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# Pre-settlement Vegetation of Greene, Jersey and Macoupin Counties along the Prairie/Forest Border in Illinois

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## ABSTRACT

In the late 18th and 19th centuries the US Federal Government established the Public Land Survey (PLS) to survey the lands west of the original thirteen states and to sell it to settlers. The surveyors identified and measured diameter and distance of trees from section corners, as well as diameters of some trees on section lines across the landscape. Treeless areas were simply labelled "prairie". Ecologists have used this record to reconstruct forests everywhere west of the original 13 states before settlement. We used a Geographic Information System (GIS) and the PLS to explore the relationship among fire frequency, topography, and soils in Greene, Jersey and Macoupin Counties in SW Illinois. The PLS data was digitized from microfiche copies of the original notebooks archived in the Lovejoy Library at Southern Illinois University Edwardsville. Maps of tree distributions showed clear differences based on topography. The floodplains along the Illinois River supported a fire-intolerant forest of *Salix* sp., *Populus deltoides*, *Acer* spp., and *Fraxinus* spp. located on frequently flooded soils. The floodplain is bordered by a line of bluffs which forms a region of broken topography supporting moderately fire tolerant species –especially *Quercus alba*, *Quercus velutina* and *Carya* spp. These existed on alfisols with little prairie. To the East lay a region of mixed prairie and forest. The prairie was located on flat land and mollic soils where it was intermixed with the forest located on hillier slopes. The forest areas supported a highly fire tolerant forest including *Quercus palustris*, *Quercus stellata* and *Quercus marilandica* on alfisols. These observations are supported by measuring distances from the quarter section corners and diameters of trees. Fire-tolerant oaks were located far from the quarter section corners. Most also had large diameters. An exception was *Quercus marilandica* which forms fire tolerant "barrens" with small diameter, shrubby trees which are distant from quarter section corners. Non-Metric Multidimensional scaling is an ordination technique which reveals a close relationship among topography, vegetation and soils. Upland oak woodlands are located on alfisols which are indicative of forests. Prairies are located on mollisols which are clearly differentiated on the first NMDS axis. Prairies are located on level uplands where there were no firebreaks. Floodplains are just as level as prairies. They are also located on mollisols adjacent to the river. They are protected from fire by sloughs, swamps and lakes. The results of our study support the conclusion that topography and moisture are important controls on the geographical distribution of vegetation in the study area. These factors likely operated by controlling fire frequency.

## INTRODUCTION

The Public Land Survey (PLS) was a survey conducted by the U.S. government (Government Land Office) on all lands west of the original thirteen states. Its purpose was to survey land prior to sale and subsequent settlement. The survey created a grid of square "townships" which were 6 miles (9.7Km) on a side. Each township contains 36 square "sections" a mile on a side. The sections are further subdivided into four 1/4 square mile "quarter sections". In the PLS "bearing trees" (*sensu* Grimm 1984) were blazed with an axe at each section and quarter section corner throughout the survey area to mark the land for later sale to pioneer farmers. The center section corner was not surveyed. Surveyors also identified and measured so called "line trees" that they found on section lines. The bearing trees were identified, measured, and located with respect to the quarter section corner. Line trees were not located with respect to quarter section corner, but with respect to the section line. The survey can be used today to reconstruct the vegetation present at the time of the survey—just prior to settlement. The PLS was completed in SW Illinois between 1818 and 1820. It provides a database that can be used to examine the relationships among vegetation, topography, drainage and soils. It also provides an environmental baseline for conditions at the time of the survey.

Over approximately the past eighty years, analyses of the original survey notes have been carried out in many states providing valuable basic ecological information that in turn has been used to reconstruct original vegetation patterns (Kilburn 1959; Grimm 1983; Brugam and Patterson 1996).

Over time in Illinois more and better uses of the PLS records have been made as researchers have been able to go well beyond the simple enumeration of the various tree species. Savannas (barrens) have been mapped (Kilburn et al. 2009). King and Johnson (1977) compared vegetation with topography in the Sangamon River watershed. Development of computer systems has enabled a useful analysis of these data (Grimm 1983; Schaetzl and Brown 1996; Schulte and Mladenoff 2005). The application of digital methods has allowed investigators to ask and answer questions about tree distributions at the time of the survey.

Analyses of these data have become increasingly sophisticated because of the application of Geographical Information Systems (GIS). In the Sylvania Wilderness Area, an undisturbed wilderness reserve in the Upper Peninsula of Michigan, investigators confirmed the accuracy of the PLS using GIS (Manies and Mladenoff 2000). Vadeboncoer et al. (2012) and Thompson et al. (2013) compared the PLS with the USDA Forest Service Forest Inventory Analysis data in the Northeast to determine how forests have changed since the PLS. Hanberry et al. (2014) completed a similar study in Northern Missouri. Thomas-Van Gundy et al. (2015) categorized the fire adaptations of the PLS survey trees in the Northeast to reconstruct the fire frequency in various landscapes. In Illinois 48 of 103 counties have been either completely or partially analyzed (Kilburn and Brugam 2014). However, most studies are too old for GIS analysis. In Illinois, the original surveyor plat maps have been georeferenced for GIS and published in CD format (Illinois Natural History Survey 2005). Data analysis in Illinois has not yet been as sophisticated as in Missouri and the Northeast because, as yet, there is no state-wide database available for analysis.

This paper analyzes the pre-settlement forest-prairie transition east of the Illinois River ranging from the heavily forested western portions of Greene and Jersey Counties to the upland prairies of Macoupin County in the east (Fig. 1). This paper is based on the original survey notes and plat maps recorded by the Deputy Surveyors of the Public Land Survey (PLS). Our goal is to use the PLS in Green, Jersey and Macoupin counties to understand the causes of the complex pattern of prairie and forest in these southwest Illinois counties. We will compare vegetation, topography and soils to reconstruct the patterns of vegetation distribution. We will extend the work of King and Johnson (1977) testing the significance of topography and soils in controlling tree distribution. We will expand the study area and apply modern data analysis techniques to the dataset.

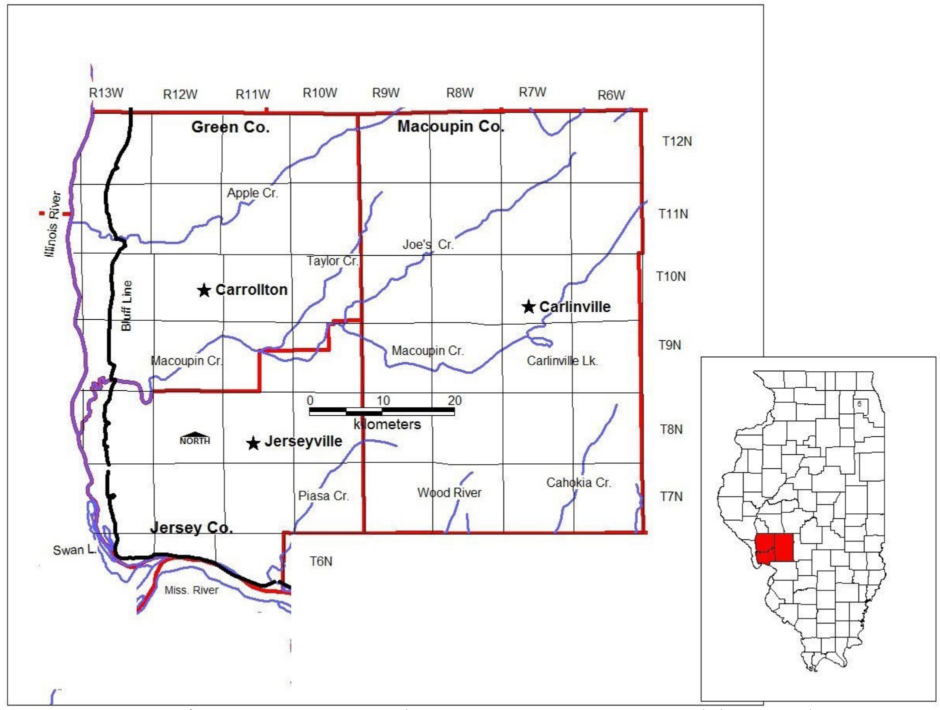


**Figure 1.** Map of Greene, Jersey and Macoupin Counties. Red lines indicate county boundaries. The inset show the location of the three counties within the state of Illinois.

## STUDY AREA

**Location.** The study area covers the counties of Jersey, Greene and Macoupin in southwestern Illinois (Fig. 1). The area ranges approximately 42 miles (66 km) north and south and 52 miles (83 km) east and west. This tri-county area lies east of and adjacent to the southern portion of the Illinois River and a few miles north of the Mississippi River which here is flowing mainly west to east. The Mississippi forms the southern border of Jersey County.

The study area has a continental climate typical of SW Illinois (Natural Resources Conservation Service 2007). The average monthly range of high temperature is from 40°F (4.4°C) in January to 90°F (32.2°C) in July. The lower average temperature ranges from 21° F (-6.1°C) in January to 66°F (18.9°C) in July. Total average precipitation is 34.3 inches (87.1 cm) with the lowest monthly average 1.6 inches (4.1 cm) in February and highest average of 4.4 inches (11.2 cm) in June. The growing season is approximately 180 days.

**Soils and Topography.** Floodplains lie adjacent to the Illinois River extending for one to eight km east These are covered by alluvial soils (Natural Resources Conservation Service 2007, 1974). Bottomland soils extend east along major streams sometimes through the Greene and Jersey counties and into Macoupin County (Natural Resources Conservation Service 2004). This is particularly true of Macoupin Creek (Fig. 1). There the floodplain is often more than 1.6 km wide through Greene County and into Macoupin County. Apple Creek which runs through Greene County turning north and having its headwaters in Scott and Morgan Counties to the north. Many other creeks run into these rivers but are much shorter, have steeper gradients and little or no alluvial soils.

To the east of the Illinois River floodplain limestone bluffs form escarpments rising up to 75m. These are capped with 15-20m of loess. These bluffs represent a boundary between the Illinois River floodplain and the uplands. They are penetrated by stream valleys. The loess cap thins sharply to the east until it is no more than an average of two meters in depth in Macoupin County at the eastern edge of the study area. This average depth varies and in some areas is completely absent exposing Illinoisan glacial age tills. East of the bluffs is a 6 to 9 km wide belt of very irregular topography with deep ravines.

Prairie and forest are mixed in the eastern portions of the county. The upland loess-capped prairie soils are easily distinguished from the forest soils by the black color imparted by the decay of prairie roots and above ground growth (mollic epipedon). These prairie soils (mollisols) are extensive on level to gently rolling lands. They generally have slopes less than four percent and are some of the most productive soils in the world. Where cut by streams, valleys and ravines the vegetation is dominated by forest and forest soils (alfisols).

## METHODS

Data were obtained from microfilm copies of the Public Land Survey Field Notes housed in Lovejoy Library of Southern Illinois University Edwardsville. The mapping program, National Geographic TOPO (version 4.5.0), was used to locate all outside quarter section corners and all line trees. TOPO is a digitized version of the U.S. Geological Survey 7.5' topographic map series that allows the user to mark locations and to enter notes at those locations. We transcribed data from the Field Notes into a file maintained in TOPO. The TOPO file recorded the coordinates of each quarter section corner or line tree. Trees were listed according to the species identified by the surveyors (Table 1).

The taxonomic abilities of the surveyors is unclear (Table1). Most commonly names used by the surveyors have clear modern botanical meanings. "Spanish oak" is an exception. Edgin (1997) and Edgin and Ebinger (1997) in Illinois and Bragg (2002) in Arkansas interpreted this species as *Quercus falcata*. Stolynoff and Hess (2002) did a survey of the genus *Quercus* in Illinois and found the taxonomic confusion of *Quercus falcata* found in southern Illinois and *Quercus ellipsoidalis* found in northern Illinois. The PLS was conducted in winter when it was probably difficult to differentiate between the species. Here we follow the convention of Edgin (1997), Edgin and Ebinger (1997) and Bragg (2002) in calling the surveyor's "Spanish oak" *Quercus falcata*.

Where no tree was indicated, the quarter section corner was identified as prairie. In addition to coordinates and tree species, the diameter of each tree was noted in inches by the surveyors. Distance from the quarter section corner was measured in links and copied from the field notes. Slope was measured on TOPO and tabulated as a percent. Topography was determined for each section corner based on TOPO slope measurements.

**Table 1.** Tree species represented at more than 10 quarter section corners or section lines.

| Surveyor designation | Scientific Name | Number of Section corners and Line Trees | Tree Abbreviation |
|---|---|---|---|
| Prairie | | 2234 | PR |
| White Oak | *Quercus alba* L. | 1759 | QA |
| Black Oak | *Quercus velutina* Lam. | 1652 | QV |
| Hickory | *Carya* spp. | 1151 | C |
| Post Oak | *Quercus stellata* Wangh. | 597 | QS |
| Elm | *Ulmus* spp. | 429 | U |
| Pin Oak | *Quercus palustris* | 225 | QP |
| Black Jack Oak | *Quercus marilandica* Muenchh. | 225 | QM |
| Ash | *Fraxinus* spp. | 151 | A |
| Hackberry | *Celtis* sp. | 107 | CE |
| Black Walnut | *Juglans nigra* L. | 106 | JN |
| Red Oak | *Quercus rubra* L. | 92 | QR |
| Overcup Oak | *Quercus lyrata* Walt. | 85 | QL |
| Cottonwood | *Populus deltoides* Marsh. | 76 | PD |
| Dogwood | *Cornus* sp. | 69 | C |
| Sycamore | *Platanus occidentalis* L. | 61 | P |
| Maple | *Acer* spp. | 58 | AI |
| Sugar Maple | *Acer saccharum* Marsh. | 46 | AU |
| Spanish Oak | *Quercus falcata* Michx. | 38 | QC |
| Willow | *Salix* spp. | 37 | S |
| Sassafras | *Sassafras albidum* Nutt, | 32 | SA |
| Lyn | *Tilia americana* L. | 32 | TA |
| Mulberry | *Morus rubra* L. | 22 | M |
| Buckeye | *Aesculus* sp.. | 22 | A |
| Butternut | *Juglans cineria* L. | 20 | JC |
| Birch | *Betula nigra* Ehrh. | 19 | B |
| Burr Oak | *Quercus macrocarpa* Michx. | 16 | QM |
| Black Locust | *Robinia pseudoacacia* L. | 14 | RP |
| Honey Locust | *Gleditsia triacanthos* L. | 13 | GT |
| Box Elder | *Acer negundo* L. | 13 | AN |
| Red Bud | *Cercis canadensis* | 13 | CE |

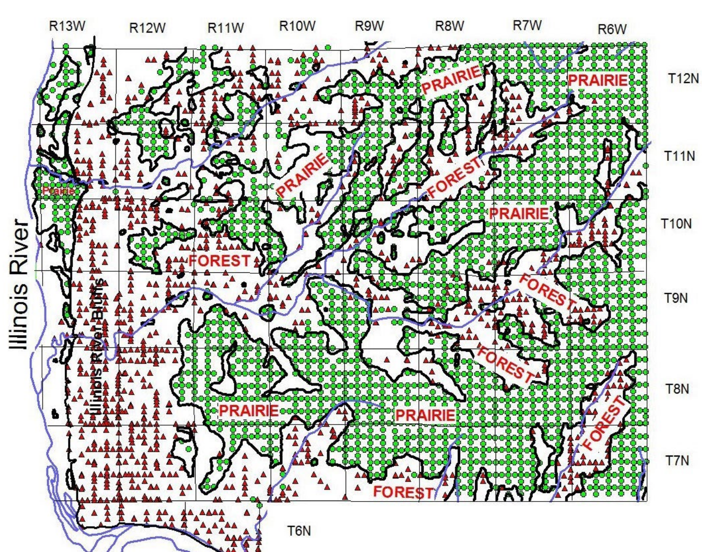


**Figure 2.** Distribution of prairie (green dots) and *Quercus alba* (red triangles) in Greene, Jersey and Macoupin Counties, Illinois.

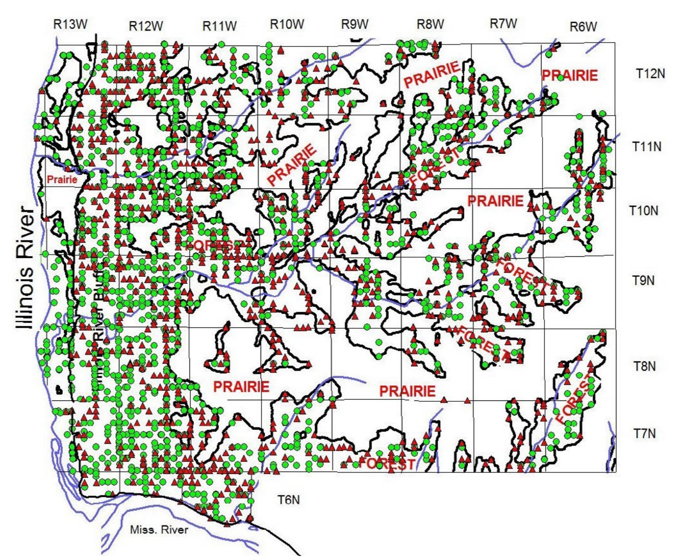


**Figure 3.** Distribution of *Quercus velutina* (green dots) and *Carya* spp. (red triangles) in Greene, Jersey and Macoupin Counties, Illinois.

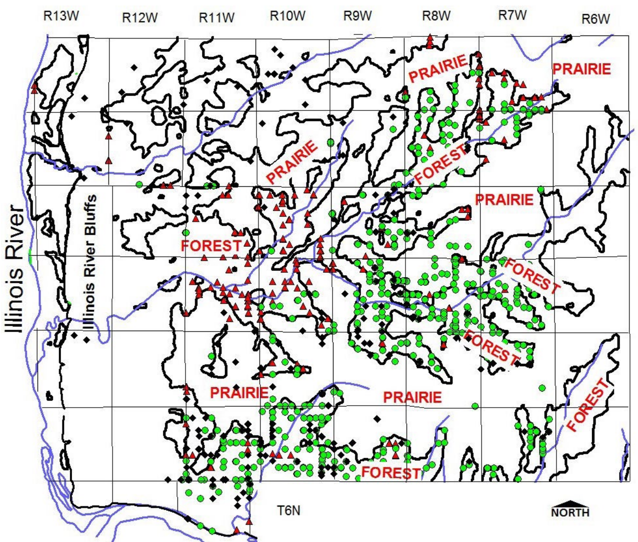


**Figure 4.** Distribution of *Quercus stellata* (green dots) *Quercus palustris* (red triangles) and *Quercus marilandica* (black diamonds) in Greene, Jersey and Macoupin Counties, Illinois.

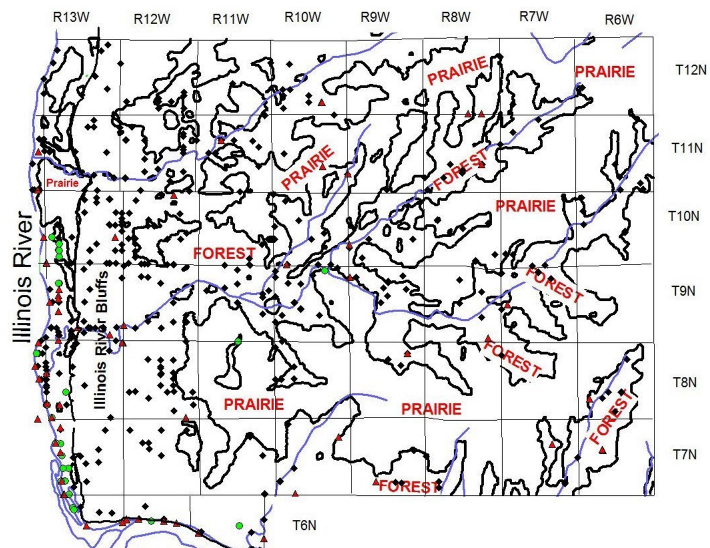


**Figure 5.** Distribution of *Salix* sp. (green dots) *Populus deltoides* (red triangles) and *Ulmus* sp. (black diamonds) in Greene, Jersey and Macoupin Counties, Illinois.

The latitude/longitude-indexed spreadsheet that resulted from digitization of the vegetation data using TOPO contained 9,520 data points. At many quarter section corners surveyors listed 2 trees. We entered each tree as a separate data-point. Prairie points were entered as single data points. This data-set was exported from TOPO and converted into an excel spreadsheet. The spreadsheet was uploaded into MAPINFO 6.5, a geographic information system (GIS) to create maps of tree locations (Figs. 2 through 5).

Georeferenced digital maps of soil series for all three counties were obtained from the Natural Resources Conservation Service. These maps showed the locations of all soil series. The excel vegetation data-set was overlain on the soil maps using MAPINFO and the files were combined. The result was that the official soil series name was determined for each data point.

Non-metric multidimensional scaling (NMDS) ordination was performed on tree species and soils using PC-Ord version 6.01 (Peck 2010). Minchin (1987) showed that this non-parametric method is relatively robust to variations in community models. It is an appropriate choice for most ecological applications. In our analysis we used 41 soil series with > 10 quarter section corners and line trees as "plots" (Table 2). We also used 16 tree species present in >25 soil series (Table 1). This number is smaller than the total number of trees in the dataset. The reduced dataset was used for NMDS analysis because many species from the total dataset were too rare for inclusion in the statistical analysis (Peck 2010). This use of ordination asks how tree species are organized among soils.

## RESULTS

The total data-set includes 29 tree species that have more than 10 recorded individuals (Table 1). Not all species were included in the ordination. There were 2,234 prairie quarter section corners (Fig. 2). The 5 most abundant tree species (Table 1) were *Quercus alba* (1,759), *Quercus velutina* (1,657), *Carya* spp. (1,152), *Quercus stellata* (598) and *Ulmus* sp. (429).

**Geographic Distribution of Prairie and Tree Species.** We can locate trees on a map to show their geographic distribution. *Quercus alba* is abundant along the river bluffs and up river valleys (Fig. 2). A narrow band along the Illinois River does not have prairie or *Quercus alba* but does have floodplain species (Fig. 5). Our results show that prairie covers the uplands in the eastern ¾ of the study area. Our prairie section corners coincide with the locations of prairies indicated in PLS summary maps. The prairie-forest borders on Figures 2 through 5 were traced from the Illinois Natural History georectified survey maps. (Illinois Natural History Survey 2005). These boundaries were copied by the INHS from survey maps prepared shortly after the completion of the original survey.

*Carya* spp. and *Quercus velutina* are less abundant in the east, which had large areas of prairie and forests of *Quercus stellata* and *Quercus palustris*. *Quercus alba* and *Carya* spp. were more common in the western part of the study site along the Illinois River bluffs (Fig. 3). The trees extend up stream valleys on more sloping ground.

*Quercus stellata*, *Quercus marilandica*, and *Quercus palustris* are abundant on the edges of prairie (Fig. 4). All three species are found in narrow areas of forest surrounded by prairie. They do not appear in the 5 to 13 km of land between the river bluffs and the westernmost extension of prairie. This belt is populated with *Quercus alba*, *Quercus velutina* and *Carya* spp. (Figs. 2 and 3). *Quercus stellata*, *Quercus palustris* and *Quercus marilandica* segregate themselves geographically. *Quercus stellata* is most abundant in the forested areas on the southern border of the study site and in the upstream parts of Macoupin Creek and its tributaries. *Quercus palustris* is abundant along the downstream parts of Macoupin Creek in areas of the floodplain surrounded by prairie. *Quercus marilandica* is widely scattered in the same areas as *Quercus stellata* and *Quercus palustris*.

**Table 2.** Soils containing more than 10 quarter section corners or line trees.

| Names Soil Series | Number of Section Corner and Line Trees | Suborders Soil |
|---|---|---|
| Fayette | 966 | hapludalf |
| Hickory | 661 | hapludalf |
| Herick | 498 | argiudoll |
| Virden | 406 | argiaquoll |
| Rozetta | 358 | hapludalf |
| Keomah | 329 | endoaqualf |
| Clinton | 298 | hapludalf |
| Lawson | 287 | hapludoll |
| Homen | 235 | hapludalf |
| Muscatine | 212 | argiudoll |
| Clarksdale | 172 | endoqualf |
| Elco | 172 | hapludalf |
| Wakeland | 171 | fluvaquent |
| Ipava | 158 | argiudoll |
| Sylvan | 148 | hapludalf |
| Marine | 127 | albaqualf |
| Downs | 116 | hapludalf |
| Bunkum | 110 | hapludalf |
| Titus | 89 | endoaquoll |
| Cowden | 86 | albaqualf |
| Oconee | 85 | endoqualf |
| Menfro | 81 | hapludalf |
| Beaucoup | 73 | endoaquall |
| Winfield | 62 | hapludalf |
| Sable | 50 | endoaquoll |
| Petrolia | 48 | endoaquepts |
| Blyton | 45 | udifluvent |
| Coffeen | 45 | hapludoll |
| Haymond | 44 | fluvaquent |
| Greenbush | 36 | hapludalf |
| Atterberry | 35 | endoqualf |
| Fishhhook | 32 | hapludalf |
| Worthen | 32 | hapludoll |
| Rushville | 31 | albaqualf |
| Elsah | 30 | udifluvent |
| Quiver | 30 | fluvaquent |
| Darwin | 29 | endoaquoll |
| Keller | 29 | argiudoll |
| Assumption | 28 | argiudoll |
| Emery | 27 | endoqualf |
| Tama | 25 | argiudloll |

*Salix* sp. and *Populus deltoides* are all located near the Illinois River. Ulmus sp. are scattered throughout the study area (Fig. 5).

**Size, Distance and Slope.** Some investigators (Fralish et al. 1991; Anderson et al. 2006) have used the distances of trees from quarter section corners to estimate the density of trees in the pre-settlement forests using various plotless sampling techniques. We have not followed that approach because our large study area makes it difficult to relate a tree density to a county-wide area. However, distance from the section corner does indicate distance between forest trees of particular species and, thus is a rough indicator of fire frequency. It is likely to reveal responses of species to fire. Woodlands burned frequently are more open than ones that have less frequent fire (Fralish et al. 1991; Anderson et al. 2006). The 5 species located, on average, farthest from the quarter section corner were *Quercus marilandica* (28.6±2.2m), *Quercus stellata* (24±2m), *Quercus palustris* (18±2m), *Quercus velutina* (16±.6m) and *Carya* spp. (16±.6m). Thomas-Van Gundy et al. (2014) classified these species as "pyrophyllic". They are all highly fire tolerant species. The 5 species located nearest to the quarter section corner were *Cercis* sp. (4±.6m), *Morus* sp. (5±.8m), *Acer saccharum* (6±.6m), *Juglans cinerea* (6.5±1m) and *Acer* sp. (7±.6m). All are "pyrophobic" using Thomas-Van Gundy's et al.'s (2014) scheme.

The data-set also contains information on tree diameter. The five trees with largest diameter are *Quercus macrocarpa* (62±16cm), *Quercus falcata* (56±9cm) *Quercus lyrata* (52±6cm), *Populus deltoides* (48±5cm) and *Platanus occidentalis* (48±6cm). The 5 species with the smallest diameter are *Cornus* sp. (19±2cm), *Cercis* sp. (20±5cm), *Aesculus* sp. (24±5cm), *Quercus marilandica* (28±2cm) and *Morus* sp. (28±6cm).

A plot of tree diameter against distance from the quarter section corner indicates a wide range of variation in our data-set (Fig. 6). *Quercus marilandica* individuals are farthest from the section corners but each tree species has a relatively small diameter. *Quercus falcata*, *Quercus macrocarpa* and *Quercus lyrata* are some of the largest diameter trees in the data set, but they are not particularly far from the quarter section corner. *Quercus alba* and *Quercus velutina* are very common in the data-set, but neither is particularly large or widely spaced. *Quercus stellata* is the second most widely spaced tree in the data-set. The smallest trees nearest to the quarter section corner are *Cornus* sp., *Cercis* sp. and *Aesculus* sp. An exception is *Quercus marilandica* whose diameter is among the smallest in the data-set, but whose distance from the quarter section corner is the largest.

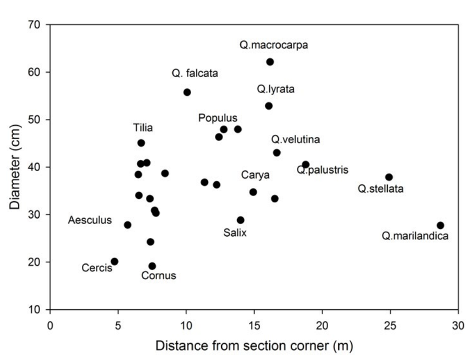


**Figure 6.** Mean diameter of tree (cm) vs. mean distance from the quarter section corner (m). Due to limitations of space, not all species are indicated.

**Slope, Species and Soils.** King and Johnson (1977) working in the Sangamon River Valley argued that slope is a proxy for fire frequency because areas of steep slopes represent fire breaks. For this reason, we recorded the slopes of trees and prairie points in our study area (Fig. 7). The five trees located on the highest slopes were *Cornus* sp. (10.3±4.0), *Sassafrass* sp. (6.9±2.6), *Quercus alba* (6.0±2.6%), *Quercus falcata* (5.2±2.6%) and *Acer saccharum* (4.8±1.8%). Plants on the shallowest slopes were *Acer negundo* (.2±.3%), *Acer saccharinum* (.2±.3%), *Salix* sp. (.2±.3%), *Populus deltoides* (.8±.6%), and prairie grasses (1.0±.8%).

In addition to relating species to slope, it is important to relate slope to soils. The Soil Surveys for all three counties (NRCS 1974, 2004, 2007) provide a range of slopes for each Official Soil Series Description. However, we noted the slope and soils for each of our quarter section corners and line trees so that we could directly compare soil, slope and trees. The five steepest slope soils are: Sylvan (13.0±.6%), Fayette (7.4±.2%), Memfro (7.2±.5%), Elsah (5.6±.9%), and Hickory (5.6±.2%). These soils vary from 88 to 100% forested. The soils with least slope are: Petrolia (.12±.06%), Beaucoup (.16±.05), Darwin (.17±.1%), Titus (.22±.08%) and Sable (.44±.1%). These soils are very level. Petrolia, Beaucoup and Darwin soils are classified as fluvaquentic in the soil surveys (Table 2). All are located adjacent to streams and are heavily forested with floodplain species. Soils that supported prairie are nearly level but often more sloping than the floodplains. These soils are Virden (.44±.04% slope, 92% prairie), Cowden (.48±.06% slope, 99% prairie), Herrick (.53±.03% slope, 93% prairie) and Ipava (.61±.06% slope, 83% prairie).

**Pre-settlement Vegetation and Soils.** Because georeferenced soil surveys are available for the three counties in this study, it is possible to relate vegetation with official USDA-NRCS soil descriptions. We can determine whether species found in the PLS are associated with particular soil series. Figure 8 shows an NMDS ordination of soil series versus the vegetation found on that soil. The data points are marked to differentiate among mollisols, alfisols and wetland soils. The species plot of the NMDS (Fig. 8) shows that prairies are plotted at high values on Axis 1 among mollisols. An exception is the Cowden soil which is classified as an alfisol, but had 99% prairie. Axis 1 is positively correlated with percent prairie points associated with a particular soil (Fig. 8). Mollisols lower on Axis 1 support *Populus deltoides*, *Fraxinus* spp., *Acer negundo*, *Ulmus* sp. and *Acer saccharum*. It is also clear from Figure 8 that mollisols have high Axis 2 values and alfisols have low values. Oak species are all located at negative values of Axis 2 among alfisols suggesting an association between woodlands and alfisols.

## DISCUSSION

Our hypothesis is that the distribution of vegetation in the study area is controlled by fire frequency which will vary in different geographical areas as a result of topography. King and Johnson (1977) hypothesized that variations in slope will result in firebreaks. Furthermore, the effectiveness of firebreaks will vary with topography. Differences in topography will limit the distribution of fire-sensitive species to particular low-fire locations.

Our maps of the three counties support this hypothesis. Prairie is very fire tolerant requiring fires at frequent and sometimes nearly annual intervals (Grimm 1986, Kilburn et al. 2009, Kilburn and Brugam 2010). Our maps show a series of bands of vegetation along the Illinois River and extending eastward across the counties (Figs. 2 to 5). These bands (Fig. 9) are based on the distribution of vegetation that we found. They reflect differences in topography. They are very similar to the physiographic regions of the state outlined by Schwegman (1974).

Nearest to the Illinois River is a band about 8 km wide that supported flood plain species including a group of species that are highly intolerant of fire. In this location the topography is very level (Floodplain mean slope .86±17%, Fig. 10), but fire is sup-

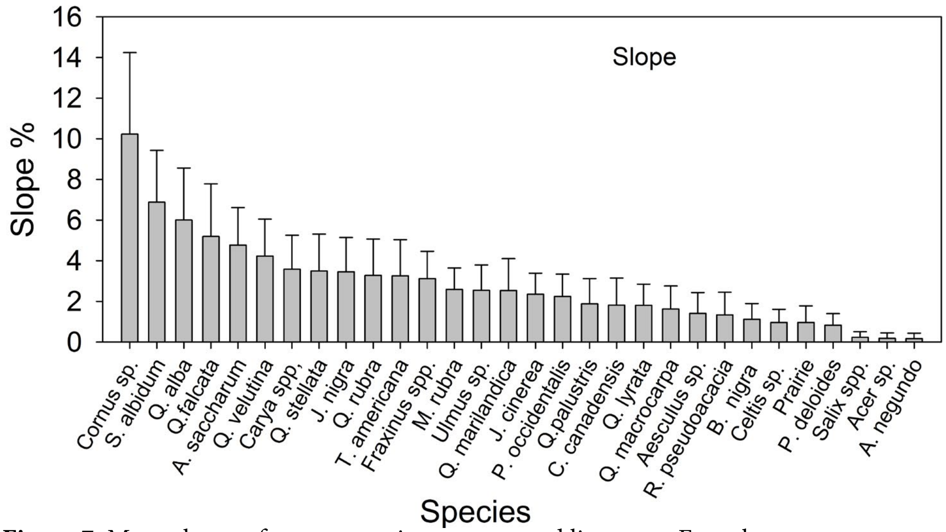


**Figure 7.** Mean slopes of quarter section corners and line trees. Error bars represent standard error of the mean.

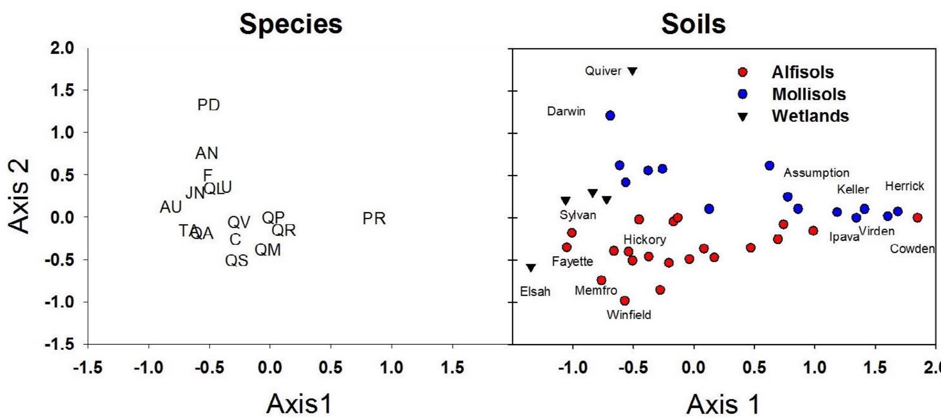


**Figure 8.** Non-metric Multi-Dimensional Scaling (NMDS) analysis of trees and soils. Points represent soils. Two-letter codes represent tree species.

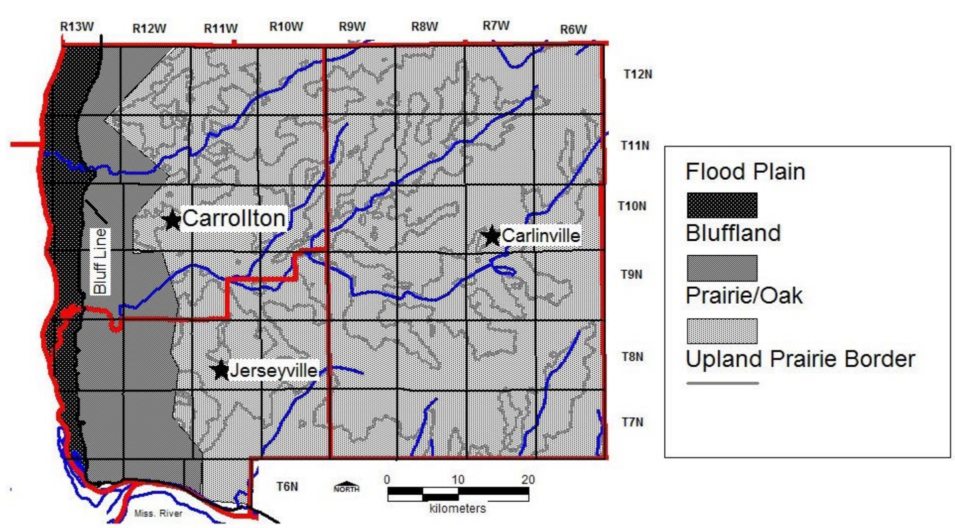


**Figure 9.** Vegetation types in Greene, Jersey and Macoupin Counties, Illinois as shown by the PLS Survey from 1818 to1820. Red lines indicate county boundaries.

pressed by broad expanses of moist floodplain lakes, and marshes. This region has large areas of frequently flooded soils (Natural Resources Conservation Service 1974, 2004, 2007). There was usually a strong spring flood along the Illinois River (Junk et al. 1989).

East of the Illinois River bluffs, on hilly land, was a 13 km band of moderately fire tolerant oak and hickory species – *Quercus alba*, *Quercus velutina*, *Carya* spp. (Fig. 3). This region (Fig. 9) has the highest mean slope of the dataset (6.3±.14%, Fig. 10). The steep slopes allow only occasional fires by providing firebreaks. King and Johnson (1977) and Brugam and Patterson (1996) emphasize the role of steep slopes in preventing the spread of fires. On flat land all areas will dry at a similar rate with large areas being capable of supporting fire at the same time. However, in broken topography different patches will dry at different rates reaching combustibility at different times. This difference in patches will impede the spread of fires.

Still further to the east highly fire tolerant oak species (*Quercus palustris*, *Quercus stellata* and *Quercus marilandica*) are added to *Quercus alba*, *Quercus velutina* and *Carya* spp. (Fig. 9) These are intermixed with prairie on flat uplands and with forests primarily confined to the slopes. Forests are located on intermediate slopes (2.2±.05% slope, Fig. 10). Prairies are located on level uplands with low slope (.99±.03% slope, Fig. 10). These level uplands had few firebreaks and supported frequent fires. It is likely that these fires burned into adjacent forests, establishing forests of relatively high fire frequency. King and Johnson (1977) sought to relate fire frequency to slope. Our dataset supports their hypothesis, but because it is larger and more topographically complex it reveals more about the ecology of the southwestern Illinois landscape. King and Johnson (1977) argued that because of the lack of firebreaks, prairie developed on flat uplands. This was also the case with our dataset.

The floodplain along the western border of the study site is even more level than the prairies. This region was covered by flood-tolerant species like *Acer* sp., *Salix* spp. and *Populus deltoides*. Their presence suggests that these sites were frequently

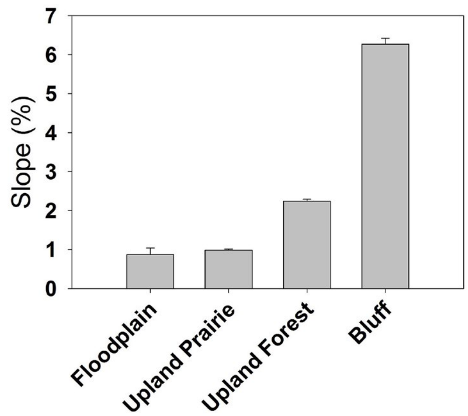


**Figure 10.** Mean slopes of topographic groupings. Error bars represent standard error of the mean. All medians are significantly different from each other using the Kruskal-Wallis test.

flooded. There were many section corners without trees on the floodplain but it is unclear whether these locations were true prairies or marshes. True prairie is found on slightly higher average slope.

Trees on the steepest slopes were fire intolerant species (*Cornus* sp, *Sassafras* sp. and *Acer saccharum*). *Quercus alba* and *Q. falcata* are the only oaks inhabiting steeper slopes. Our results support King and Johnson showing prairie on level ground without flooding. However, our results support the basic understanding that the floodplain environment is very different from uplands because of periodic flooding and poorly drained soils and resulting in strikingly different vegetation. Flooding can be added to the other abiotic controls on forest composition.

*Quercus stellata* is a species which is frequently found in a peculiar Illinois vegetation type called the "Illinois Post Oak Flatwoods" (Coates et al. 1992, Taft et al. 1995, Edgin et al. 2003, Taft 2005). This vegetation type grows on relatively flat topography where soils are underlain by a "hard pan" that inhibits drainage through the soil column.

**Distance, Size and Slope.** In our dataset, known fire-tolerant genera (*Quercus* and *Carya*, Abrams 1992, Abrams 2003) are generally far from quarter section corners indicating wide spacing in the forest. In contrast, closely spaced species are fire intolerant supporting the argument that the forests receiving frequent fires have more broadly spaced individuals. In addition the largest trees are mostly fire-tolerant *Quercus*. The smallest are mostly fire intolerant successional species. An exception is *Quercus marilandica*. In our dataset it is both far from the quarter section corners and small in diameter. Carey (1992) reports that *Quercus marilandica* is even more fire-tolerant than *Quercus stellata* and *Quercus velutina*. This species has a peculiar ecology because it root sprouts vigorously after fire. Kilburn et al, (2009) reported that it is a major component of Illinois barrens. These are areas of woody vegetation that support fires. However, fires in barrens are probably not as frequent as in prairies allowing some woody vegetation to survive. Figure 6 shows how anomalous *Quercus marilandica* is. On the basis of distance from quarter section corners, it seems to be adapted to a higher fire frequency than other tree species in the dataset.

**Species, Slopes and Soils.** Another question about vegetation in the study site is the relationship among vegetation slope, fire frequency and soils. How does soil develop in the Southwestern Illinois mosaic of prairie, forest and wetland? Brady and Weil (1996) identified 5 soil forming factors, 1) parent material, 2) climate, 3) topography, 4) organisms, 5) time. In our location parent material has limited effect because the study area is covered by at least two meters of loess nearly everywhere. To the east on slopes some Illinoisan till is exposed. Climate is similar across the counties and today's soil types developed in this overlying material. The time interval since loess deposition ceased is similar in all study locations. Topography and vegetation (organisms) vary across the landscape. It is clear that soil development will depend on the complex of factors described here and that soils, topography and vegetation in our study counties will not be independent variables. All are be interrelated and variations in any of these three factors will influence the others.

We can use NMDS ordination techniques to discover the relationships among Brady and Weil's (I996) soil forming processes in Greene, Jersey and Macoupin Counties. Mollisols are darkly colored soils (mollic epipedon) with high amounts of organic matter (Foth 1984). These include prairie and wetland soils. Alfisols are light colored soils (ochric epipedon) that develop under forests (Foth 1984). NMDS ordination can be used to relate vegetation type to soils – answering the question; are particular vegetation types associated with particular soil series? Each soil series is used as a sample "plot" for vegetation (Fig. 8).

The ordination associates soils with vegetation. The result of the ordination is that prairie vegetation clusters at high Axis 1 values. Forests have low Axis 1 values. Oak species of mesic upland forests are located on alfisols and have low Axis 2 values. Trees of wetland forests have high Axis 2 values and are located on mollisols.

The average percentage of prairie section corners is strongly correlated with Axis 1 of the ordination (Fig. 8). High prairie percentages are associated with high axis 1 values. These are located on prairie soils. There is a weaker correlation between average percent slope and Axis 1 (Fig. 8). The heavily forested soils (Sylvan, Fayette and Memfro) have the steepest average slope. The soils with highest percent prairie (Virden, Cowden, Herrick, Ipava) are also extremely level. It is clear that soil series are strongly associated with slope and vegetation type. It is likely that topography controls fire frequency which, in turn, controls vegetation type and soils.

**Pre-Columbian Human Activity and SW Illinois Vegetation.** Human activities are another potential influence on the vegetation mosaic in the study area. Attention has been focused on the extensive Indian settlements in and around Cahokia, on the Mississippi floodplain only about 30 km to the southeast (Emerson and Lewis 1991). This was one of the largest Indian settlements in North America at the time (1000 CE), with extensive cultivated fields growing four varieties of maize. Around 1500 CE the population declined, and their consequent influence on surrounding vegetation greatly diminished.

In contrast, the Illinois River Valley has been densely populated for at least 8700 years (Brown and Viera 1996). However, it is still unclear what part Native Americans have played in landscape management. Many investigators have argued that they used fire as a tool to drive game and to develop edible wild plant resources (review in Abrams and Nowacki 2015). The vegetation of SW Illinois could have been heavily modified by Native Americans.

There has been a long-running controversy among ecologists whether the prairies of Illinois are a result of climate or of human activities (Transeau 1935, Abrams and Nowacki 2015). Wright (1968) demonstrated that the climate of Illinois is more drought-prone than regions to the north east and south. The climate is more like regions to the west. Illinois has been termed the "Prairie Peninsula" (Transeau 1935) as a consequence of the climatic conditions.

It may be that the PLS data is a reflection of Native American use of the landscape. Unfortunately, there is little direct experimental evidence for or against Indian landscape modification, however, there is lots of anecdotal evidence for Native American use of fire. They might well have provided the ignition source for the highly fire tolerant vegetation that we have described. Grimm (1984) emphasized that Indians were a major ignition source for Minnesota forests. He emphasized that lightning strikes, though present, were rare and that Indian fires were likely to have been more frequent. Hotchkiss et al. (2007) working in the large Northwestern Wisconsin sand plain found that changes in the pollen record occurred at the same time as changes in Indian cultural practices. Munoz and Gajewski (2010) working in southern Ontario using pollen and charcoal analysis in lake cores showed increases in human indicators in pollen and increases in charcoal occurring together. Thomas Van-Gundy et al. (2014) associated pyrophyllic vegetation in the Northeast with likely villages and trails in the PLS record. This result shows increased fire frequency near Indian settlements.

The climate of Illinois likely permits fire as Wright suggested (1968), but the large population of people in presettlement times probably increased the frequency of ignition as it did in Minnesota (Grimm 1984). The SW Illinois vegetation was clearly heavily influenced by fire. However, we do not yet understand the role of active fire management in Illinois by Native Americans.

## CONCLUSION

Our examination of the PLS record for Greene, Jersey and Macoupin Counties show a clear variation in vegetation from west to east that is probably dependent on variations in fire frequency. The western part of the study area, adjacent to the Illinois River had floodplain vegetation. The bluffs to the east of the River had forests of *Quercus alba*, *Quercus velutina* and *Carya* spp. These forests had an intermediate tolerance for fire. To the east of these woodlands was a mosaic of prairie and patches including very fire-tolerant trees like *Quercus stellata*, *Quercus palustris* and *Quercus marilandica*.

The variations in vegetation corresponds strongly with topography. Both the floodplain and the prairie are nearly level. The bluff lands have most variable topography. Upland forest have intermediate slopes. The differences in slope result in differences in fire-breaks and fire frequency.

Variations in topography result in variations in soil series. Varying soils support different vegetation. Thus, the complex variations in topography, vegetation and soils result in a complex mosaic of vegetation and fire-frequency.

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