HISTORIC LANDSCAPE VEGETATION PATTERN, COMPOSITION, AND STRUCTURE OF WILL COUNTY, ILLINOIS, AS RECORDED BY THE U. S. PUBLIC LAND SURVEY (1821-1838)

Marlin L. Bowles and Jenny McBride
The Morton Arboretum, Lisle, Ill.

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SUMMARY

We mapped and described the presettlement vegetation pattern and structure of Will Co., Illinois based on tree data from the Government Land Office Public Land Survey (PLS), which was conducted between 1821 and 1838. Vegetative cover was 80% grassland. The predominant woody vegetation was timber, with smaller amounts of scattering timber, barrens, brush, and hazel thickets. The vegetation pattern fit an expected landscape model driven by the interaction between landscape fire and fire breaks. Larger blocks of timber and fire-intolerant tree species persisted in the protection of fire barriers that blocked prairie fires driven by prevailing southwesterly winds. Savanna with fire-tolerant oaks occurred in areas with less fire protection, primarily on the western sides of landscape fire barriers. Most of the woody vegetation described as timber by the PLS averaged < 50 trees/ha, corresponding to a modern savanna analog. On areas of glacial till, this vegetation was dominated by white oak. Bur oak, black oak, scarlet oak, and hickory had secondary dominance. Maple, basswood, ash, and elm were less frequent, but increased in abundance along an increasing tree density gradient associated with greater fire protection. Woody undergrowth, primarily oak, hickory and hazel, averaged less than 20% cover in timber, about 35% in scattering timber, and 45% in areas of brush or barrens. Tree density and tree species richness, as well as richness of woody undergrowth, were lower on sand soils, which occur in the southwestern part of the county. Black oak was the predominant species on sand, while, maple, basswood, ash, and elm were essentially absent.

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INTRODUCTION

Background

At the time of European settlement, the Chicago region of northeastern Illinois was a broad mosaic of prairie and oak (*Quercus*)-dominated savanna, woodland and forest (Curtis 1959, 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 fire-protected lee side of barriers such as topographic relief and water courses (Gleason 1913, Moran 1978, 1980, Anderson 1991, Leitner *et al.* 1991, Bowles *et al*. 1994) and shifting with changing climatic conditions (Grimm 1983, 1984).

Much of this vegetation has been lost because of wide-scale deterioration from fragmentation, fire suppression, overgrazing, and agriculture (Cottam 1949, McCune & Cottam 1985, Anderson 1991, Stearns 1991, Robertson & Schwartz 1994, Leach & Ross 1995, Packard & Mutel 1997, Schwartz 1997, Bowles & McBride 1998), and its management and restoration represents an important and difficult challenge (Apfelbaum & Haney 1991, Packard 1991). Conservationists seek an understanding of the composition, structure, processes, and dynamics of pre-European vegetation so as to better manage and restore its biodiversity. Ecological models that apply presettlement processes to vegetation pattern, composition, and structure will best meet these needs (Leach & Ross 1995).

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 grid upon which the identity, diameter, distance, and direction for two to four bearing trees were recorded at half mile intervals. These data were accompanied by the identity and diameter of trees intercepted by section lines, as well as section line vegetation summaries, other notes, and township plats distinguishing timber, prairie, and other important landscape features.

Despite bias in tree selection (Bourdo, 1956), the bearing tree data represent a large-scale vegetation survey that can be used to reconstruct landscape-scale pre-European vegetation (Brugam & Patterson 1996), and occasionally site-specific comparisons (*e.g.* Donnelly & Murphy 1987, Bowles & McBride 1998). These data also can provide important 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). For example, in DuPage and Kane counties, 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 occurred in more fire-protected landscape positions (Bowles *et al.* 1994). This study also documented presence and structure of woody understory vegetation, which appears critical to understanding and guiding management and restoration of oak savanna and oak woodlands.

Study objectives

In this study, we examined pre-European settlement (or "presettlement") woody vegetation pattern and structure in Will 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 landscape features and fire processes, 3) describe presettlement vegetation, and 4) apply these results toward management and restoration guidelines for native woody-dominated ecosystems.

STUDY AREA

Will County is one of the southern counties that comprise the Chicago region of Illinois. This comparatively large county contains 23 complete and two fractional townships, totaling 219,572.58 hectares. Will County occupies the Morainal Natural Division and the Grand Prairie Natural Division of the Chicago region. Northeastern Will County is within the Western Morainal Section of the Morainal Natural Division. The remainder of the county occupies the Grand Prairie Natural Division. The county's central part occupies the Grand Prairie Section, its southwestern area lies within the Kankakee Sand Section, and the DesPlaines River occupies the Bedrock Valley Section.

The county is situated primarily on Woodfordian-aged glacial drift deposited during the close of Wisconsinan glaciation in Illinois (Wascher *et al.* 1960, Willman & Frye 1970). A predominant landscape feature is the Valparaiso Moraine complex, which forms a drainage divide between the extreme eastern vs. the central and western part of the county (Figure 1). Drainage northeast of the moraine is primarily through Thorn Creek and Plum Creek. Drainage to the south and west is through the DuPage River and Hickory Creek into the DesPlaines River, or into the Kankakee River. The Kankakee and DesPlains rivers reach their confluence in Grundy County, just to the west of Will County. Glacial outwash sands of the Kankakee River are a distinctive feature of southwestern Will County. Maximum relief in Will County is over 300 ft, ranging from 500 ft above sea level near the confluence of the Des Plaines and Kankakee Rivers to over 800 ft on the Valparaiso Moraine. The most xeric conditions in the county probably occur along the south-facing bluffs of the Des Plaines River valley and in the Kankakee sand deposit. Most of the glacial till soils are mollisols (developed primarily under grassland). Alfisols (developed primarily under forest) are restricted in distribution to forest fragments, while transitional soils between mollisols and alfisols occur primarily on the Valparaiso moraine. Soils of the Kankakee sand deposit are primarily mollisols.

HISTORIC METHODS

With the exceptions of two islands surveyed in the Kankakee River in 1846 and 1855, most of the Will County PLS was completed between 1821 and 1838 by eight deputy surveyors (Table 1). European settlement also began during that period, and escalated after the 1832 Black Hawk War. Two Indian boundaries cross the county diagonally from northeast to southwest. The first was surveyed in 1834 across the center of the county and the second in 1837 across the northwest corner of the county. About 53% of the county survey took place in 1821, in a central area lying southeast of the 1837 Indian boundary and northwest of the 1834 Indian boundary. Another 45% of the survey took place east of the 1834 Indian boundary during 1833-34, and three remaining townships lying northwest of the 1837 Indian boundary were surveyed during 1837-38. Differences in time, surveyor bias, and geography have potential for affecting data from these different survey areas (Clark 2000).

Each township was mapped after completion of its survey, showing the distribution of timber, watercourses, and settlement features. The PLS also described five different vegetation types that were large enough in area to map and statistically analyze: *"prairie," " brush," "barrens," "scattering timber"* and *"timber."* The PLS indicated distances along section lines for transitions between these vegetation types, which facilitated our mapping precision. The primary data collected by the PLS were the identity, diameter, distance, and direction for two to four bearing trees, each in one of the four quadrants at each quarter corner. It also recorded the identity and diameter of "line trees" intercepted by section lines and summarized tree species present along section lines. Some surveyors also recorded section lines in which woody undergrowth was present, and summarized the species present in undergrowth along each section line. However, these data were apparently not recorded for all section lines.

The surveyors identified about 30 bearing tree species by common name or by abbreviation, including most of the dominant native tree species. We assume that most bearing tree species were correctly identified and placed them in modern species analogs (Append III). However, species identified as "Blackjack oak," "Overcup oak," and "Post oak" (Table 2) do not occur in the Chicago region (Swink &

Wilhelm 1994). Identification of red oak, black oak, and Hill's oak, all members of the black oak group, also appears to have been inconsistent among surveyors (Collins 1997, Clark 2000). Species identified as "Jack oak," "Spanish Oak, or "S Oak" may have been Hill's oak (*Q. ellipsoidalis*), which was apparently frequent in the Chicago region (Trelease 1919, Waterman 1920). References to pin oak may have been this species, as its northern form is also known as northern pin oak (Kilburn 1959). However, true pin oak (*Q. palustris*) is also known from Will Co. (Swink & Wilmelm 1994). Abbreviations used for black and bur oak during the 1821 survey period are also problematic. Apparently "B oak" was applied to bur oak (which occurs primarily on till) and black oak (primarily on sand), as neither species was identified during this period. For example, at one Will Co. section corner, trees identified as "B oak" in 1821 county were confirmed as "Black oak" when their locations were re-surveyed in 1833. In DuPage County, Pierre (1962) relocated several bur oak bearing trees originally recorded as "B Oak." Misidentifications also occurred. In Cook Co, trees originally identified as white oak were confirmed as bur oak (Bowles & McBride 1998). In 2000, we relocated one section corner at which "B oak" bearing trees were apparently scarlet oak (*Q. coccinea*).

The surveyors also identified fourteen additional species present as woody undergrowth. Although some of these, such as the shrub American hazelnut (*Corylus americana*), could be assigned to species, other names such as vines or briars are vague. Many shrub species may have been unknown to the surveyors (Bowles 1999, Clark 2000).

MODERN METHODS

Mapping and interpretation

We transcribed and analyzed the PLS data 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 and roads, were not included in the GIS maps or landscape analysis.

Data analysis

We used all recorded bearing tree distances 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 present (Cottam & Curtis 1956). We then used these densities to calculate average densities for the different PLS vegetation types. For prairie, these densities represent only corners with trees, and thus only 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 bias on vegetation classification, we placed density calculations into broad 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 Anderson & Anderson (1975) and Bowles *et al*. (1994). Because of potential ecological differences between sand and glacial till soils, we subdivided each of these four classes into either sand or till 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 in square meters by converting from the original measure of diameter in inches.

We determined the abundance of each species of woody undergrowth in each vegetation type in which it occurred by calculating the percentage of each section line from which it was recorded. These percentages were averaged across all vegetation types to rank undergrowth species at the landscape level. Because woody undergrowth was apparently not recorded for all section lines, its total linear cover could not be calculated for vegetation types.

The Shannon diversity index (H') was calculated for each bearing tree density class (open savanna, savanna, woodland, & forest), where H' = $-\sum p_i \log p_i$, and p_i = the relative density of each tree species (Brower & Zar 1984). Using basal area as a metric, we ordinated tree density classes on sand and till (N = 8 classes) and corresponding species groups with Detrended Correspondence Analysis (DECORANA) on PCORD software (McCune & Mefford 1995). Ward's Cluster Analysis was then used to identify stand clusters using a Euclidean distance metric on PCORD. Only tree species with a total BA of > 1 were used in this analysis. We then used known ecological adaptations of different species (e.g. Swink & Wilhelm 1994) to make inferences about presettlement habitat conditions and vegetation types.

RESULTS

Comparison of bearing and line tree diameters

On glacial till soils, there were only minor differences in tree sizes, with all trees averaging < 20 inches (51 cm) dbh. For white oak, the most frequently sampled tree, bearing trees averaged 17.44 (+7.9 se) inches dbh and line trees averaged 17.67 (+6.8 se) inches. Greater differences occurred on sand soils, where white oak bearing trees averaged 10.98 (+10.3 se) inches in comparison to 15.17 (+5 se) inches for line trees. White oaks may have been smaller on sands because of less favorable growing conditions, or possibly because sand sites were more susceptible to frequent or severe fires that would have maintained trees as smaller post-fire sprouts. These results also suggest that surveyors were not selecting trees that differed in size from line trees, although larger trees have a higher probability of being intercepted by line transects (Brower & Zar 1994).

Landscape pattern and composition of vegetation as described by the PLS

The presettlement vegetation of Will County was predominantly prairie, accounting for 80.5% of the landscape (Table 3). Prairie wetlands (marshes, sloughs, & swamps) comprised about 3% of the landscape, but were widespread and probably under-represented because they were mapped primarily along section lines. Open water, including rivers, creeks, lakes, and ponds comprised about 1% of the landscape. Timber and related vegetation accounted for 18.5% of the landscape, with < 2% scattering timber, barrens, brush and hazel thickets. As a result, areas described as timber by the PLS were the dominant woody vegetation type.

As expected, the largest areas of timber were associated with water courses, primarily the north-south oriented DuPage, DesPlaines, and Kankakee Rivers and their immediate drainages, as well as in the Kankakee sand deposit (Figure 2). The broad floodplain of the upper portion of the DesPlaines River also supported grassland along its east side. Timber also occurred along Jackson Creek and Hickory Creek, which drain westward to the DesPlaines River, as well as along Thorn Creek, Deer Creek, and Plum Creek, which drain to the northeast. More isolated prairie groves also occurred along Spring Creek and the headwaters of Rock Creek. Scattering timber was most frequent in association with the southern borders of timber on the eastern drainage of the Valparaiso Moraine. Only a few areas of brush or barrens were mapped, occurring on the exterior margins of timber or scattering timber. Woody undergrowth was recorded infrequently along all major streams except for the DuPage River, where it was not recorded. It was most frequent in timber along Plum Creek, but also occurred in small isolated groves, such as along Rock Creek, as well as in the eastern drainage of Hickory Creek and in timber on the Kankakee sand deposit. Locations of timber correspond with alfisols, although the soil mapping scale prevents detailed comparison.

Timber

Areas mapped as timber by the PLS accounted for about 80% of the bearing tree corners on both till and sand (Figure 3). White oak was the dominant tree on till, with secondary dominance of B oak (probably bur oak), and minor importance of bur oak, black oak, and Hill's oak (Appendix I). B oak (probably black oak) was the dominant tree on sand, with secondary abundance of white oak and black oak (Appendix II). However, tree density was greater on till, averaging 88.5 trees/ha, and tree species richness was four times higher on till due to the absence of non-oak species from sand (Table 4). Percent linear cover of woody undergrowth was also greater on till, where it exceeded 35%, and more than four times as many woody undergrowth species occurred on till than on sand (Table 4). Oak, hickory, and hazel were the dominant undergrowth species on till, while hazel, willow, and vines were more abundant on sand (Table 5).

<u>Scattering timber and barrens or brush</u>

Scattering timber accounted for < 10% of the landscape on both till and sand (Figure 3). As with timber, white oak was the dominant tree on till, but with secondary dominance of black oak and bur oak (Appendix I). In contrast, B oak (probably black oak) was the single important tree in scattering timber on sand (Appendix II). However, tree density was similar on till and sand, averaging about 30 trees/ha (Table 4). Percent cover of woody undergrowth was 75%, almost twice as high as on till (Table 4). However, only four undergrowth species were recorded, with oak, hickory, and hazel on till, and willow on sand (Table 5). Barrens or brush were not recorded on sand, but had 45% cover of oak, hickory, and hazel on till with no bearing trees recorded.

<u>Prairie</u>

Bearing tree corners in prairie accounted for slightly over 10% of all corners with trees on till, and about 5% on sand (Figure 3). Local tree densities reached 17.5 trees/ha in prairie on till (Table 4). White oak was the dominant tree at these corners, with lesser importance of bur oak and B oak (Appendix I). However, on sand, white oak was absent and bur oak was more important (Appendix II). Woody undergrowth was absent from prairie on sand and had < 1% cover on till, where oak, hickory, and hazel were most important (Table 5).

Landscape pattern and composition of vegetation based on tree density vegetation classes

The landscape vegetation pattern based on tree density classes was predominantly open and closed savanna. This vegetation accounted for about 30-40% of the bearing tree corners on till and 30-60% of the corners on sand (Figure 3). Large areas of savanna occurred primarily along the east side of the Kankakee River and in the Kankakee Sand Deposit, with smaller amounts throughout other timbered areas (Figure 2). On till, open savanna accounted for about 45 % of the bearing corners on the exterior of blocks of timber. On sand, open savanna accounted for about 70 % of these exterior bearing tree corners. Savanna accounted for about 32 % and 23 % of these corners, respectively. Woodland vegetation accounted for < 15% of all bearing tree corners on till, and < 5% on sand, occurring primarily along the lower DuPage River and the mid section of the DesPlaines River, as well as along Plum Creek and the west side of the Kankakee River. Forest was slightly more common than woodland, accounting for < 20% of all bearing tree corners on till, and < 10% on sand. Areas containing forest tree densities occurred along the east sides of the upper DuPage and Des Plaines Rivers, along Hickory Creek, and also in more isolated groves such as along Spring Creek, Thorn Creek, and Rock Creek. However, none of these areas were dominated by forest, and bearing tree corners with forest tree densities tended to concentrate along water courses.

<u>Stand ordination and classification</u>

DECORANA ordination separated sand and till vegetation on the first axis, with till forest and woodland having the highest first axis scores (Figure 4). Sand woodland and forest had higher scores on the second axis. Ward's Cluster Analysis corresponded to the first ordination axis by producing primary sand and till vegetation groups, with till and woodland vs savanna as secondary groups on both till and sand (Figure 4). The species ordination resulted in strong first axis correlations for fire-intolerant forest species such as maple, ash and basswood, and ordination positions for these species corresponding to forest tree densities. In contrast, most oak species tended to have lower first axis values corresponding to lower tree densities. White oak had a high first axis correlation even at high tree densities. Black oak and

B oak strongly affected ordination positions of sand vegetation, with black oak having greater importance in sand woodland and forest, and B oak (probably black oak) in sand savanna vegetation.

Stand composition

Tree species richness and diversity was much higher on till than on sand (Table 4). On till, white oak was the dominant tree species across all vegetation classes, with secondary dominance of B oak (probably bur oak) and bur oak, and lower abundance of other oak species (Figure 5). On till, dominance of white oak tended to be inversely related to that of bur oak, B oak, and black oak across tree density classes. White oak had slightly greater importance in forest, while other species were more important in savanna (Figure 5). Among non-oaks, maple, ash, basswood, walnut and elm had higher relative abundance in forest, while hickory was more important in savanna. Black oak was the most important species in sand forest and woodland, while B oak (probably black oak) and white oak were more abundant in sand savanna (Figure 5).

DISCUSSION

Fire and landscape vegetation pattern in Will County

As in other presettlement vegetation studies of areas with a prairie-forest transition, the landscape vegetation pattern in Will County fits a landscape fire model in which prairie fires driven by prevailing southwesterly winds eliminated timber in fire-prone areas of the landscape (Gleason 1913, Grimm 1984, Moran 1978, Anderson 1991, Leitner *et al*. 1991, Bowles *et al*. 1994). This pattern also represents a fire-caused process of forest deterioration, with prairie representing the most advanced stage of complete conversion to grassland. It is presumed to have developed from holocene (post glacial) deciduous forests during the eastward extension of the prairie peninsula (Gleason 1922, Transeau 1935, Curtis 1959), which occurred 6,000-8,000 years BP during the xerothermic interval (Geis & Boggess 1967, King 1981, Webb *et al*. 1983, Baker *et al*. 1992). With amelioration of the dry climate, drought induced fire and burning by indigenous people apparently maintained a prairie-oak ecosystem mosaic (Taft 1997, Anderson & Bowles 1999). The location of a large area of transitional soils supporting prairie on the Valparaiso Moraine suggests a more recent expansion of prairie into this area. The northeastern aspect of this morainal topography could have reduced the impact of eastward moving prairie fires and thus slowed the process of conversion from forest to prairie, leaving the transitional soils.

Fire appears to have played a fundamental role not only in shaping vegetation pattern, but also in affecting the composition and structure of woody vegetation. The dominance of oak species across all vegetation types suggests that fire affected the entire landscape continuum because oaks are considered fire dependent and shade intolerant. However, the occurrence of greater tree densities in fire protected habitats, as well as greater abundance of fire-intolerant tree species (e.g. maple, ash and basswood) in these habitats, suggests a fire-effect gradient. Increasing landscape fire protection probably resulted in a combination of decreasing fire frequency and fire intensity that allowed greater tree densities and greater abundance of shade-tolerant and fire-intolerant species.

The greater area of open savanna and lower woody species richness and diversity in sand areas than on till may be due to increased effects of drought and fire severity caused by more rapid drainage of sandy soils. Plants on well drained sands often experience water stress and dry quickly during droughts, increasing the susceptibility of vegetation to fire. Yet, fuel loads may be high in wet sand areas, allowing severe fires. Few forest tree species can tolerate such conditions, which generally select for grassland or savanna, and dominance by drought tolerant species such as black oak (Curtis 1959, Anderson 1991, Swink & Wilhelm 1994).

Composition and structure of woody vegetation types

Barrens

Barrens vegetation was recorded infrequently in Will County, and few data could be compiled for this vegetation type. Small areas of barrens occurred in one locality on the margin of scattering timber on the Valparaiso Moraine and on the margin of timber in two areas west of the DesPlaines River. These occurrences are similar to those suggested by historic descriptions. In the glaciated region of Illinois, barrens vegetation usually developed at the western edge of tracts of timber, often as part of a zone of scattering timber intermediate between prairie and timber. They resulted from fire-caused conversion of timber to a mosaic of fire-sprouting oaks and shrubs such as hazel (Gleason 1913, 1922, Bowles & McBride 1994, Anderson & Bowles 1999). Early residents also observed conversion of prairie to barrens and then to timber with fire protection, a process that would have been accelerated by post fire-sprouting trees and shrubs (Bowles & McBride 1994).

Savanna

Open savanna (> 0-10 trees/ha) was wide spread and the most common vegetation type in Will Co.; it tended to be associated with landscape areas that did not have a high degree of fire protection, including small areas of timber, and the exterior edges of larger blocks of timber. White oak dominated this vegetation on till, where mesic species such as maple and ash had lower dominance than in other vegetation types. Open savanna was most extensive on the sand plain southwest of the Kankakee River, where b oak, apparently black oak, was the dominant tree species. The PLS concept of scattering timber in Will Co. is similar to open savanna. Its identification may have relied not only on tree density but also on the amount of dispersion or “scattering” of timber fragments left by the process of fire-caused deterioration of timber. Therefore, this vegetation may have been detected most easily by the PLS at a large landscape scale.

Savanna conditions (>10-50 trees/ha) were also widespread but had slightly less cover than open savanna. The lower frequency of savanna tree densities on the exterior of blocks of timber suggests that savanna received slightly greater fire protection than did open savanna. Likewise, savanna also tended to occur more within the interiors of larger blocks of timber than did open savanna. However, as both savanna and open savanna were dominated by white oak on till and black oak on sand, these fire effects were apparently not strong enough to alter floristic composition.

Woodland and forest.

Woodland and forest were much less frequent than savanna in Will Co. especially on sand. Woodland (> 50-100 trees/ha) is often thought of as typifying the Chicago region’s presettlement oak timber, with intermediate canopy cover between savanna and forest, and is therefore an important restoration goal (Chicago Wilderness Biodiversity Council 1999). Paradoxically, woodland was the least abundant of any tree density class, occurring at < 15 % of all corners on till, and < 5 % on sand. It also did not occur as a well-defined landscape unit, and shared strong floristic and compositional similarity with savanna. No dominant or subdominant tree reached their greatest relative basal area dominance in woodland conditions on glacial till. One tree, black oak, did so in sand. This suggests that woodland did not represent an important transition between savanna and forest in Will Co. Rather, there may have been a comparatively abrupt shift from savanna to forest. Nevertheless, forest conditions were also rare. Although corners representing forest tree densities occurred throughout Will Co., they did not dominate blocks of timber, and tended to be concentrated along major watercourses, which would have provided fire protection. Forests differed compositionally from savanna and woodland by having greater dominance of white oak and lesser dominance of other oaks. Their primary difference was greater relative basal area of mesic forest species such as maple, ash, basswood and elm, fire-tolerant species that would have benefited from the landscape fire protection associated with forest tree densities.

Management and restoration

Management and restoration applications based on pattern, structure and composition of woody vegetation in the early 1800s must take into account the temporal status of these data, as well as differences in scale between PLS data and modern ecological data. Woody vegetation in this time period was probably in a fire- and climatic-mediated equilibrium, shifting as fluctuating climate caused fluctuating fire frequency. The Will County PLS provides a landscape-level model of woody vegetation pattern, composition, and structure at one time period, but which can be applied to management and restoration if process oriented.

In general, management to restore savanna and woodland should focus on restoring fire as a natural process for maintaining oak dominance. However, mechanical thinning may be needed to remove larger fire-resistant non-oaks and promote oak regeneration. Maintaining woody understory vegetation dominated by hazel should also be a prority. More specific guidelines can be related to landscape features, remnant vegetation types, or to arbitrary objectives. Restoration of savanna and barrens would be most applicable in fire-prone areas of moderate topographic relief without protection of stream fire barriers, while woodland and forest management would be most applicable where more relief or watercourses add to fire protection.

Presettlement woody vegetation structure appears to have been either one- or two-layered, depending upon the presence or absence of woody undergrowth. When present, woody undergrowth would have been an important component of biodiversity as it provides nesting habitat for many bird species (Whelan & Dilger 1992). Unfortunately, the Will Co. PLS did not record enough data on the presence or absence of woody undergrowth to allow a quantitative description of this vegetation. However, clearing of all native woody understory species should not be an overriding objective for management or restoration of these communities, and in many cases restoration of woody undergrowth with hazel can increase structural and compositional diversity. Because of its high light requirement, management to restore hazel would be most appropriate in savanna and woodland, or in forest light gaps.

No information is available from the PLS on the composition and structure of presettlement ground layer herbaceous vegetation. Studies of few remaining savanna remnants have illustrated an expected strong negative relationship between amount of available light and tree density, and a positive relationship between available light and ground layer species richness and diversity (Bowles & McBride 1998). Management that reduces overstory tree density should help maximize groundlayer species diversity in savannas. Because savanna, woodland, and forest species are adapted to a range of light conditions that help define these habitats, managing for a continuum of tree densities will maximize ground layer species richness across vegetation types.

Developing management and restoration guidelines for forest habitats based on PLS information is more difficult and challenging, and their management will require careful experimentation (Bowles *et al*. 2001). Many of these habitats have undergone dramatic loss of canopy oaks and increased numbers of maples in smaller size classes in the last 20 years, after a series of post-settlement disturbances including fire-protection, burning, logging, and grazing. Here, management goals must take into account unknown precise historic conditions, recent successional changes, and the effects of fire on forest groundlayer vegetation (Bowles *et al*. 1998, Mendelson 1998).

CONCLUSIONS

The Will County PLS maps and data provide an important framework for understanding how landscape fire processes patterned and structured woody vegetation prior to European settlement. At the landscape level, presettlement woody vegetation occurred along an increasing tree density and fire protection gradient extending from prairie through savanna, woodland, and forest. This information provides a landscape model that can be used to help set management and restoration goals for oak savanna and woodland vegetation. However, the specific frequency and intensity of fire needed to manage and restore different components of this landscape continuum are not well known. Using fire-management to replicate presettlement landscape processes and restore fragmented oak ecosystems is an important conservation challenge that will require long-term experimental management.

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Table 1. Survey dates, Deputy Surveyors, and survey regions of Will County

Year	Surveyor	Porton of county	Percent of survey
1821	Miller	Central	42.02
1821	Walls	Central	7.56
1821	Thomas	Central	3.92
1833-34	Beckwith	SE of Indian Boundary	1.12
1834	Spaulding	SE of Indian Boundary	33.47
1834	Clark	SE of Indian Boundary	3.22
1834	Sibley	SE of Indian Boundary	7.56
1837-38	Prescott	NW of Indian Boundary	1.12

Table 2. Translations of oak (*Quercus*) identifications and abbreviations used by the Deputy Surveyors. Species marked with asterisks (*) do not occur naturally in Will County

Common Name	Scientific name	1821- Miller	1821- Walls	1821- Thomas	1833-34 Beckwith	1834- Spaulding	1834- Clark	1834- Sibley	1837-38 Prescott
B oak	Unknown	B oak	B oak	B oak	---------------	---------------	---------------	---------------	---------------
Black oak	***velutina***	---------------	---------------	---------------	Black oak	Black oak	---------------	---------------	---------------
*Blackjack oak	***marilandica**	---------------	---------------	---------------	Blackjack oak	---------------	---------------	---------------	---------------
Bur oak	***macrocarpa***	---------------	---------------	---------------	Bur oak	Bur oak	---------------	Bur oak	Bur oak
Jack oak	*ellipsoidalis*	---------------	---------------	---------------	Jack oak	---------------	---------------	---------------	---------------
Overcup oak	***macrocarpa***	---------------	---------------	---------------	---------------	Overcup oak	---------------	---------------	---------------
Pin oak	***palustris***	P oak	P oak	---------------	---------------	P oak	---------------	---------------	---------------
*Post oak	***stellata**	---------------	---------------	---------------	---------------	---------------	---------------	Post oak	---------------
Red oak	***rubra***	R oak	---------------	---------------	Red oak	Red oak	Red oak	---------------	Red oak
Scarlet oak	***ellipsoidalis***	S oak	---------------	S oak	---------------	Spanish oak	---------------	---------------	Spanish oak
White oak	***alba***	W oak	W oak	W oak	White oak	White oak	White oak	White oak	White oak
Chinkapin	***muhlenbergii***	---------------	---------------	---------------	---------------	Yellow oak	---------------	---------------	---------------

Table 3. Coverage of pre-European landscape features.

Vegetation Type	Hectares	% of total
Grassland	**176,689.99**	**80.47**
Prairie	169,879.63	77.37
Marsh	120.76	0.05
Wet/marshy prairie	3,388.52	1.54
Slough	164.48	0.07
Swamp	3,112.29	1.42
Grass swamp	24.31	0.01
Woody	**40,717.56**	**18.54**
Timber	36,937.71	16.82
Scattering timber	3,628.47	1.65
Brush/undergrowth	78.55	0.04
Barrens/Scattering Timber	71.91	0.03
Hazel thicket	0.92	<0.01
Aquatic	**2,165.03**	**0.99**
River/Creek	2,038.21	0.93
Lake/pond	126.82	0.06
Total	219,572.58	

Table 4. Statistical characteristics of Public Land Survey and tree density class vegetation types. Tree densities for prairie are based only on corners with bearing trees and represent local tree densities within prairie.

Public Land Survey vegetation types

Till	N	Tree density (+se)	Tree species richness	Percent undergrowth	Undergrowth richness
Prairie	66	17.54 (+5.89)	14	0.28	3
Barrens/brush	--	-----	--	45.2	3
Scatt. timber	51	29.33 (+8.50)	10	35.48	3
Timber	430	88.54 (8.81)	25	18.83	23
Sand					
Prairie	--	----	--	--	-
Barrens/brush	--	----	--	--	-
Scatt. Timber	5	33.64 (+25.98)	2	75.0	1
Timber	63	58.6 (+38.93)	6	13.4	5

Tree density vegetation types

Till	N	Tree density	Tree species richness	Tree species Diversity (H')
Open savanna	255	> 0-10 trees/ha	17	1.501
Savanna	191	>10-50 trees/ha	21	1.696
Woodland	81	> 50-100 trees/ha	19	1.386
Forest	103	>100 trees/ha	18	1.541
Sand				
Open savanna	45	> 0-10 trees/ha	6	1.187
Savanna	20	>10-50 trees/ha	5	1.127
Woodland	1	> 50-100 trees/ha	1	0.000
Forest	6	>100 trees/ha	5	1.191

Table 5. Linear % cover of woody undergrowth species in PLS vegetation types on till and sand soils

	Till	Till	Till	Till	Till	Sand	Sand	Average	Std.
	Prairie	**Brush prairie**	**Brush**	**Scatt. Timber**	**Timber**	**Scatt. Timber**	**Timber**	**Cover**	**Error**
Oak	1.11	100.00	100.00	100.00	48.20	0.00	9.97	51.33	18.25
Hickory	1.11	100.00	100.00	100.00	43.59	0.00	0.00	49.24	18.85
Hazel	98.31	26.46	38.01	30.75	38.85	0.00	44.09	39.49	11.22
Willow	0.00	0.00	0.00	0.00	1.17	100.00	41.92	20.44	14.50
Barrens	0.00	0.00	0.00	0.00	3.83	0.00	31.64	5.07	4.46
Vines	0.00	0.00	0.00	0.00	19.60	0.00	15.59	5.03	3.27
Briers	0.00	0.00	0.00	0.00	10.04	0.00	0.00	1.43	1.43
Lynn	0.00	0.00	0.00	0.00	6.34	0.00	0.00	0.91	0.91
Prickleash	0.00	0.00	0.00	0.00	6.22	0.00	0.00	0.89	0.89
Plum	0.00	0.00	0.00	0.00	6.17	0.00	0.00	0.88	0.88
Walnut	0.00	0.00	0.00	0.00	5.77	0.00	0.00	0.82	0.82
Ash	0.00	0.00	0.00	0.00	4.14	0.00	0.00	0.59	0.59
Thornvine	0.00	0.00	0.00	0.00	3.38	0.00	0.00	0.48	0.48
Elm	0.00	0.00	0.00	0.00	2.94	0.00	0.00	0.42	0.42
Sugar maple	0.00	0.00	0.00	0.00	2.94	0.00	0.00	0.42	0.42
white oak	0.00	0.00	0.00	0.00	1.98	0.00	0.00	0.28	0.28
Sassafras	0.00	0.00	0.00	0.00	1.16	0.00	0.00	0.17	0.17
Blackberry	0.00	0.00	0.00	0.00	0.81	0.00	0.00	0.12	0.12
Sumac	0.00	0.00	0.00	0.00	0.70	0.00	0.00	0.10	0.10
box elder	0.00	0.00	0.00	0.00	0.30	0.00	0.00	0.04	0.04
Hawthorn	0.00	0.00	0.00	0.00	0.22	0.00	0.00	0.03	0.03
Grapevine	0.00	0.00	0.00	0.00	0.18	0.00	0.00	0.03	0.03
Feverbush	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.02	0.02

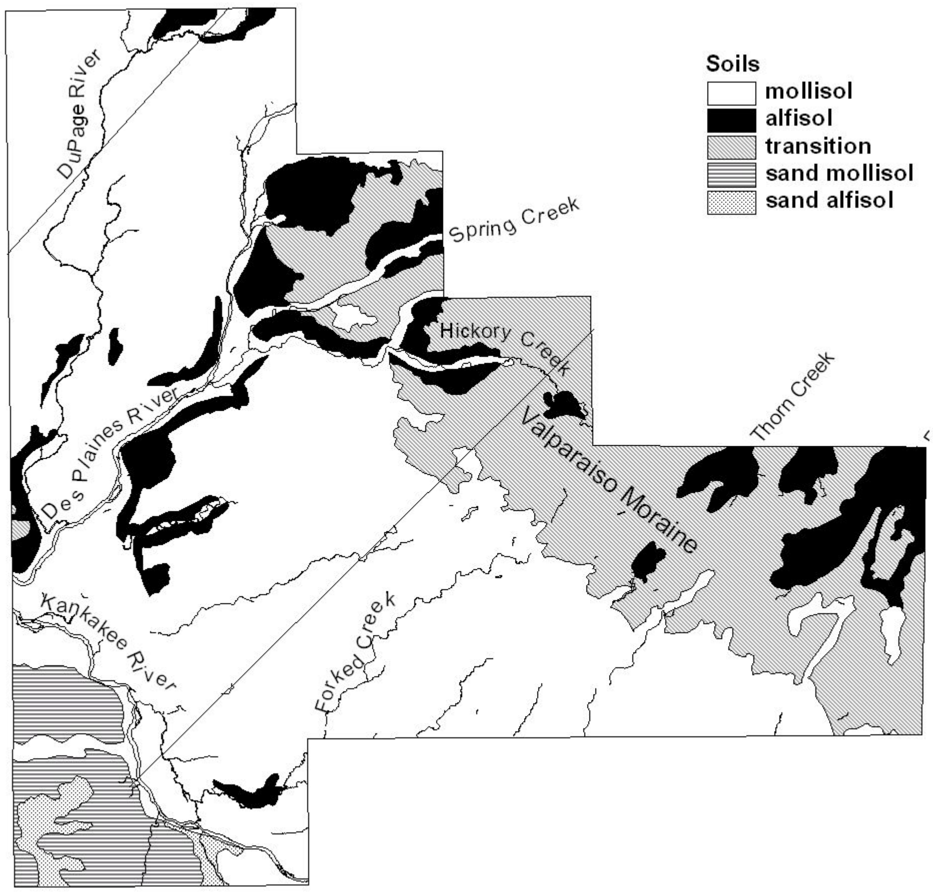


Figure 1. Major stream drainages and soils groups of Will County. Diagonal lines are Indian Boundaries.

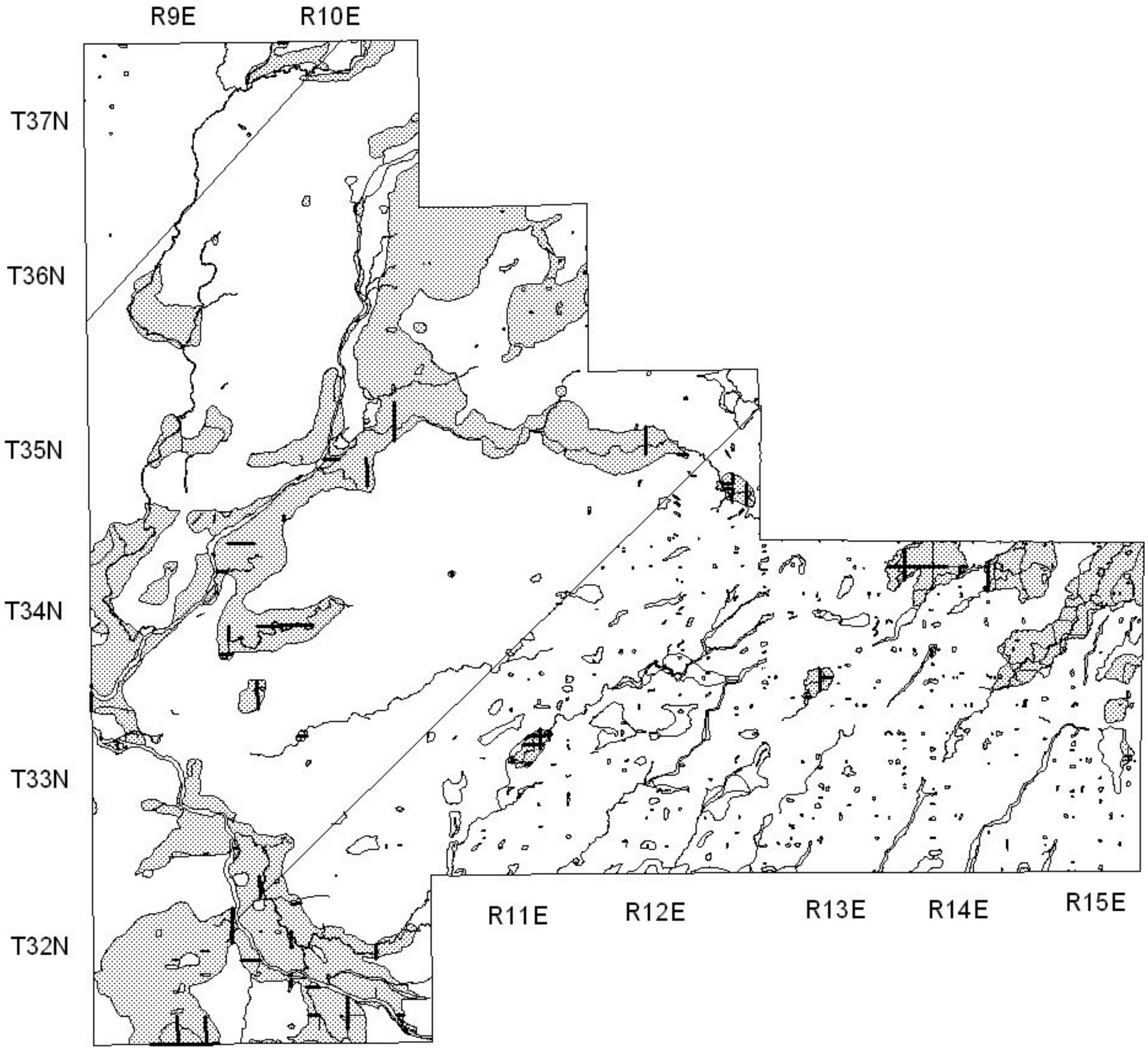
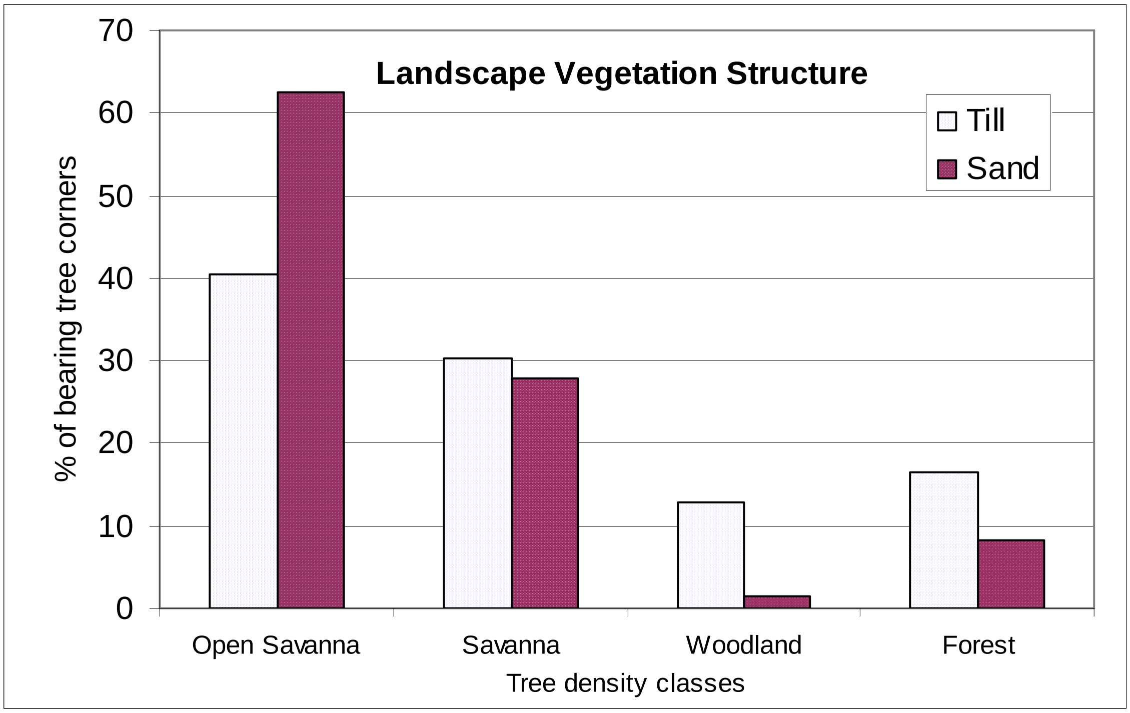


Figure 2. Landscape pattern of prairie (un-shaded) timber and scattering timber (shaded), and presence (thickened section lines) or absence (un-thickened section lines) of woody undergrowth recorded by the Public Land Survey of Will Co., Illinois. Note: absence of section lines indicates that neither presence nor absence of woody undergrowth was recorded. Diagonal lines are Indian Boundaries.



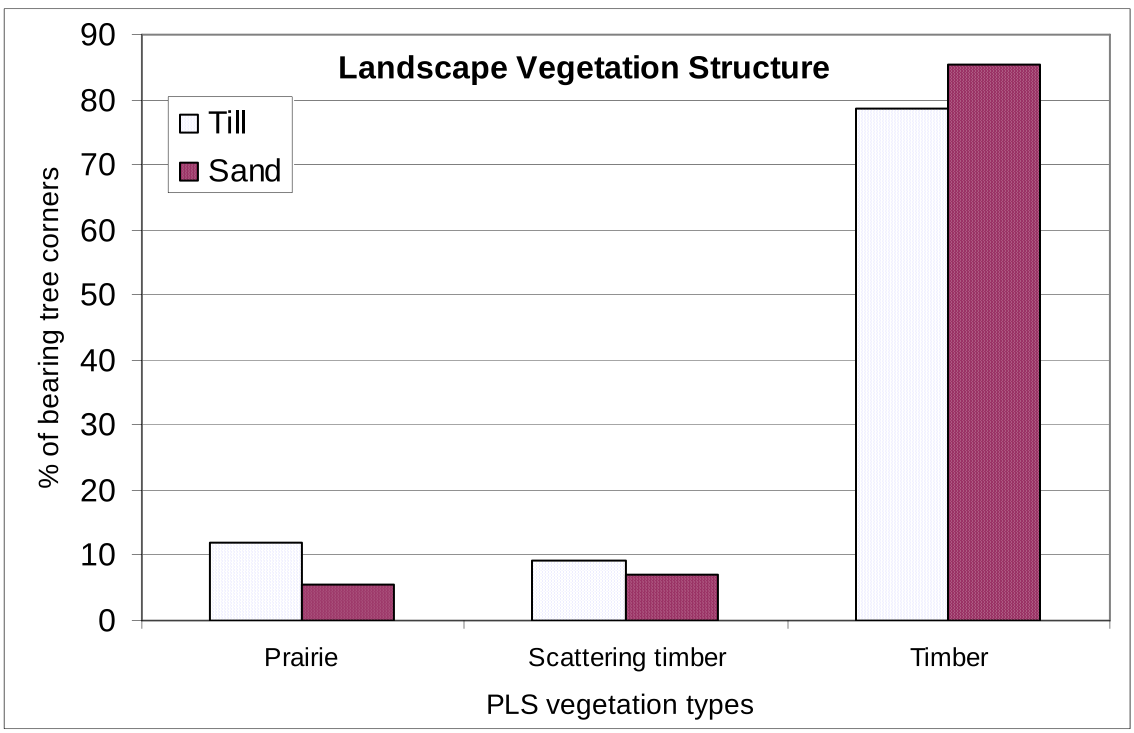


Figure 3. Presettlement landscape vegetation structure on sand and till substrates based on Tree density classes (upper) and Public Land Survey vegetation types (lower) in Will Co., Illinois

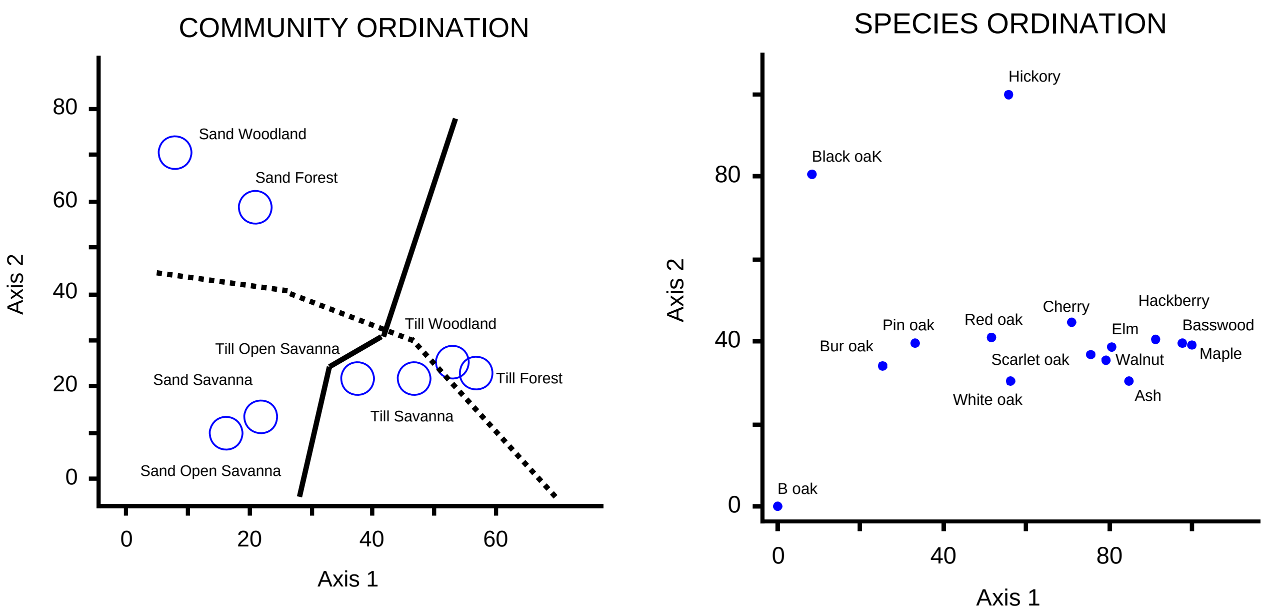


Figure 4. DECORANA ordination of presettlement vegetation of Will County. Open Savanna = >0-10 trees/ha, Savanna = >10-50 trees/ha, Woodland = >50-100 trees/ha, Forest = >100 trees/ha. Solid line indicates Ward's Cluster Analysis separation of sand from till, dashed lines indicate secondary separation of savanna from woodland and forest.

Species correlations with Axis I and Axis II

	Axis I			Axis II		
Species	**r**	**r-sq**	**tau**	**r**	**r-sq**	**tau**
B oak	0.192	0.037	0.214	-0.648	0.42	-0.643
Black oak	0.293	0.086	0.143	-0.383	0.147	-0.286
Pin oak	0.348	0.121	0.483	-0.259	0.067	-0.161
Bur oak	0.367	0.135	0.286	-0.361	0.13	-0.429
Cherry	0.527	0.278	0.445	-0.211	0.044	-0.089
Walnut	0.639	0.409	0.643	-0.256	0.066	-0.189
Scarlet oak	0.654	0.428	0.794	-0.264	0.07	-0.113
Red oak	0.667	0.445	0.403	-0.345	0.119	-0.081
Ash	0.719	0.516	0.643	-0.267	0.072	-0.189
Maple	0.851	0.725	0.886	-0.24	0.058	0.081
White oak	0.866	0.749	0.5	-0.435	0.19	-0.357
Basswood	0.892	0.796	0.802	-0.261	0.068	0.089
Elm	0.897	0.804	0.806	-0.33	0.109	0
Hackberry	0.924	0.854	0.886	-0.284	0.081	0.081
Hickory	0.929	0.862	0.869	-0.163	0.027	0.113

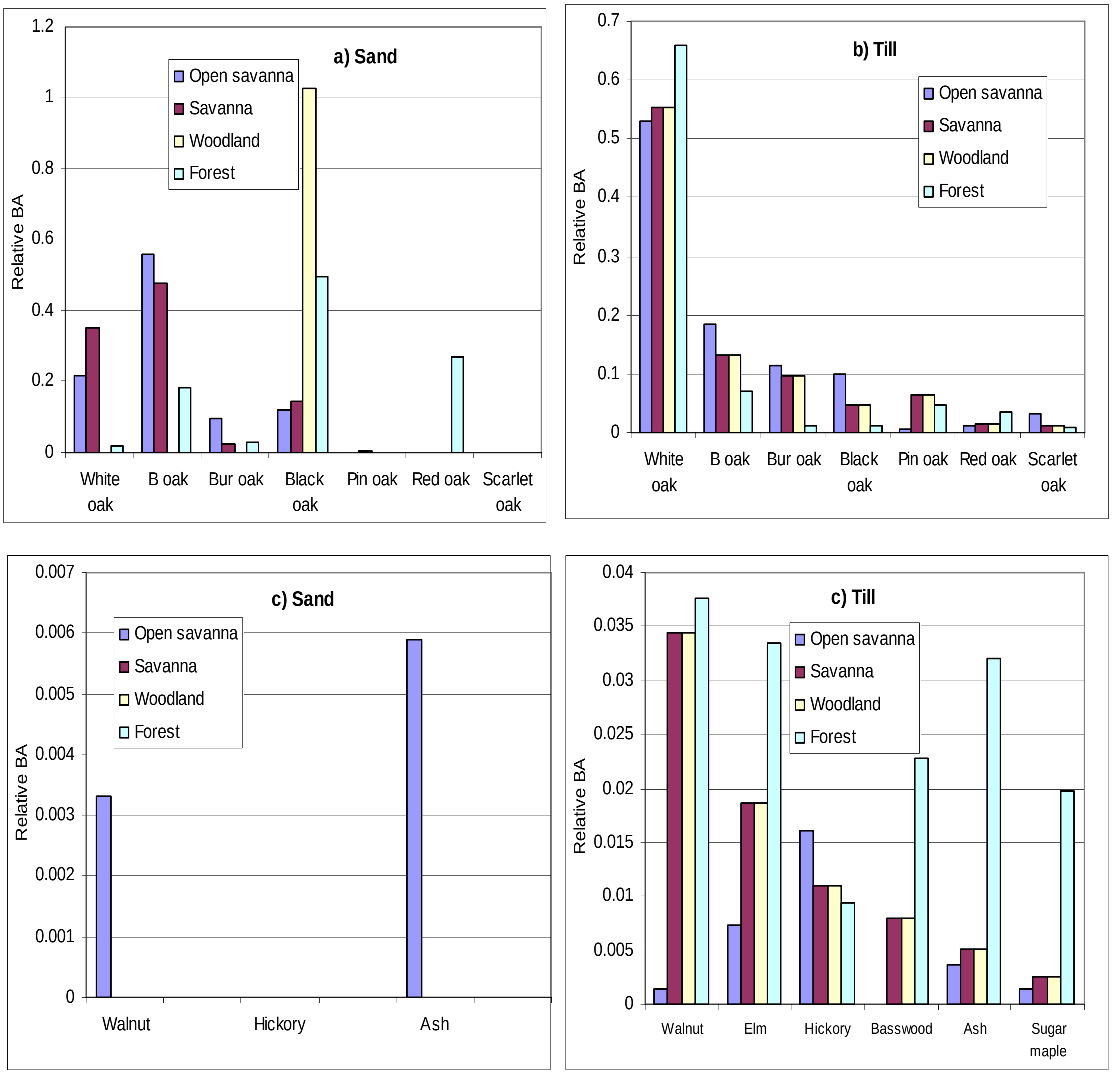


Figure 5. Dominance (relative Basal Area) gradients across tree density classes for a) oaks on sand, b) oaks on till, c) non-oaks on sand, and d) non-oaks on till within tree density vegetation classes. Note differences in scale.

Appendix I. Scientific names assigned to common tree names and abbreviations used by the Will County Public Land Survey

Common name	***Scientific name***
Ash	*Fraxinus sp.*
B oak	*Quercus sp.*
B. Walnut	*Juglans nigra*
Basswood	*Tilia americana*
Black oak	*Quercus velutina*
Box elder	*Acer negundo*
Buckeye	*Aseculus glabra*
Bur oak	*Quercus macrocarpa*
Cherry	*Prunus serotina*
Coffee nut	*Gymnocladus dioicus*
Coffee tree	*Gymnocladus dioicus*
Cottonwood	*Populus deltoides*
Elm	*Ulmus sp.*
Hackberry	*Celtis occidentalis*
Hickory	*Carya sp*
Ironwood	*Ostrya virginiana*
Jack oak	*Quercus ellipsoidalis*
Oak	*Quercus sp.*
P oak	*Quercus palustris*
Pin oak	*Quercus palustris*
Post oak	*Quercus stellata*
Red oak	*Quercus rubra*
S oak	*Quercus ellipsoidalis*
Scarlet oak	*Quercus ellipsoidalis*
Maple	*Acer saccharinum*
Spanish oak	*Quercus ellipsoidalis*
Sugar tree	*Acer saccharum*
Sycamore	*Platanus occidentalis*
Thorn	*Crataegus sp?*
Walnut	*Juglans nigra*
White oak	*Quercus alba*
Willow	*Salix sp*
Yellow o	*Quercus muhlenbergii*
Yellow oak	*Quercus muhlenbergii*

Appendix II. Abundance, basal area, and importance values of tree species by PLS and tree density class vegetation types on glacial till. Data from bearing trees recorded by the Will Co., Illinois Public Land Survey.

Tree density classes

TILL — OPEN SAVANNA

TILL	Number	BA	R. abun.	R. BA	IV
White oak	160	28.18	50.63	52.33	51.48
B oak	46	9.76	14.56	18.12	16.34
Bur oak	39	6.05	12.34	11.24	11.79
Black oak	31	5.23	9.81	9.71	9.76
Pin oak	14	1.67	4.43	3.09	3.76
Hickory	8	0.58	2.53	1.07	1.80
Elm	5	0.39	1.58	0.72	1.15
Red oak	2	0.86	0.63	1.60	1.11
Scarlet oak	2	0.24	0.63	0.44	0.54
Ash	2	0.20	0.63	0.37	0.50
Sycamore	1	0.29	0.32	0.54	0.43
Yellow oak	1	0.13	0.32	0.24	0.28
Hackberry	1	0.10	0.32	0.18	0.25
Sugar maple	1	0.07	0.32	0.14	0.23
Walnut	1	0.07	0.32	0.14	0.23
Cherry	1	0.02	0.32	0.03	0.18
Cottonwd	1	0.02	0.32	0.03	0.18
	316	53.845	100	99.991	99.996

TILL — SAVANNA

TILL	Number	BA	R. abun.	R. BA	IV
White oak	161	31.31	48.06	53.84	50.95
B oak	46	7.50	13.73	12.89	13.31
Bur oak	31	5.54	9.25	9.53	9.39
Black oak	22	2.67	6.57	4.60	5.58
Scarlet oak	15	3.68	4.48	6.33	5.41
Walnut	9	1.95	2.69	3.35	3.02
Hickory	13	0.84	3.88	1.44	2.66
Elm	8	1.05	2.39	1.81	2.10
P oak	7	0.62	2.09	1.06	1.58
Red oak	5	0.62	1.49	1.07	1.28
Ash	4	0.29	1.19	0.50	0.85
Cherry	1	0.66	0.30	1.13	0.71
Basswood	2	0.46	0.60	0.78	0.69
Sugar ma	2	0.15	0.60	0.25	0.42
Post oak	2	0.15	0.60	0.25	0.42
Oak	1	0.29	0.30	0.50	0.40
Jack oak	2	0.03	0.60	0.05	0.33
Hackberry	1	0.16	0.30	0.28	0.29
Buckeye	1	0.13	0.30	0.22	0.26
Cottonwd	1	0.04	0.30	0.07	0.18
Willow	1	0.02	0.30	0.03	0.16
	335	58.15	100.00	100.01	100.00

PLS vegetation types

TILL — PRAIRIE

TILL	Number	BA	R. abun.	R. BA	IV
White oak	33	4.47	35.87	37.69	36.78
Bur oak	17	2.50	18.48	21.07	19.77
B oak	14	2.64	15.22	22.25	18.73
Pin oak	5	0.49	5.43	4.12	4.78
Elm	6	0.29	6.52	2.43	4.48
Black oak	4	0.43	4.35	3.66	4.00
Scarlet oak	3	0.33	3.26	2.80	3.03
Hickory	3	0.29	3.26	2.43	2.84
Ash	2	0.17	2.17	1.45	1.81
Yellow oak	1	0.13	1.09	1.09	1.09
Cottonwood	1	0.04	1.09	0.35	0.72
B.Walnut	1	0.04	1.09	0.35	0.72
Cherry	1	0.02	1.09	0.15	0.62
Willow	1	0.02	1.09	0.15	0.62
	92	11.86	100.00	100.00	100.00

TILL — SCATTERING TIMBER

TILL	Number	BA	R. abun.	R. BA	IV
White oak	31	5.01	31.63	37.50	34.57
Black oak	29	3.35	29.59	25.07	27.33
Bur oak	19	2.27	19.39	16.97	18.18
B oak	5	1.20	5.10	8.97	7.04
Hickory	6	0.30	6.12	2.25	4.19
Cherry	1	0.66	1.02	4.92	2.97
Red oak	2	0.25	2.04	1.90	1.97
Pin oak	2	0.15	2.04	1.09	1.57
Post oak	2	0.15	2.04	1.09	1.57
Spanish oak	1	0.03	1.02	0.24	0.63
	98	13.36	100.00	100.00	100.00

TILL — TIMBER

TILL	Number	BA	R. abun.	R. BA	IV
White oak	443	94.26	53.89	61.48	57.69
B oak	101	17.24	12.29	11.24	11.77
Bur oak	42	7.67	5.11	5.01	5.06
Black oak	35	6.19	4.26	4.04	4.15
Scarlet oak	31	6.28	3.77	4.10	3.93
Hickory	34	2.89	4.14	1.89	3.01
Walnut	16	3.76	1.95	2.45	2.20
Elm	20	2.85	2.43	1.86	2.15
Pin oak	19	2.04	2.31	1.33	1.82
Basswood	17	1.85	2.07	1.21	1.64
Ash	13	1.57	1.58	1.02	1.30
Red oak	10	1.94	1.22	1.26	1.24
Sugar maple	12	1.35	1.46	0.88	1.17

Appendix II. Continued

Tree density classes

TILL — WOODLAND

	Number	BA	R. abun.	R. BA	IV
White oak	89	22.94	54.94	69.41	62.17
B oak	14	1.42	8.64	4.31	6.47
Black oak	8	1.86	4.94	5.63	5.28
Bur oak	8	1.18	4.94	3.58	4.26
Hickory	8	0.85	4.94	2.57	3.75
Elm	7	0.56	4.32	1.68	3.00
Scarlet oak	5	0.88	3.09	2.68	2.88
Basswood	5	0.62	3.09	1.89	2.49
Red oak	3	0.39	1.85	1.18	1.52
Soft maple	2	0.58	1.23	1.77	1.50
Hackberry	3	0.37	1.85	1.11	1.48
Cherry	2	0.36	1.23	1.10	1.17
Sugar maple	1	0.46	0.62	1.38	1.00
Pin oak	2	0.08	1.23	0.25	0.74
Ash	1	0.16	0.62	0.50	0.56
B.Walnut	1	0.16	0.62	0.50	0.56
Oak	1	0.07	0.62	0.22	0.42
Ironwood	1	0.05	0.62	0.15	0.39
Box elder	1	0.04	0.62	0.12	0.37
	162	33.05	100.00	100.01	100.01

TILL — FOREST

	Number	BA	R. abun.	R. BA	IV
White oak	106	22.40	50.48	64.30	57.39
B oak	14	2.40	6.67	6.89	6.78
Scarlet oak	13	1.57	6.19	4.50	5.35
Hickory	14	1.22	6.67	3.51	5.09
Basswood	10	0.77	4.76	2.22	3.49
Ash	8	1.09	3.81	3.12	3.46
Elm	6	1.14	2.86	3.27	3.06
Sugar maple	8	0.67	3.81	1.92	2.87
Walnut	3	1.28	1.43	3.67	2.55
Black oak	8	0.41	3.81	1.18	2.50
Hackberry	4	0.39	1.90	1.12	1.51
Bur oak	4	0.35	1.90	1.02	1.46
Pin oak	3	0.31	1.43	0.89	1.16
Red oak	2	0.32	0.95	0.91	0.93
Soft maple	2	0.26	0.95	0.74	0.85
Ironwood	2	0.15	0.95	0.42	0.69
Thorn	2	0.04	0.95	0.11	0.53
Coffee nut	1	0.07	0.48	0.21	0.34
	210	34.83	100.00	99.99	100.00

PLS vegetation types

TILL — TIMBER CONTINUED

	Number	BA	R. abun.	R. BA	IV
Hackberry	9	1.02	1.09	0.67	0.88
Soft maple	4	0.84	0.49	0.55	0.52
Ironwood	3	0.20	0.36	0.13	0.25
Cherry	2	0.36	0.24	0.24	0.24
Oak	2	0.36	0.24	0.24	0.24
Sycamore	1	0.29	0.12	0.19	0.16
Thorn	2	0.04	0.24	0.02	0.13
Jack oak	2	0.03	0.24	0.02	0.13
Buckeye	1	0.13	0.12	0.08	0.10
Coffee tree	1	0.07	0.12	0.05	0.08
Box elder	1	0.04	0.12	0.03	0.07
Cottonwood	1	0.02	0.12	0.01	0.07
	822	153.30	100.00	100.00	100.00

TILL — SWAMP

	Number	BA	R. abun.	R. BA	IV
White oak	4	0.64251	44.4444	41.8205	43.1325
Bur oak	4	0.69115	44.4444	44.9867	44.7156
Black oak	1	0.20268	11.1111	13.1926	12.1518
	9	1.53634	100	99.9998	99.9999

TILL — BRUSH

	Number	BA	R. abun.	R. BA	IV
White oak	4	------	------	------	------

Appendix III. Abundance, basal area, and importance values of tree species by PLS and tree density class vegetation types on sand. Data from bearing trees recorded by the Will Co., Illinois Public Land Survey.

Tree density classes

SAND	OPEN SAVANNA				
	Number	BA	R. abun.	R. BA	IV
B oak	36	6.92	58.06	55.79	56.93
White oak	14	2.68	22.58	21.58	22.08
Black oak	5	1.49	8.06	12.02	10.04
Bur oak	5	1.20	8.06	9.71	8.89
Ash	1	0.07	1.61	0.59	1.10
Walnut	1	0.04	1.61	0.33	0.97
	62	12.40	100.00	100.03	100.01

SAND	SAVANNA				
	Number	BA	R. abun.	R. BA	IV
B oak	19	3.01	55.88	47.50	51.69
White oak	8	2.21	23.53	34.87	29.20
Black oak	5	0.91	14.71	14.38	14.54
Bur oak	1	0.16	2.94	2.59	2.77
Scarlet oak	1	0.04	2.94	0.65	1.79
	34	6.33	100.00	99.99	99.99

SAND	WOODLAND				
	Number	BA	R. abun.	R. BA	IV
Black oak	1	0.1642	100	100	100

SAND	FOREST				
	Number	BA	R. abun.	R. BA	IV
Black oak	6	0.95	40.00	49.82	44.91
B oak	5	0.35	33.33	18.41	25.87
Hickory	2	0.52	13.33	27.19	20.26
Bur oak	1	0.05	6.67	2.65	4.66
White oak	1	0.04	6.67	2.15	4.41
	15	1.91	100.00	100.23	100.11

PLS vegetation types

SAND	PRAIRIE				
	Number	BA	R. abun.	R. BA	IV
Bur oak	1	0.29	16.667	30.046	23.356
B oak	4	0.52	66.667	53.049	59.858
Black oak	1	0.16	16.667	16.901	16.784
	6	0.9714	100	99.996	99.998

SAND	SCATTERING TIMBER				
	Number	BA	R. abun.	R. BA	IV
B oak	5	0.9212	83.333	95.738	89.536
Scarlet oak	1	0.041	16.667	4.2656	10.466
	6	0.9622	100	100	100

SAND	TIMBER				
	Number	BA	R. abun.	R. BA	IV
B oak	53	9.03	53.00	47.71	50.36
White oak	22	4.85	22.00	25.64	23.82
Black oak	16	3.35	16.00	17.72	16.86
Bur oak	6	1.13	6.00	5.96	5.98
Hickory	2	0.52	2.00	2.75	2.37
Walnut	1	0.04	1.00	0.22	0.61
	100	18.92	100.00	99.99	100.00

SAND	LAKE				
	Number	BA	R. abun.	R. BA	IV
Ash	1	0.073	50	50	50
White oak	1	0.073	50	50	50
	2	0.146	100	100	100