of woody vegetation prior to European settlement is analysis of the Government Land Office Public Land Survey (PLS) vegetation notes, maps, and bearing tree data, which were recorded in the early 1800s in Illinois (Hutchison 1988, Ebinger 1997). This survey comprised a square-mile landscape grid upon which the identity, diameter, distance, and direction for one to four bearing trees were recorded at half mile intervals. These data were accompanied by measures of trees intercepted on section lines, section line vegetation summaries, other notes, and township plats distinguishing timber, prairie, and other important landscape features.

Despite evidence for biased or non-random selection of bearing trees (Bourdo 1956), the PLS data represent a large-scale vegetation survey that can be used to reconstruct landscape-scale pre-European vegetation (Brugam & Patterson 1996). These data can allow estimates of forest composition and ranking of species dominance, but the large sampling scale usually prevents accurate and detailed mapping of vegetation types (Manies & Mladenoff 2000). However, site-specific comparisons and precise mapping of vegetation boundaries may be possible (*e.g.* Bowles & McBride 1998). These data also can provide ecological information when landscape features, such as soils, topography, or fire barriers, are used to interpret the distribution pattern of different vegetation types based on their composition and structure (Leitner *et al*. 1991, Anderson & Anderson 1975, Moran 1978, 1980, Rogers & Anderson 1979, Bowles *et al.* 1994, 1999, and Edgin & Ebinger 1997). A useful landscape fire model predicts that fire driven by prevailing westerly winds would eliminate trees on the western sides of landscape fire breaks (Leitner *et al*. 1991). For example, in Illinois, Cook, DuPage, Will and Kane counties had greater landscape cover of prairie and savanna occurred in areas with little landscape fire protection, while higher tree densities and greater abundance of fire-intolerant trees, as well as presence of woody undergrowth, occurred in more fire-protected landscape positions on the eastern sides of watercourses (Kilburn 1959, Moran 1980, Bowles *et al.* 1994, 1999, Bowles & McBride 2001, 2002, 2003, 2004; McBride & Bowles 2001). The Fox and Desplaines rivers had a strong firebreak effects in Kane and McHenry counties, with higher tree densities and greater abundance of sugar maple on their eastern flanks (Bowles & McBride 2003, 2004). However, the Fox River drainage had a weaker affect in McHenry County, where timber with savanna tree densities was wide spread and there were few areas of forest tree densities.

<u>Study area</u>

Lake County lies along the northeastern border of the Chicago region and the northeastern border of the Prairie Peninsula (Figure 1). It comprises 8 full and 8 partial townships covering 121,624 hectares (300,411 acres). The glacial stratigraphy of Lake County is primarily Woodfordian-aged glacial drift, including alternating end-moraines, ground moraines and outwash (Figure 2). The western edge of the county lies on the Fox Lake moraine and drains into the Fox River. Most of the western half of the county lies on the undifferentiated Valparaiso moraine, which drains either west into the Fox River or east into the Des Plaines River. The eastern part of the county includes the Lake Border Morainic System which also drains primarily into the Des Plaines River. A two-kilometer broad sand plain forms the Lake Michigan border in the northern two townships of Lake County, while the Highland Park Moraine borders Lake Michigan in the southern townships.

Lake Co. comprises three sections of the Morainal Natural Division and one section of the Lake Plain Natural Division of the Chicago Region, which correspond to glacial drift of different ages (Mierzwa 1984). The Kettle Moraine Section includes glacial lakes and wetlands, outwash features, and kame and kettle topography. The Western Morainal Section is less rugged and more poorly drained, while the Racine Till Plain Section includes ravines that drain into Lake Michigan, as well as adjacent uplands. The Illinois Dunes Section of the Lake Plain Natural Division comprises an extensive ridge and swale sand deposit bordering Lake Michigan.

In a previous study of the presettlement vegetation of Lake County, Moran (1978) indicated that the Des Plaines River had a strong fire break effect on vegetation pattern, with fire-sensitive maple-basswood forests developed in the floodplain of the east flank of the river. In comparison, oak-hickory forests occurred on the Highland Park Moraine along Lake Michigan, which would also have been fire protected, but to a lesser degree than the floodplain of the DesPlaines River. Modern vegetation studies also support this concept, as maple-dominated forest remnants still occur along the Des Plaines River floodplain, while oak-dominated forest remnants occur on upland habitats of the Lake Michigan bluffs (Bowles et al. 2000, Bowles et al. 2003).

Study objectives

We examined the presettlement woody vegetation pattern and structure in Lake County based on analysis of PLS maps and data. Our objectives were to: 1) assess how the PLS described and sampled vegetation and relate the results to modern concepts of savanna, woodland, and forest, 2) correlate vegetation pattern and structure with geographic location, landscape features and fire processes, 3) describe presettlement vegetation based on the PLS data, and 4) apply these results toward management and restoration guidelines for native woody-dominated ecosystems.

Based on our previous studies of Chicago region counties, we expected that vegetation in Lake County was patterned by an interaction between eastward moving prairie fires (driven by westerly winds) and potential landscape firebreaks such as steep topography or water courses. This process would result in persistence of timber on the leeward sides of waterways, ravines or bluffs, or in areas of rugged topography (Anderson 1991, Ebinger 1997). We also expected fire to affect forest structure and composition. For example, low tree density (savanna) and dominance by oaks (*Quercus* spp.) would be expected in areas receiving only moderate fire protection. Greater tree density and presence of fire sensitive species, such as maple (*Acer*), ash (*Fraxinus*), basswood (*Tilia*) and elm (*Ulmus*) species would be expected in more fire-protected areas. In particular, we sought to determine whether different forest associations or communities, such as maple-basswood (Moran 1978), could be described from the notes and bearing tree data..

HISTORIC METHODS

PLS Vegetation types

The Lake County Public Land Survey was conducted primarily in 1833-39 by the Deputy surveyors George Harrison, Eli Berry, and James Galloway, with the state line surveyed by Lucius Lyons (Table 1). Each township was mapped after completion of its survey, showing the distribution of timber, watercourses, and settlement features. The Lake Co. PLS also described different vegetation types, including *prairie, wet prairie, sandbanks, marsh, slough, swamp, barrens, scattering timber* and *timber*. The PLS indicated distances along section lines for transitions between these vegetation types, which facilitated their mapping. The primary data collected by the PLS were the identity, diameter, distance, and direction for one to four bearing trees, each located in one of the four quadrants at each section corner, as well as for up to two bearing trees located in different quadrants at section quarter-corners. Surveyors also recorded the identity and diameter of line trees intercepted by section lines and summarized tree species present along section lines. They also often recorded the species present in undergrowth along each section lines, and the distances along section lines with and without undergrowth. In the case of Lake County, presence or absence of woody undergrowth was recorded primarily for the western quarter of the county. For this reason the data represented may not be a representative sample of the abundance or characteristics of woody undergrowth.

<u>Species identification</u>

The surveyors identified about 28 different bearing trees by common name, including most of the dominant native tree species. We assume that most witness tree species were correctly identified and placed them in modern species analogs following Swink and Wilhelm (1984). However, identification of oaks, especially members of the black oak group, appears to have been difficult or inconsistent among surveyors (Collins 1997, Clark 2000, Table 1). Scarlet oak (*Quercus coccinea*), also known as Hill's oak or jack oak (*Q. ellipsoidalis*), was not identified by the PLS for Lake Co., although it was apparently frequent in the Chicago region (Trelease 1919, Waterman 1920). References to Spanish oak or to pin oak by the Lake Co. PLS may have been *Q. coccinea* as its northern form is also known as northern pin oak (Kilburn 1959). Numerous references to black oak (*Q. velutina*) in Lake Co. also may have been scarlet oak or hybrids among scarlet, black and red oak, as pure black oak is infrequent in Lake Co. (Swink and Wilhelm 1994). The term "maple" was applied to soft maple (*Acer saccharinum*), a floodplain species, while "sugar tree" was applied to *A. saccharum*, a species of mesic forest habitat (Swink and Wilhelm 1994). Ash species (*Fraxinius* sp.) probably included white ash (*Fraxinus americana*), red ash (*F. pennsylvanica*), green ash (*F. pennsylvanica* var. *sub-integerrima*), blue ash (*F. quadrangulata*) or black ash (*F. nigra*). The surveyors also identified 23 species present as woody undergrowth, including many canopy trees. Some of the shrubs, such as hazel (*Corylus americana*), redroot (*Ceanothus americana*), sumac (*Rhus* sp.) could be assigned to species or genera, other names such as "vines" or "briars" are vague. Many additional shrub species may have been unknown to the surveyors (Clark 2000).

MODERN METHODS

<u>Mapping and interpretation</u>

The PLS data were transcribed and analyzed from microfilm copies of the original notes. These data were used to refine the original PLS vegetation plat maps by digitizing vegetation boundaries and bearing tree locations using ARC/INFO Geographical Information System (GIS) software (http://esri.com). GIS was also used to add layers for section lines, bearing trees, section and quarter-corner tree densities, line trees, tree species summaries and woody undergrowth summaries. Features of European settlement, such as fields, were included as separate GIS layers not used in vegetation maps or landscape analysis.

<u>Tree density classes</u>

All recorded bearing tree distances were used to calculate tree density for each section and quarter-corner. This procedure followed the modified point-center-quarter sampling method, where trees/hectare = 10,000 $m^2 \div (\bar{x}\ d)^2$, and $\bar{x}$ d = the mean distance of up to four bearing trees at each corner adjusted for the number of trees sampled (Cottam & Curtis 1956). A 400 trees/ha ceiling for tree densities was used to avoid artificially high values that can result from the point-center-quarter method. Corner and quarter corner bearing tree densities were used to calculate average densities for the PLS vegetation types of timber, scattering timber, prairie and wet prairie, and wetlands. For vegetation that usually did not support bearing trees, such as prairie, these densities represent only corners with trees, and thus local tree densities. According to Clark (2000) selection of the Q1 (nearest) bearing tree was least likely to be biased, and calculation of density using additional bearing trees from the same corner will result in low estimates of stand density. To reduce effects of this potential bias tree density, we placed density calculations into classes of *open savanna* (> 0-10 trees/ha), *savanna* (> 10-50 trees/ha), *woodland* (> 50-100 trees/ha) and *forest* (> 100 trees/ha) categories following Bowles *et al*. (1994, 1999). Moran (1978) separated only savanna (< 70 trees/ha) from forest (≥70 trees/ha) and did not recognize open savanna and woodland as distinct categories. The total and relative (R) density (D) and basal area (BA) and importance value [IV = (RD + RBA)÷2] were calculated for each bearing tree species in all vegetation types and categories. Basal area was calculated as $BA = \pi * r^2$, where r = tree diameter. This was expressed in square meters by converting from the original measure of diameter in inches. These data are based on total occurrences within each vegetation type, thus represent an unbalanced sample. As a result, only species relative data and importance values can be compared among vegetation types.

<u>Statistical comparisons and analysis</u>

Bearing tree data were used to make comparisons among the vegetation types identified by the PLS (i.e. timber, scattering timber, barrens etc.) and among tree density classes. The structure of PLS vegetation types was determined by comparing the relative abundance of section and quarter corners assigned to savanna (> 0-10 trees/ha), open savanna (> 10-50 trees/ha), woodland (> 50-100 trees/ha) and forest (> 100 trees/ha) tree density classes within each of these vegetation types. We also calculated and compared the abundance of dominant trees (bur oak, white oak and black oak), as well as mesophytic forest trees, among these tree density classes. We expected that bur oak would be more important in open savanna than white and black oak because it has more fire-resistant bark. We expected that fire intolerant and shade tolerant mesophytic trees, such as maple, ash, basswood and elm, would be more important at higher tree densities, which are usually associated with more fire-protected habitats that are also often more mesic. To determine landscape effects on vegetation structure, we compared tree densities and species composition at two-mile intervals extending east from the fire-protected east side of the Des Plaines River to Lake Michigan, assuming that greater tree densities and abundance of mesophytic species would occur adjacent to the these water bodies because of their fire-break effects (Moran 1978).

Section line summary data were used to calculate the extent and composition of woody undergrowth. The linear extent of section lines for which woody undergrowth was recorded was summed for each PLS vegetation type and expressed as a percentage of the total length of all section lines in which woody undergrowth was recorded as either present or absent. This statistic was also calculated for each species, and converted to relative abundance among all species recorded.

We used species tree presence data from section line summaries to help define vegetation types for both timber (n = 796 summaries) and scattering timber (n = 248 summaries). These data were ordinated using Non Metric Multi-dimension Scaling PCORD software with a Sorensen (Bray-Curtis) distance measure (McCune & Mefford 1995). For this analysis, species with fewer than five occurrences were eliminated from the timber data set, and species with fewer than two occurrences were eliminated from the scattering timber data set. Species identified to the genus level were also eliminated for oak and pine. Flexible Beta cluster analysis (β = -0.25) was then used to identify species groups using a Sorensen distance metric on PCORD. We then used known ecological adaptations of different species to make inferences about presettlement habitat conditions and vegetation types.

RESULTS

Vegetation pattern and structure

About 29 % of the presettlement vegetation cover of Lake County was grassland, with 63 % woody vegetation including 50 % timber, 13 % scattering timber, and less than 1 % barrens (Table 2, Figure 3). Aquatic systems represented about 9 % of the landscape, with about half represented by lakes or ponds and less than one-third described as marsh. Where measured in the western part of the county, linear cover of woody undergrowth measured on section lines was about 16 % in timber, 18 % in scattering timber, and 11 % in barrens. At the county-wide scale, tree densities were lower ($\bar{x}$ = 39.25 trees/ha, sd =72.89, n = 539) in habitats associated with the Valparaiso Moraine in the western part of the county than on the Lake Border Moraine in the east ($\bar{x}$ = 88 trees/ha, sd = 104.3 n = 622).

Tree densities exceeded 100 trees/ha within one mile of the Des Plaines River on its east flank, and also within one mile of Lake Michigan, indicating forest conditions in these areas (Figure 4). As the distance from these landscape features increased, tree densities dropped first to woodland conditions (50 - < 100 trees/ha) and then to savanna (< 50 trees/ha). Tree species abundances also varied across this gradient (Figure 4). Bur oak was more abundant than white oak in woodland and savanna near the Des Plaines River, while white oak was more abundant elsewhere. Mesophytic forest species were most abundant in forest conditions, while hickory tended to be most abundant in savanna and woodland (Figure 4).

Landscape vegetation structure based on tree density classes was about 75% open savanna and savanna combined, and about 10 % woodland and 15 % forest (Figure 5). Based on vegetation described by the PLS, 63 % of the bearing tree corners were described as occurring in timber, with 24 % in scattering timber and 1 % in barrens and brush. Timber averaged about 59 trees/ha and was 36 % open savanna and 33 % savanna, with about 13 % woodland and 18 % forest (Figure 5). Scattering timber averaged about 28 trees/ha and was 60 % open savanna and only 28 % savanna, with 12 % woodland and forest (Figure 6). Barrens averaged about 48 trees/ha, with 50 % open savanna and 29 % savanna.

Woody vegetation composition

Species richness among the PLS vegetation types was greatest in timber, where 26 species were sampled (Table 3). Timber was dominated by white oak, with bur oak subdominant and black oak, hickory and red oak important secondary species. Only 12 bearing trees were recorded in scattering timber, which was dominated by bur oak with white oak subdominant. Black oak, hickory and white pine were important secondary species in scattering timber. Bur and black oak were the first and second most important trees in barrens, which were usually recorded as either “bur oak barrens,” or as “black oak barrens.” Bur, black and white oak were also the predominant species recorded from wetland habitats, with a single tamarack bearing tree was recorded from a swamp.

The greatest number of woody undergrowth species, 22, was also found in timber, which included three shrub species, as well as vines and briers (Table 4). Black oak was the dominant undergrowth species in all PLS vegetation types. In timber, black oak had 63 % linear cover and 39 % relative cover (Table 5). Vines were the second most important species category in timber, followed by bur oak and hazel (*Corylus americana*). Eleven species were recorded as woody undergrowth in scattering timber, where hazel, willow and quaking aspen were important secondary species. Only three species were recorded in barrens undergrowth, where bur oak accounted for about half the abundance of black oak and hazel was a minor component.

Species richness did not vary among the tree density classes, ranging from 17 species in open savanna to 19 species in timber (Table 5). However, composition differed across this tree density gradient (Figure 6). Among dominant species, bur oak was most important in open savanna, with white oak subdominant. This relationship was reversed in savanna, woodland and forest, where white oak was more important that bur oak and black oak had greater importance than in open savanna. Composition among less important species also shifted across this gradient, with most species (e.g. ash, basswood, elm, sugar maple) having greater importance in woodland and forest conditions (Figure 6).

The ordination and cluster analysis of scattering timber section line summaries separated multiple species groups (Figure 7). White pine and jack pine, which occurred primarily in the Lake Michigan sand plain, had the highest first-axis scores, and clustered separately from other species. Ash and basswood had low first-axis scores, and clustered as a subset with Hill's oak and hickory, which had high second axis scores. White, bur, black and red oaks clustered together and were more centrally located. A stronger mesophytic component occurred in timber, with elm, ash, basswood, walnut and sugar maple having greatest first axis scores (Figure 8). However, these species clustered separately. Hill's oak and aspen had the lowest first axis scores, but clustered as a subset with maple and elm. Other oaks and hickory were centrally located and clustered together.

DISCUSSION

Landscape vegetation pattern and structure

The structure, composition and pattern of presettlement vegetation in Lake County has strong similarities and differences with other Chicago region counties. The extensive coverage of savanna dominated by bur and white oak reinforces that fire-maintained oak savannas were widespread and typical of the Chicago region vegetation. In addition, the occurrence of forest tree densities and greater abundance of mesophytic species along the east flank of the Des Plaines River and adjacent to Lake Michigan indicates that landscape firebreaks were critical in providing the greater degree of fire protection needed for persistence of these species. Although cover of woody undergrowth was lower than in most other counties, this vegetation was surveyed primarily in the western part of the county where tree density was also comparatively low and low cover of undergrowth might be expected. The dominance of woody undergrowth by black oak also differed from other counties, where hazel was the most frequent woody understory species. The relatively high abundance of black oak bearing trees is also unexpected, as this species occupies dry habitats and is a rare component of modern Chicago region forests (Bowles et al. 2000). Misidentification of other oak species for black oak is one possible explanation. Nevertheless, excessive drainage on thin layers of till or gravel deposits may have promoted black oak in some parts of the county. For example, black oak remains a dominant species in sand savanna habitats on the Lake Michigan sand plain (Swink & Wilhelm 1994).

The excessively large area of timber in Lake, County, exceeding 60% of the landscape, indicates a trend toward greater cover of timber and less prairie in the northern portion of the Chicago region, as cover of timber reached 40 % in McHenry County and 36 % in Kane County but did not exceed 20 % in the east and south. This shift toward greater coverage of timber probably represents the transition toward forest that occurs at the northeastern border of the Prairie Peninsula. Conversely, the large area of prairie in the south central part of the county is also an extension of prairie that extended south through DuPage and Cook counties, where timber was much less extensive.

The vegetation pattern in the Chicago region at the time of settlement represents an intermediate stage in a dynamic process of fire-caused conversion from forest to prairie, a process that began 8,000-6,000 years ago during the hottest and driest part of the Holocene in Illinois and continued with Indian-set fires as the Holocene climate began to moderate (Gleason 1922, Transeau 1935, Curtis 1959, Grimm 1984). This vegetation shifted spatially over time in response to changing climatic conditions, favoring either forest during periods of greater rainfall and less frequent fire, or prairie and savanna during periods of less rainfall and more frequent fire. It may have been stabilized by fire, as well as stable climatic conditions, over short time periods, such as at the time of the PLS (Anderson & Bowles 1999). Our analysis of the spatial pattern and relationship between prairie, timber and scattering timber in Chicago region presettlement vegetation also indicates that open savanna (<10 trees/ha) as well as scattering timber probably represent an extremely late stage before conversion to prairie. Thus, the extensive area of scattering timber in northern Lake County might eventually have been converted to prairie if fire processes interrupted by settlement had continued.

<u>Woody vegetation types</u>

Savanna

Open savanna (< 10 trees/ha) dominated by bur oak with secondary abundance of white oak and black oak was the predominant woody vegetation type in Lake Co. This vegetation appears to correspond most closely to scattering timber described by the Public Land Survey, which was also dominated by bur oak. However, scattering timber most extensive northern Lake Co., while open savanna was more widespread and formed a major component of areas mapped by the PLS as timber as well. With increasing tree density, open savanna graded into savanna (10 - < 50 trees/ha) in which white oak replaced bur oak as the dominant species. This shift toward greater tree density, as well as dominance by a less fire resistant oak, appears to correspond to a decreasing fire effect. However, this apparently had no effect on abundance of more mesophytic species, as they had equally low importance values in both open savanna and in savanna. Open savanna on the sand plain of Lake Michigan differed by the occurrence of white pine and jack pine with black oak in vegetation described as scattering timber, which remains extant at Illinois Beach State Park (Swink & Wilhem 1994).

Woodland

Although oak woodland (> 50-100 trees/ha) is often thought of as typifying the Chicago region's presettlement oak timber, this vegetation component has been found to be the most infrequent of presettlement vegetation types based on tree density classes (Bowles *et al.* 1994, 1999, Bowles & McBride 2001, 2002; McBride & Bowles 2001). Indeed, woodland was the rarest wooded landscape component in Lake Co., represented by about 15 % of the bearing tree corners. Woodland probably occurred along stream drainages or lakes, in the interior of tracts of timber, presumably in more fire-protected mesic situations than savanna. Woodland tree species composition appears to have been intermediate between savanna and forest. For example, this vegetation had greater dominance of white oak and mesophytic tree species than savanna, but these mesophytic tended to be more important in forest.

Forest

Forest habitat was rare in Lake County, and only slightly more frequent than woodland. Although this vegetation was dominated by the white oak, as was savanna and woodland, it had greater abundance of red oak and hickory, as well as mesophytic forest species. Cluster analysis indicates that these mesophytic species tended to form several distinct groups. A sugar maple-elm group may have been associated with wet-mesic habitats such as the floodplain terraces of the Des Plaines River, where similar forests existed at the Ryerson Forest Preserve before loss of elms to disease (Bowles et al. 2003). The ash-basswood-walnut group may have represented more mesic upland sites associated with the Des Plaines River. Moran (1978) indicated these forests represented maple-basswood forests. However, our data suggest that basswood was never co-dominant, and that white oak may have been a leading dominant over maple in most habitats. Moran (1978) also suggested that oak-hickory forest occurred along the lake Michigan bluffs, with mesophytic species including American beech (Jensen 1928) restricted to lake-shore ravines. Our data suggest that these upland forests may have had tree densities similar to forests of the Des Plaines, but with lower abundance of maple and greater abundance of hickory, red oak and basswood.

Minor communities

The large-scale sampling of the Public Land Survey provided little information about rare vegetation types that are known to have existed before settlement. For example, although Moran (1978) mapped an area of “Tamarack Bog,” the PLS recorded only a single tamarack bearing tree from habitat described as “swamp.” Although Barrrens occupied less than 1 % of the woody vegetation of Lake County, they have been consistently identified and mapped by the PLS in all Chicago region counties. Barrens vegetation is one of the most ambiguous presettlement vegetation types. The term was originally applied to areas where poor soil limited tree growth, such as “pine barrens.” However, in the glaciated region of Illinois it was applied to areas of the forest-prairie border where burning had reduced woody vegetation to post-fire sprouts - a condition though by the surveyors to represent poor soil conditions because of the poor condition of trees. As a result, most barrens mapped by the PLS in the Chicago region had high % cover of woody undergrowth comprising hazel and oak sprouts and low tree density. Barrens in Lake County were somewhat atypical, as they had only about 10 % cover of woody undergrowth with low abundance of hazel, and had relatively high tree density of bur and black oak, reaching about 50 trees/ha.

MANAGEMENT AND RESTORATION

Issues of scale and accuracy and vegetation change

Although the PLS sampling data provide meaningful information, applying landscape data directly to small-scale restoration and management can be problematic without an appropriate transfer of scale (Manies & Mladenoff 2000). For example, the landscape-scale PLS sample coverage would provide few sample points that might directly apply at a small scale to existing sites (Bowles & McBride 1998). Further, the point-center-quarter sampling method is vulnerable to non-random vegetation patterns and to sampling error, and may provide erroneous information with small sample sizes. A single random sample occurring within a small group of trees in open savanna could result in an estimate of forest tree density, leading to a conclusion that the site was forest. The linear measure of woody undergrowth also represents a large-scale sample that does not directly translate to more precise small-scale measures of woody undergrowth.

Management to restore presettlement or "natural" vegetation conditions also must take into account the dynamic nature of vegetation and the strong possibility that many, if not most, Holocene fires were Indian set. If presettlement vegetation pattern and structure changed very little during periods of stable climatic conditions, then conditions present in the early 1800's probably would have persisted after the 19th century, especially if the presettlement fire regime had been stable. Therefore, the structure and composition of this vegetation would represent a framework for setting restoration management goals and objectives, and for understanding the landscape processes needed to reach these goals.

Restoring fire processes, species composition and structure

The structure and composition of woody vegetation in Lake County indicate that restoration goals should include oak dominance in most woody vegetation types. The landscape pattern of this vegetation also indicates that fire processes played a significant role in shaping the presettlement vegetation pattern of Lake Co. Fire is therefore critical for restoring and managing woody vegetation to represent presettlement conditions, as well as for maintaining the floristic diversity present at the time of settlement. The dominance of oaks throughout all woody vegetation types also indicates that fire affected the entire continuum of woody vegetation.

The Lake County data also indicate that assumptions about former levels of abundance of woodland need to be re-evaluated. Woodland is often considered to have been the predominant woody vegetation type of the Chicago region and is an important focus of restoration activities (Chicago Biodiversity Council 1999). However, results from Lake Co., as well as from other counties (e.g. McBride and Bowles 2001), indicate that woodland occupied less than 20% of the landscape, probably covering about 15,000 hectares, and that forest vegetation was more abundant. Many existing woody vegetation remnants that are considered representative of woodland (e.g. Bowles

& McBride 1996) may have been formerly more open savanna communities (Bowles et al. 1998). As a result, management to restore woodland structure may not replicate the most widespread conditions present prior to settlement. In turn, some modern forest remnants may have been originally more open and similar to woodland. Restructuring these remnants to a former more open woodland structure will require the use of fire as well as supplemental mechanical canopy thinning (e.g. Bowles et al. 2007). However, based on tree density classes, forest vegetation was also present in fire-protected habitat, and little information is available about the fine-scale structure and composition of these forests. Because of the limited information about presettlement woodland and forest, applied research will be required to learn how to maintain biological diversity when these habitats are managed to replicate presettlement conditions (Bowles et al. 1998).

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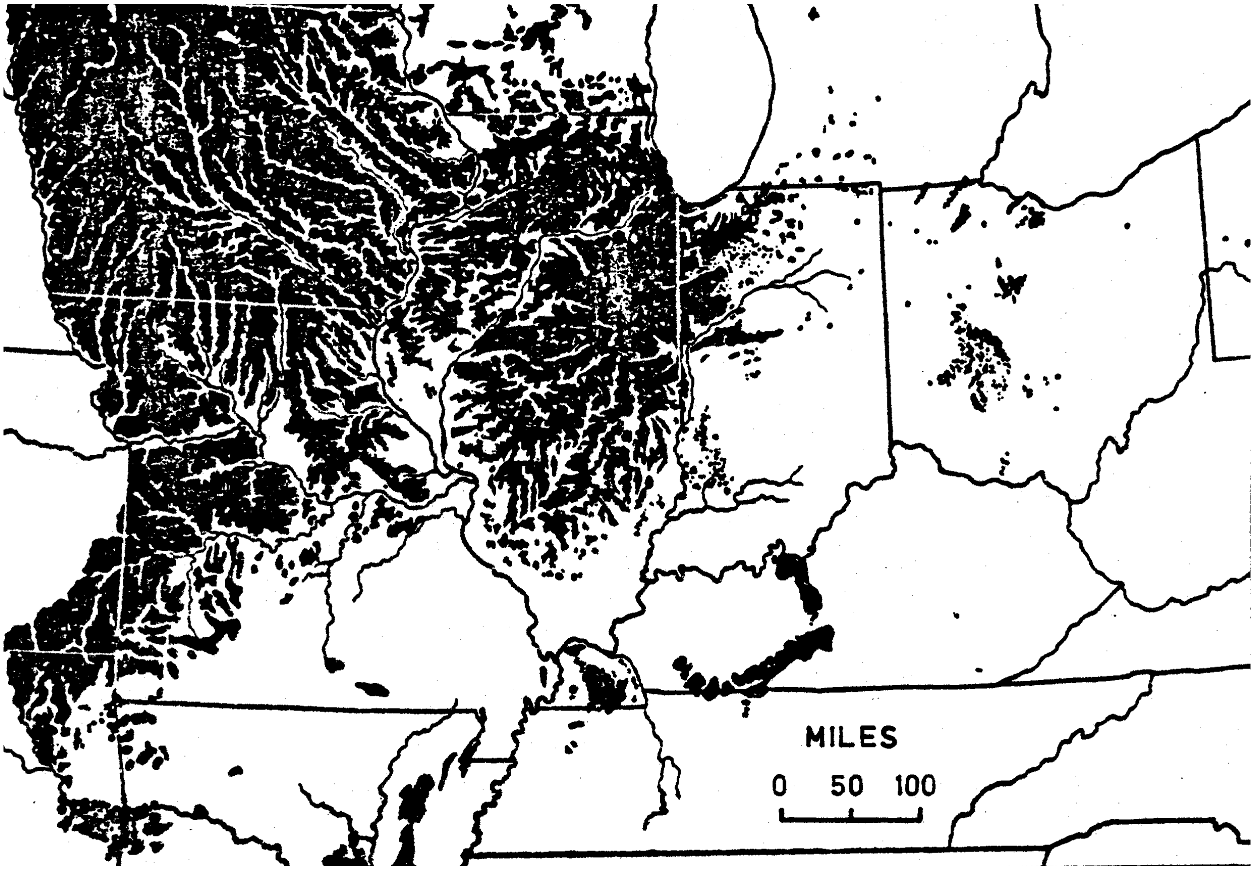


Figure 1. Extension of tallgrass prairie (in black) eastward as the “Prairie Peninsula.” Mapped by E. N. Transeau (1935). Reprinted with permission of the Ecological Society of America.

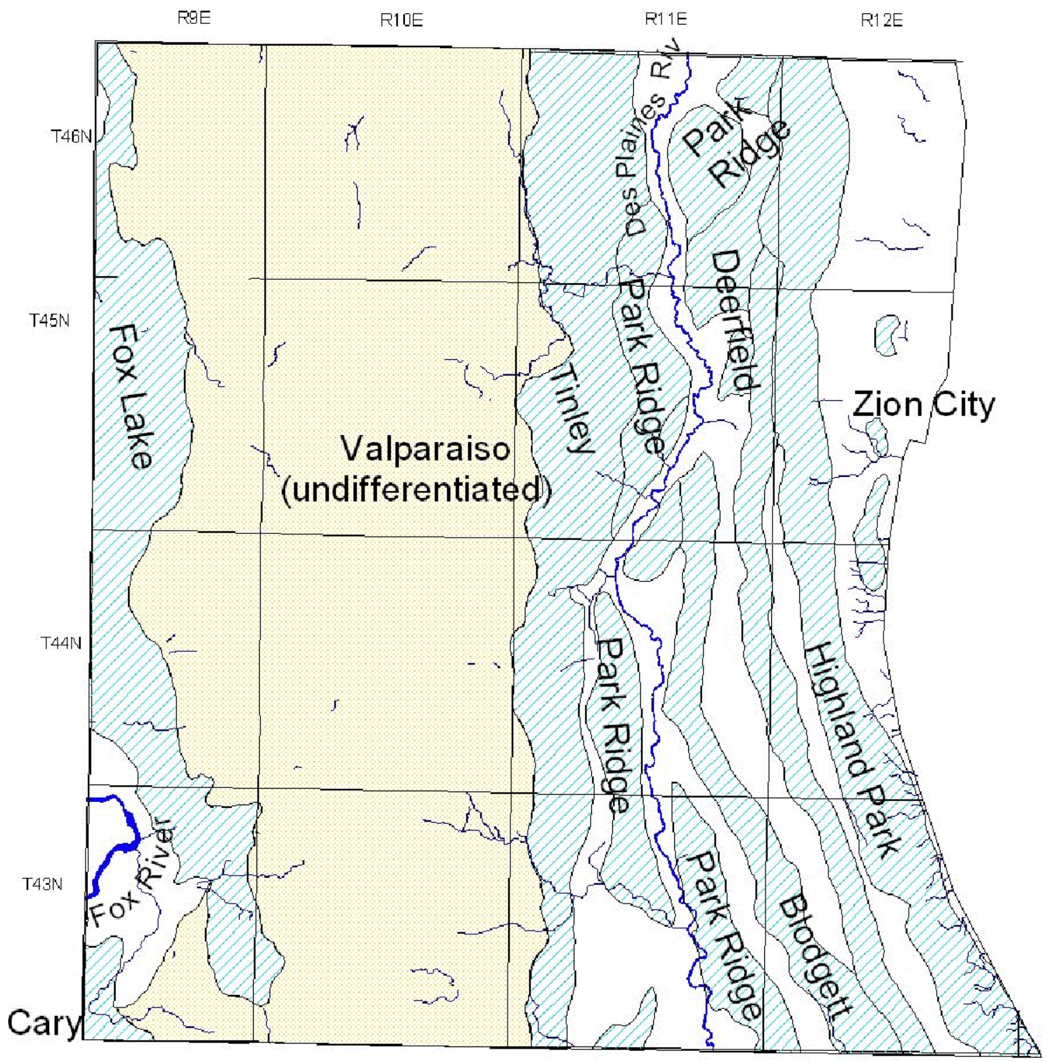
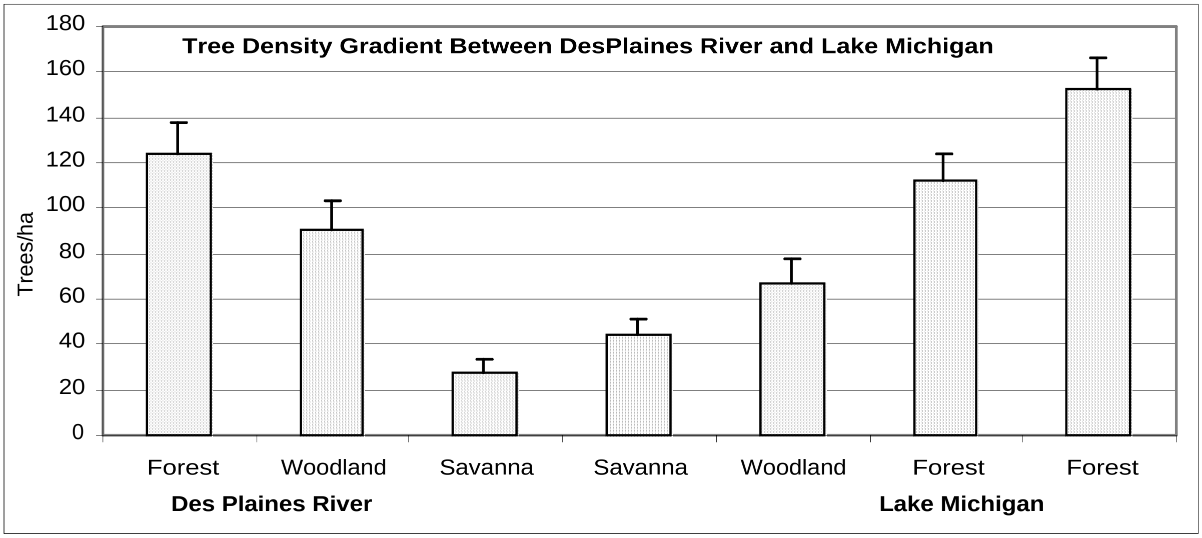
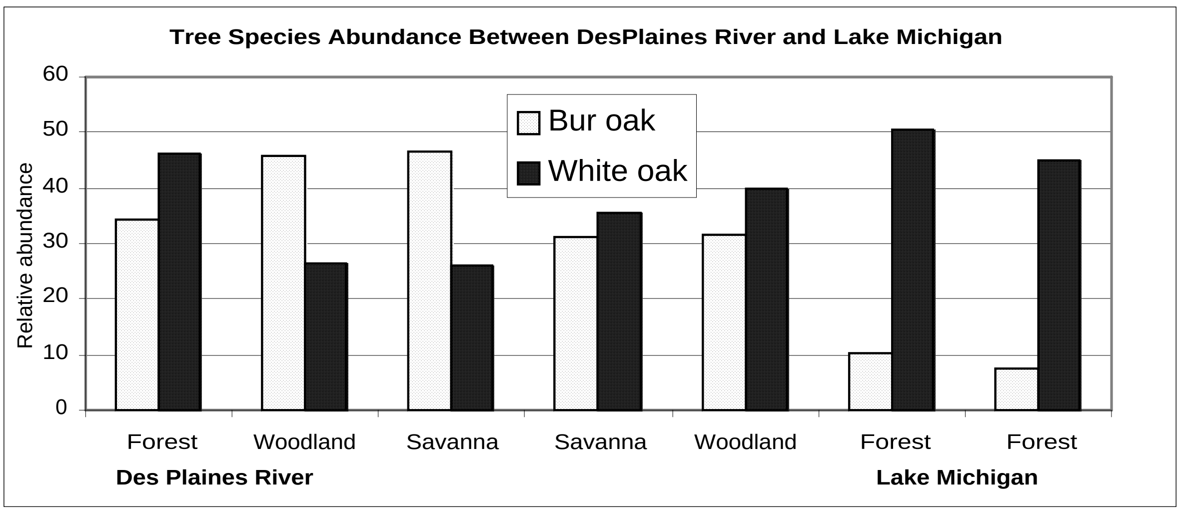


Figure 2. Glacial moraines, rivers and streams of Lake County, Illinois.

Figure 3. Landscape distribution of prairie, timber, scattering timber and barrens, and linear pattern of woody undergrowth recorded by the Lake County Public Land Survey. Absence of lines indicates that undergrowth was not recorded as present or absent.





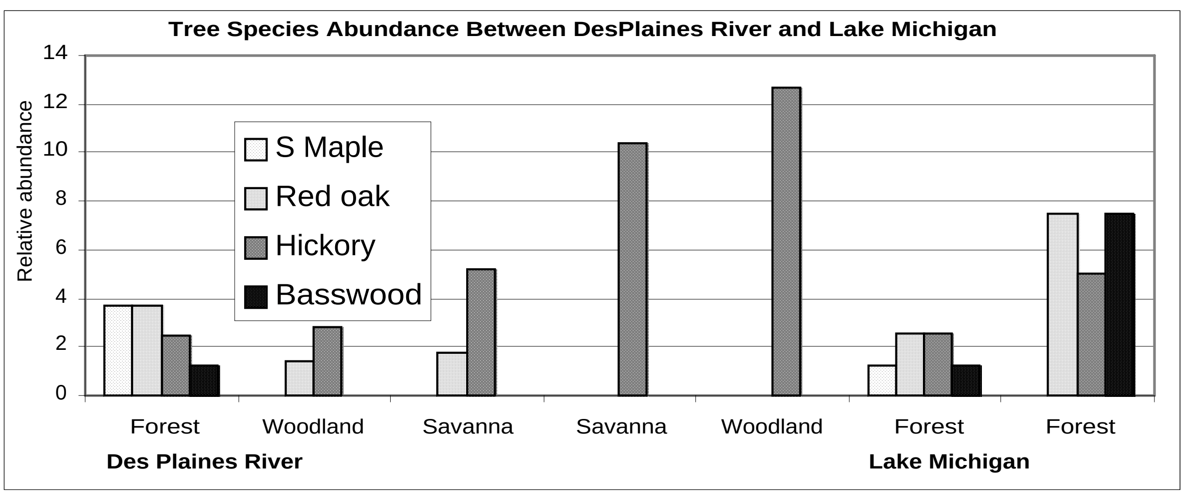


Figure 4. Gradients in tree density and species abundance between the Des Plaines River and Lake Michigan.

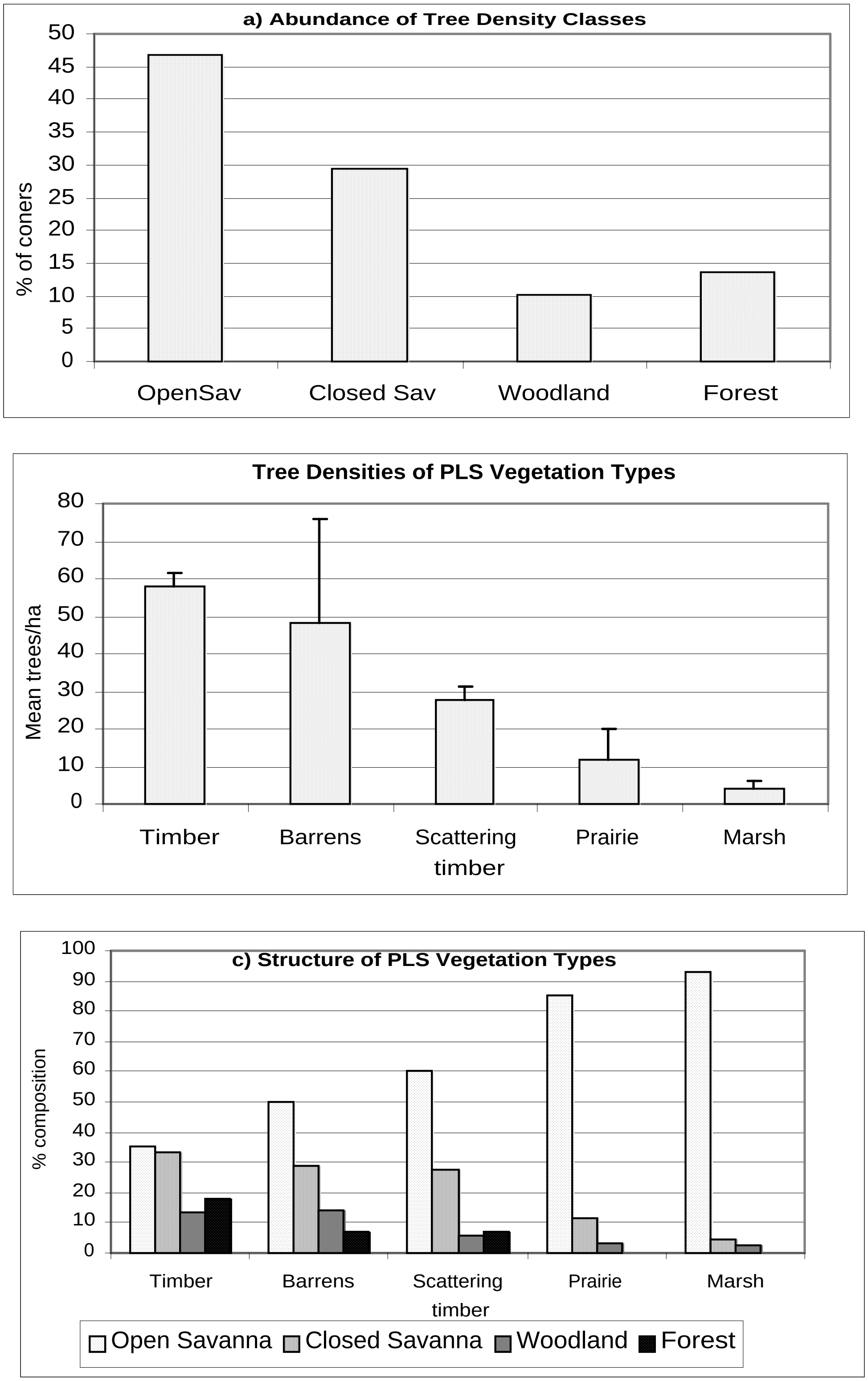
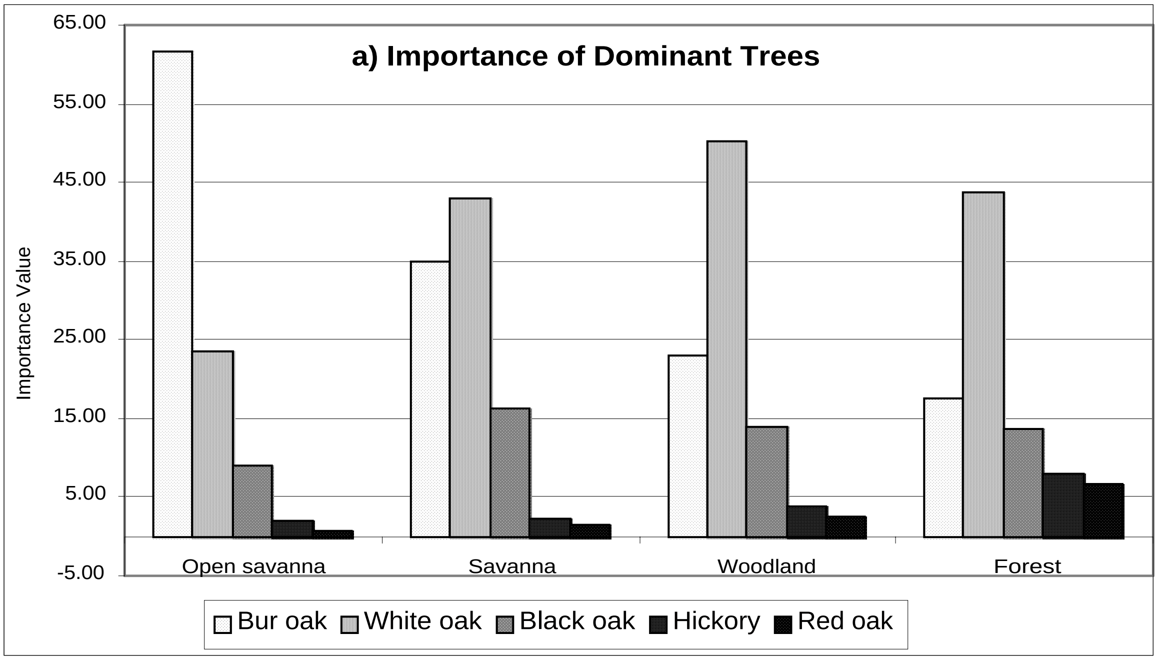


Figure 5. Landscape vegetation structure in Lake Co., Ill. Based on a) abundance of tree density classes at corners, b) tree density of PLS vegetation types, and c) relative abundance of tree density classes within PLS vegetation types.



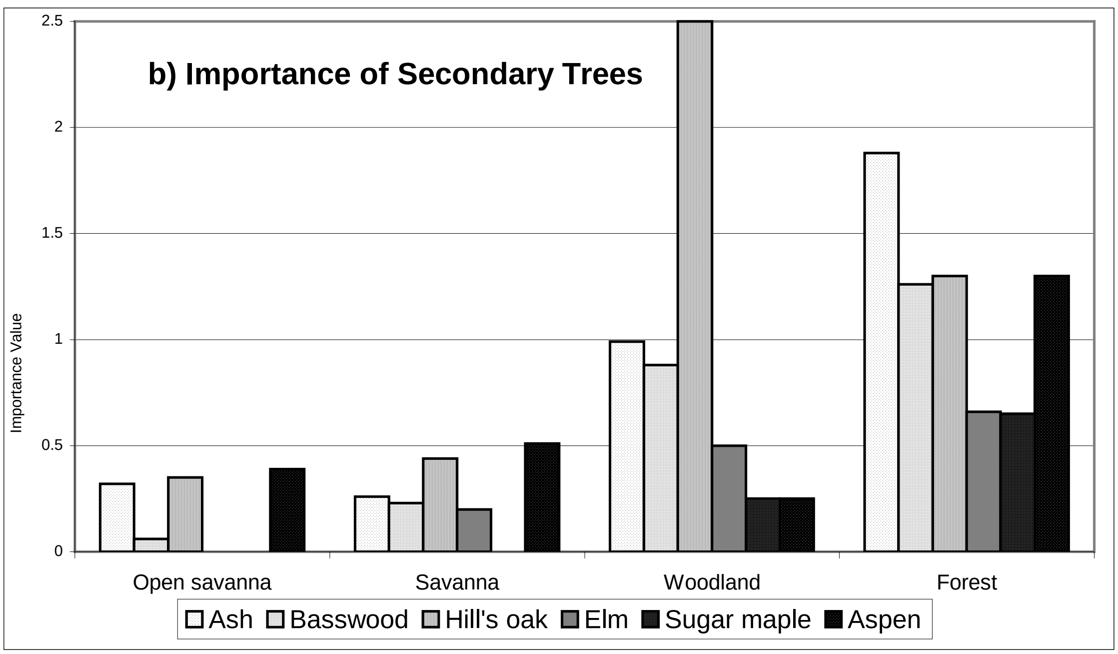
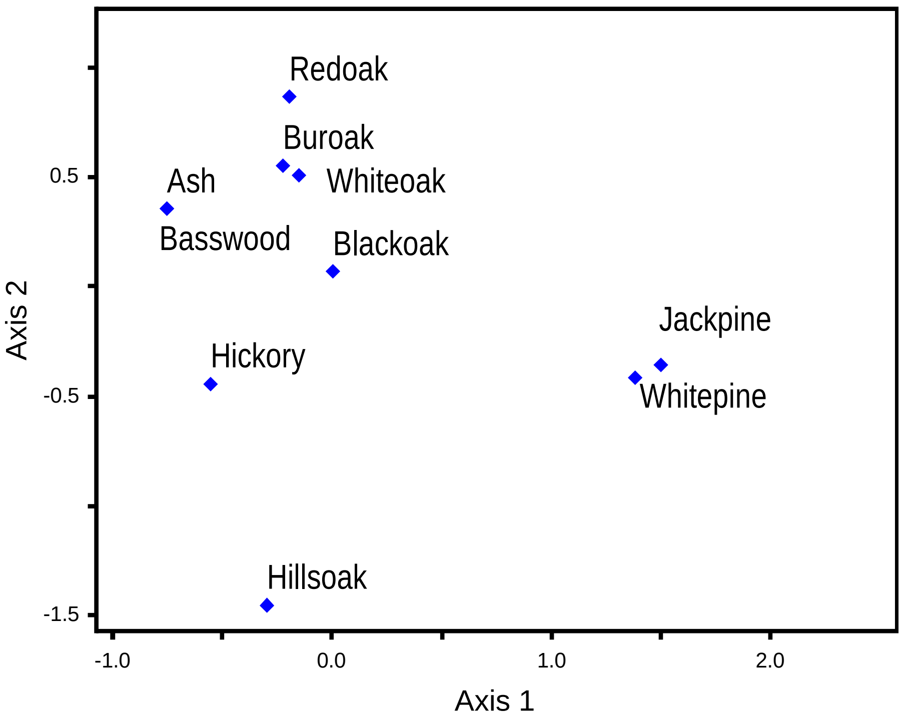


Figure 6. Relationship between tree density classes and importance values of a) dominant tree species and b) secondary tree species.



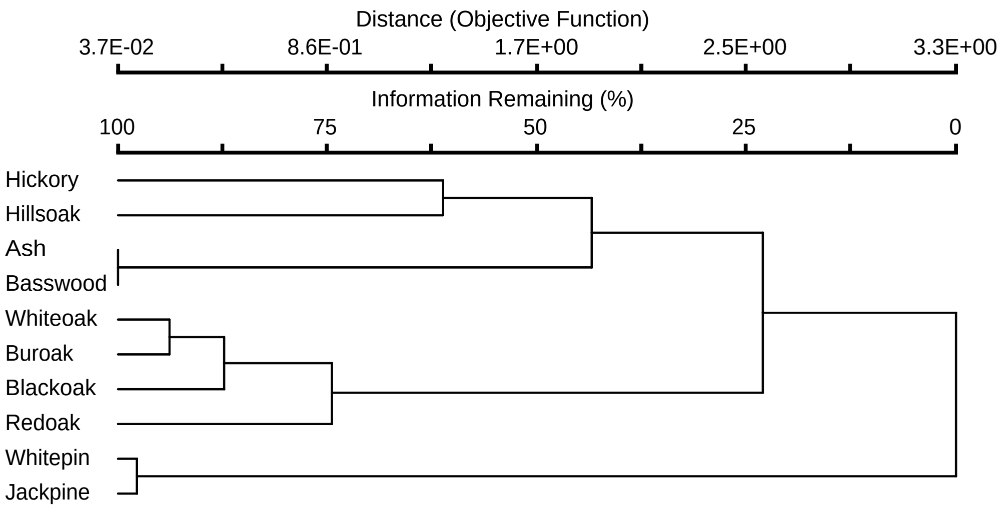
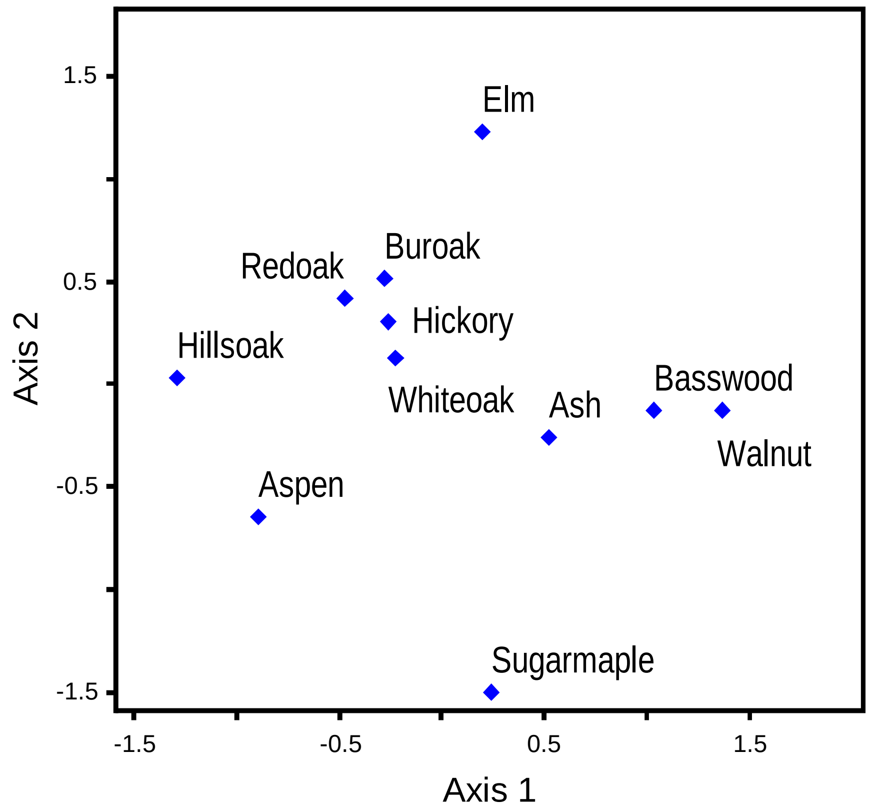


Figure 7. Non Metric Multi-dimensional Scaling ordination (upper) and Flexible Beta Cluster Analysis (lower) of section line tree species summaries from scattering timber in Lake County. NMS P < 0.05 for Axis 1 & Axis 2. Flexible Beta chaining = 15 %.



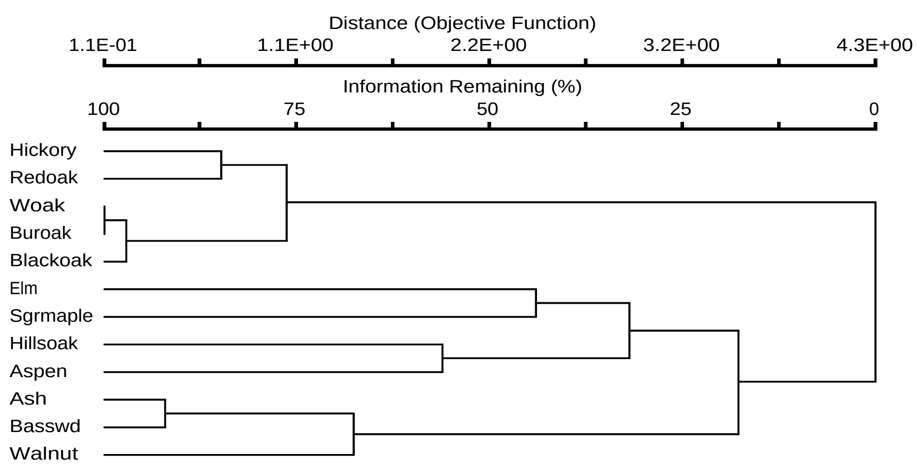


Figure 8. Non Metric Multi-dimensional Scaling ordination (upper) and Flexible Beta Cluster Analysis (lower) of section line tree species summaries from timber in Lake County. NMS Axis 1 P = 0.143, Axis 2 P = 0.047. Flexible Beta chaining = 0.0 %.

Table 1. Year of survey and species translations for bearing trees identified by Deputy Surveyors for the Public Land Survey of Lake County, Illinois. Plants are arranged alphabetically by scientific name.

Common Name	Scientific Name	1833 Lucius Lyon	1837 James Galloway	1838 Eli Berry	1839 George Harrison
Silver maple	*Acer saccharinum*	---	---	---	Maple
Sugar maple	*Acer saccharum*	---	---	Sugar maple	Sugar tree
Paper birch	*Betula papyrifera*	---	---	---	Birch
Hickory	*Carya* sp	Hickory	Hickory	Hickory	Hickory
Hawthorn	*Crataegus sp*	---	---	---	Thorn
White ash	*Fraxinus americana*	---	---	White ash	--
Black ash	*Fraxinus nigra*	---	Black ash	---	---
Ash	*Fraxinus* sp	---	---	Ash	Ash
Ash	*Fraxinus* sp	---	---	---	Swamp ash
Butternut	*Juglans cinerea*	---	---	---	White walnut
Black walnut	*Juglans nigra*	---	---	Black walnut	Walnut
Tamarack	*Larix laracina*	---	Tamarack	---	---
Ironwood	*Ostrya virginiana*	---	---	Hardhack	Ironwood
Jack pine	*Pinus banksiana*	---	---	---	Yellow pine
White pine	*Pinus strobus*	---	---	---	White pine
Pine	*Pinus* sp	---	---	---	Pine
Cottonwood	*Populus deltoids*	----	---	---	Cottonwood
Trembling aspen	*Populus tremuloides*	---	Quaking asp	Quaking asp	Quaking asp
Aspen	*Populus*	---	---	---	Aspen
Cherry	*Prunus* sp	---	Cherry	---	Cherry
White oak	*Q. alba*	White oak	White oak	White oak	White oak
Swamp white oak	*Q. bicolor*	---	Sw.wh oak	---	---
Hills/scarlet oak	*Q. ellipsoidalis/coccinea*	---	Spanish oak	Spanish oak	---
Hills/scarlet oak	*Q. ellipsoidalis/coccinea*	---	Pin oak	Pin oak	Pin oak
Bur oak	*Quercus macrocarpa*	Bur oak	Bur oak	Bur oak	Bur oak
Red oak	*Q. rubra*	---	Red oak	Red oak	Red oak
Black oak	*Q. velutina*	Black oak	Black oak	Black oak	Black oak
Oak	*Quercus*	---	Sw. blk oak	---	---
Oak	*Quercus*	Oak	---	---	Oak
Willow	*Salix* sp	---	---	Willow	Willow
Willow	*Salix* sp	---	---	Swamp willow	---
Basswood	*Tilia americana*	---	---	Lynn	Lynn
American elm	*Ulmus americana*	---	---	White elm	---
Elm	*Ulmus* sp	---	---	---	Elm

Table 2. Coverage of pre-European landscape features of Lake Co., Illinois. Aquatic features are under-represented.

Landscape feature	Type	Hectares	Percent of landscape
Woody			**62.51**
	Barrens	385.61	0.32
	Scattering timber	15,304.24	12.58
	Timber	60,334.70	49.61
Aquatic			**8.78**
	Lake/pond	5,441.77	4.47
	Marsh	3,213.91	2.64
	River/creek	317.34	0.26
	Slough	280.34	0.23
	Swamp	1,420.37	1.17
Prairie			**28.72**
	Prairie	31,365.45	25.79
	Wet prairie	3,527.62	2.90
	Sandbanks	32.39	0.03
Total		121,623.74	

Table 3. Abundance, basal area and importance values of bearing tree species by Public Land Survey Vegetation types.

Timber	**Abundance**	**Basalarea**	**Rel.abund.**	**Rel. BA**	**IV**
White oak	681	116.48	38.00	44.46	41.23
Bur oak	637	88.39	35.55	33.74	34.64
Black oak	247	36.68	13.78	14.00	13.89
Hickory	72	5.55	4.02	2.12	3.07
Red oak	49	5.99	2.73	2.29	2.51
Spanish oak	10	2.54	0.56	0.97	0.76
Ash	17	1.24	0.95	0.47	0.71
Aspen	16	1.03	0.89	0.39	0.64
Basswood	14	0.76	0.78	0.29	0.54
Pin oak	8	0.34	0.45	0.13	0.29
Ironwood	7	0.31	0.39	0.12	0.25
Elm	5	0.45	0.28	0.17	0.23
Sugar maple	4	0.29	0.22	0.11	0.17
Black walnut	3	0.41	0.17	0.15	0.16
Maple	3	0.38	0.17	0.14	0.16
Cherry	3	0.20	0.17	0.08	0.12
Quaking aspen	3	0.15	0.17	0.06	0.11
Swamp ash	2	0.15	0.11	0.06	0.08
White ash	2	0.15	0.11	0.06	0.08
White elm	2	0.15	0.11	0.06	0.08
Swamp white oak	2	0.10	0.11	0.04	0.08
Walnut	1	0.16	0.06	0.06	0.06
Pine	1	0.03	0.06	0.01	0.03
Willow	1	0.03	0.06	0.01	0.03
Cottonwood	1	0.02	0.06	0.01	0.03
Thorn	1	0.02	0.06	0.01	0.03
Total	1792	261.98	100.00	100.00	100.00

Scattering timber	**Abundance**	**Basalarea**	**Rel.abund.**	**Rel. BA**	**IV**
Bur oak	344	45.90	55.13	56.81	55.97
White oak	131	22.75	20.99	28.16	24.58
Black oak	101	8.61	16.19	10.66	13.42
Hickory	20	1.48	3.21	1.83	2.52
White pine	14	0.95	2.24	1.17	1.71
Red oak	5	0.42	0.80	0.51	0.66
Aspen	3	0.14	0.48	0.18	0.33
Pin oak	1	0.29	0.16	0.36	0.26
Birch	2	0.08	0.32	0.10	0.21
Yellow pine	1	0.07	0.16	0.09	0.13
Ash	1	0.05	0.16	0.06	0.11
Swamp ash	1	0.05	0.16	0.06	0.11
Total	624	80.79	100.00	100.00	100.00

Table 3. Continued

Barrens	**Abundance**	**Basalarea**	**Rel.abund.**	**Rel. BA**	**IV**
Bur oak	17	1.48	50.00	39.23	44.61
Black oak	11	1.33	32.35	35.13	33.74
White oak	6	0.97	17.65	25.65	21.65
Total	34	3.78	100.00	100.00	100.00

Prairie	**Abundance**	**Basalarea**	**Rel.abund.**	**Rel. BA**	**IV**
Bur oak	34	5.33	79.07	78.38	78.72
Black oak	5	0.80	11.63	11.82	11.73
White oak	4	0.67	9.30	9.80	9.55
Total	43	6.81	100.00	100.00	100.00

Lake/pond	**Abundance**	**Basalarea**	**Rel.abund.**	**Rel. BA**	**IV**
White oak	1	0.16	33.33	61.84	47.58
Black oak	1	0.05	33.33	19.09	26.21
Bur oak	1	0.05	33.33	19.09	26.21
Total	3	0.27	100.00	100.01	100.00

Marsh	**Abundance**	**Basalarea**	**Rel.abund.**	**Rel. BA**	**IV**
Bur oak	25	2.99	45.45	45.69	45.57
Black oak	18	1.45	32.73	22.19	27.46
White oak	7	1.64	12.73	25.09	18.91
White pine	2	0.26	3.64	4.03	3.83
Hickory	2	0.15	3.64	2.23	2.93
Cherry	1	0.05	1.82	0.77	1.30
Total	55	6.54	100.00	100.00	100.00

Slough	**Abundance**	**Basalarea**	**Rel.abund.**	**Rel. BA**	**IV**
White oak	1	0.20	50.00	60.98	55.49
Bur oak	1	0.13	50.00	39.02	44.51
Total	2	0.33	100.00	100.00	100.00

Swamp	**Abundance**	**Basalarea**	**Rel.abund.**	**Rel. BA**	**IV**
Bur oak	7	1.20	77.78	92.96	85.37
Hickory	1	0.07	11.11	5.63	8.37
Tamarack	1	0.02	11.11	1.41	6.26
Total	9	1.30	100.00	100.00	100.00

Table 4. Percent linear cover and relative cover of woody undergrowth species recorded by the Public Land Survey for Timber, Scattering Timber & Barrens in Lake Co., Illinois. Note: total % species cover exceeds linear cover due to species overlap. Species ranked by average cover.

	Timber % cover	Timber Rel.cover	Scattering Timber % cover	Scattering Timber Rel.cover	Barrens % cover	Barrens Rel.cover
black oak	62.94	39.44	39.23	28.56	61.16	62.30
bur oak	9.84	6.16	8.19	5.96	35.25	35.90
hazel	6.82	4.28	25.41	18.50	1.76	1.79
willow	6.13	3.84	16.34	11.90		
quaking asp	3.71	2.33	15.75	11.47		
hickory	8.66	5.43	7.17	5.22		
vines	13.15	8.24				
pin oak	2.88	1.81	7.94	5.78		
briers	6.57	4.12	3.79	2.76		
white oak	8.32	5.21	1.74	1.27		
brush			7.75	5.65		
poplar	0.87	0.54	4.03	2.93		
basswood	2.21	1.39				
white ash	2.02	1.26				
red oak	1.83	1.15				
redroot	1.66	1.04				
sumac	1.61	1.01				
ironwood	1.53	0.96				
sugar maple	1.16	0.72				
maple	1.01	0.63				
elm	0.47	0.29				
blk walnut	0.35	0.22				
ash	0.07	0.04				
Total cumulative	159.61	100.00	137.34	100.00	98.17	100.00
% landscape cover	15.79		18.26		10.84	

Table 5. Abundance, basal area and importance values of bearing tree species by tree density classes.

Open savanna	occurs	basal	rel freq	rel basal	IV
Bur oak	636	88.14	65.30	58.08	61.69
White oak	206	39.56	21.15	26.07	23.61
Black oak	58	18.64	5.95	12.29	9.12
Hickory	26	1.95	2.67	1.29	1.98
White pine	14	1.17	1.44	0.77	1.11
Red oak	10	0.74	1.03	0.49	0.76
Aspen	6	0.24	0.62	0.16	0.39
Pin oak	5	0.29	0.51	0.19	0.35
Ash	3	0.25	0.31	0.17	0.24
Spanish oak	1	0.29	0.10	0.19	0.15
Swamp ash	2	0.12	0.21	0.08	0.14
White ash	1	0.07	0.10	0.05	0.08
Birch	1	0.07	0.10	0.05	0.08
Quaking asp	1	0.07	0.10	0.05	0.08
Cherry	1	0.05	0.10	0.03	0.07
Swamp white oak	1	0.05	0.10	0.03	0.07
Basswood	1	0.02	0.10	0.01	0.06
Tamarack	1	0.02	0.10	0.01	0.06
	974	151.76	100.00	100.00	100.00

Closed savanna	occurs	basal	rel freq	rel basal	IV
White oak	337	61.32	39.46	46.28	42.87
Bur oak	310	44.59	36.30	33.65	34.97
Black oak	142	20.83	16.63	15.72	16.17
Hickory	25	2.16	2.93	1.63	2.28
Red oak	13	1.60	1.52	1.20	1.36
Aspen	6	0.42	0.70	0.31	0.51
Pin oak	3	0.32	0.35	0.24	0.30
Ash	3	0.24	0.35	0.18	0.26
Basswood	3	0.15	0.35	0.11	0.23
Elm	2	0.23	0.23	0.17	0.20
Spanish oak	1	0.20	0.12	0.15	0.14
White pine	2	0.04	0.23	0.03	0.13
Maple	1	0.16	0.12	0.12	0.12
Yellow pine	1	0.07	0.12	0.06	0.09
Swamp white oak	1	0.05	0.12	0.04	0.08
Ironwood	1	0.03	0.12	0.02	0.07
Cherry	1	0.03	0.12	0.02	0.07
Willow	1	0.03	0.12	0.02	0.07
Pine	1	0.03	0.12	0.02	0.07
	854	132.52	100.00	100.00	100.00

Table 5. Continued.

Woodland	occurs	basal	rel freq	rel basal	IV
White oak	140	22.43	45.90	54.40	50.15
Bur oak	76	8.68	24.92	21.05	22.99
Black oak	43	5.59	14.10	13.55	13.82
Hickory	15	1.16	4.92	2.81	3.86
Red oak	9	0.95	2.95	2.30	2.63
Spanish oak	4	1.38	1.31	3.35	2.33
Basswood	4	0.19	1.31	0.46	0.88
Ash	3	0.20	0.98	0.50	0.74
Maple	1	0.10	0.33	0.24	0.28
Sugar maple	1	0.07	0.33	0.18	0.25
Elm	1	0.07	0.33	0.18	0.25
Aspen	1	0.07	0.33	0.18	0.25
White ash	1	0.07	0.33	0.18	0.25
Swamp ash	1	0.07	0.33	0.18	0.25
Quaking asp	1	0.07	0.33	0.18	0.25
White elm	1	0.07	0.33	0.18	0.25
Cottonwood	1	0.02	0.33	0.04	0.19
Pin oak	1	0.02	0.33	0.04	0.19
Birch	1	0.01	0.33	0.02	0.17
	305	41.24	100.00	100.00	100.00

Forest	occurs	basal	rel freq	rel basal	IV
White oak	151	20.51	39.43	48.30	43.86
Bur oak	68	7.35	17.75	17.30	17.52
Black oak	52	5.78	13.58	13.62	13.60
Hickory	43	1.95	11.23	4.58	7.90
Red oak	22	3.12	5.74	7.35	6.55
Ash	9	0.60	2.35	1.41	1.88
Aspen	6	0.44	1.57	1.04	1.30
Spanish oak	4	0.66	1.04	1.55	1.30
Basswood	6	0.40	1.57	0.94	1.26
Ironwood	7	0.28	1.83	0.66	1.24
Black walnut	3	0.41	0.78	0.95	0.87
Sugar maple	3	0.22	0.78	0.52	0.65
Cherry	2	0.16	0.52	0.39	0.45
Elm	2	0.15	0.52	0.35	0.44
Walnut	1	0.16	0.26	0.39	0.32
Maple	1	0.11	0.26	0.27	0.26
White walnut	1	0.07	0.26	0.17	0.22
White elm	1	0.07	0.26	0.17	0.22
Thorn	1	0.02	0.26	0.04	0.15
	383	42.47	100.00	100.00	100.00