Transactions of the Illinois State Academy of Science
(1996), Volume 89, 3 and 4, pp. 125-141

Application of a Geographic Information System to Mapping Presettlement Vegetation in Southwestern Illinois

Richard B. Brugam[1] and Mary James Patterson[2]
[1]Department of Biological Sciences
[2]Environmental Studies Program
Southern Illinois University
Edwardsville, Ill. 62026

ABSTRACT

Presettlement tree distributions from two Southwestern Illinois counties were compared with physiographic regions using maps created on MAPINFO, a Geographic Information System. The ecotone between the forests of the Mississippi Borderland bluffs and the Illinoisan Till Plains is clearly shown on the GIS maps. The ecotone follows a creek valley that divides the sharply dissected bluffs from the flat till plains. Fire intolerant taxa such as *Ulmus* spp., *Celtis* spp., *Populus deltoides*, *Acer negundo*, and *Fraxinus* spp. grew in the complex of wetlands nearest to the Mississippi River. The bluffs along the river had a moderately fire tolerant forest of *Quercus alba*, *Q. velutina* / *Q. rubra*, and *Carya* spp. The Illinoisan-aged till plains of the eastern part of the study area supported a mixture of prairie, *Quercus palustris*, and *Q. stellata* on soils that were occasionally waterlogged.

Keywords: Illinois, Public Land Survey, pre-settlement vegetation, Prairie Peninsula, Oak-Hickory Forest

INTRODUCTION

The Prairie Peninsula (Transeau 1935) is a large area of mixed forest and prairie in the American Midwest that extends eastward across the state of Illinois from the Mississippi River. It is interrupted near the river by a narrow strip of forested land along the river referred to as the "Mississippi Valley Section of the Oak-Hickory Forest Region" by Braun (1964). Although this strip of land shares a climate similar to that of the Prairie Peninsula, it was heavily forested before European settlement (Transeau 1935).

The Government Land Office Survey can be used to determine the relationship of the western boundary of the Prairie Peninsula with topography. U.S. government lands were surveyed before they were sold to pioneer farmers. The survey used locations of "bearing" trees, identified to species, as markers for survey plots. These trees represent a low-density vegetation survey that can be used to reconstruct the natural vegetation before European settlement.

Many investigators have reconstructed pre-settlement vegetation of parts of Illinois using the land survey records (Anderson 1991). Anderson and Anderson (1975) and Rodgers and

Anderson (1979) used the surveys to reconstruct the distributions of prairie and forest in three Illinois counties. King and Johnson (1974) examined the distributions of tree species with respect to slope and proximity to streams. More recently, Shotola et al. (1992) used the pre-settlement survey in a comparison with modern forest composition in southwestern Illinois. Fralish et al. (1991) used the surveys to compare the distributions of particular tree species and community types with site characteristics and with modern vegetation to examine changes in forest composition since pre-settlement times.

Geographic Information Systems are computer programs which use geographically organized data to construct maps. They can be used to examine the relationship between geographic data and landforms. In particular, a Geographic Information System can be used to summarize the relationship between the distribution of trees in the U.S. Government Land Office Survey and topography.

With the exception of Grimm (1984) and Schwartz (1994), few previous investigators have used computer mapping techniques to study the Public Land Survey data. We have applied these techniques to the land survey data from southwestern Illinois to compare distributions of the tree species with major topographic features.

STUDY AREA

Location

The area of this study is Madison and St. Clair counties in Illinois with small portions of adjacent Bond, Clinton, Washington and Monroe counties (Fig. 1).

Madison and St. Clair counties were chosen for this study because of their location at the interface of the Prairie Peninsula (mapped by Transeau 1935) and the oak/hickory forest that extends northward along the Mississippi (Braun 1964). This is an ecotonal area (Fig 1) which is not associated with any sharp difference in climate. Precise maps of forest distributions along the ecotone would reveal the relationship between the distributions of particular trees and landforms along the east side of the Mississippi River.

Geology

Southwestern Illinois was covered by the Illinoisan glacier (Schwegman 1973) which has been dated between 170,000 and 125,000 B.P. (Curry and Follmer 1992). The Illinoisan glacial till plain covers most of the eastern half of the study area.

Although the Wisconsinan glacier did not reach Southwestern Illinois, the wind-blown, glacially-derived silt from the Mississippi River during Wisconsinan times forms a thick loess covering over most of the area. With the exception of the alluvial plains of the major rivers, all soils in our study area are derived from loess (Wallace 1978; Goddard and Sabata 1986).

Climate

Southwestern Illinois has a continental climate with a maximum average July temperature of 31.4 °C (88.6 °F.) and a minimum average January temperature of -7.6 °C (19.3 °F.; Wallace 1978). In most years there are strong summer droughts broken by occa-

sional frontal storms. Total rainfall averages 14.7 cm per year (36.82 inches) but the actual amount varies greatly from year to year (Wallace 1978).

Native American Occupation

Our study area was the location of the largest settlement of Native American people north of Mesoamerica (Fowler 1989). This ceremonial center, named Cahokia, dates from 1100 to 1300 A.D. and had an estimated population of between 10,000 and 30,000. Although the landscape was much modified by the Cahokian people, by the time of European contact the impact of the Cahokians probably was no longer evident. By then, native American populations at the site had declined (Fowler 1989).

Natural Divisions

The study area includes several environmental divisions described by Schwegman (1974) and classified on the basis of topography.

The environmental division nearest the Mississippi River is the Mississippi Bottomlands (Fig 1). In pre-settlement time, this region, also called the "American Bottoms" contained many lakes and wetlands developed in old river channels (Fowler 1989). Soils in this region have developed from river alluvium (Wallace 1978; Goddard and Sabata 1986).

The Mississippi Borderlands division (Fig 1) is characterized by river bluffs on its western border. This division has a dissected topography with deeply incised valleys.

The eastern part of our study area lies within the Southern Till Plains division, which extends over a large portion of Southern Illinois. It is characterized by loess-covered Illinoisan till plains crossed by major rivers (e.g. the Kaskaskia; Fig 1). The till plain is level to gently rolling except near streams where erosion has produced shallow valleys. The soils of this division are poorly drained (Wallace 1978; Goddard and Sabata 1986). Before European settlement large areas of the till plain were covered with shallow water in spring. These "wet prairies" dried by summer (Schwegman 1974).

A small part of the Western Forest and Prairie division enters the northern part of the study area (Fig. 1). As with the Southern Till Plains division, the Western Forest and Prairie division is underlain by Illinoisan glacial till plain.

The Ozark division along the southwestern edge of the study area (Fig. 1) is characterized by loess-covered karst topography with many sink holes, a few of which contain lakes. The modern flora of this division has many similarities with the eastern edge of the Missouri Ozarks (Schwegman 1974).

METHODS

Field Methods

The survey data used here are drawn from the U.S. Government Land Office Survey. The study area was surveyed in 1812 (Patterson 1989). Our data are drawn from the microfilm copies of the survey notes archived at the Illinois State Library in Springfield. These surveys were completed on public lands throughout the U.S. before the lands were sold to settlers. This survey created a grid of square "townships" which were 6 miles 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 land surveys two or four "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 trees were identified, measured, and located with respect to the quarter section corner. More complete descriptions of the survey methods are presented in Bourdo (1956) and Grimm (1984). Only bearing trees (sensu Grimm 1984) were used in this study.

The surveyors of Southwestern Illinois only recorded 2 bearing trees at each section corner. In addition to species, the surveyors recorded the size of the tree, and the distance and direction from the corner.

The surveyors identified the trees by common English names in use at the time. The Southwestern Illinois surveyors did not differentiate hickory species. Furthermore, the references of the surveyors to "black" oak probably included both *Quercus velutina* and large numbers of individuals which we would today classify as red oak, *Quercus rubra.* Fralish et al. (1991) encountered similar problems in interpreting the distributions of red and black oak in the land survey of the Shawnee Hills of southern Illinois.

The use of vernacular names by the surveyors means that the distributions of some species were obscured. For example, *Celtis laevigata* exists in the study area in modern times, but is likely to have been included with *C. occidentalis* under the name "hackberry" (Mohlenbrock1982). The surveyors also did not differentiate among species of oaks which are important in localized areas (*Q. muehlenbergii* on the river bluffs). These problems of tree identification increase our difficulties in interpreting the survey results but do not reduce the value of the distribution data that we do have.

Computer Methods

For our study the latitude and longitude of each quarter section corner was entered into a computer file. This file was used in MAPINFO, version 4, a commercially available geographic information system, to locate the trees to be mapped. Borders of physiographic regions were digitized from Schwegman (1974) and overlaid on the map of tree locations. Soil types were digitized from the soil map of Illinois and overlain on the tree maps.

Statistical Methods

The association between tree species and physiographic region were tested using a chi-squared test on a 5 by 2 contingency table.

RESULTS

Distribution of Forest and Prairie

In the Southern Till Plains division, trees were primarily along stream beds (Fig. 2). On the dry uplands surveyors found no bearing trees. These areas were covered with prairie. Toward the west, trees became more numerous and every quarter section corner in the Mississippi Borderlands division had trees. The Mississippi Bottomlands by contrast, had large treeless areas which extended to the bluff edge.

Tree Species Distributions

Southern Till Plain Division

Although the Southern Till Plain division had prairie vegetation on the uplands, it also had a distinctive assemblage of trees along stream channels and in isolated upland locations. The most common species in this division are pin oak and post oak (Fig. 3). Some specimens of overcup oak (*Q. lyrata*) occurred in this division along Sugar Creek in the eastern part of the area (Fig. 3).

The western boundary of pin, post, and overcup oak distributions does not correspond with the western boundary of the Southern Till plains division as mapped by Schwegman (1974). Our maps show this western boundary to follow an arc (labeled "Ecotone" on Fig. 3) from the northwestern to the southeastern corner of the study area. The boundary follows Silver Creek and Mud Creek (Figs 3 and 4). There is a clear demarcation of vegetation types along these streams. To the east are large expanses of prairie bordered by pin, post, and overcup oak trees along streams (Fig. 3). To the west of Silver Creek are more heavily forested areas of white, red, black and black jack oak and hickory (Figs 4 and 5).

The boundary between forest types is not an artifact of poor identifications by surveyors because the boundary transects many townships. Each township was surveyed by a single survey crew. Thus, tree identifications on both sides of the boundary within a township can be expected to be consistent.

Mississippi Borderlands

The Mississippi Borderlands supported an oak/hickory forest including white and "black" oaks (Fig. 4). Hickory was also common in this division near the bluff edge (Fig 5). As mentioned above, this classical "Oak-Hickory" forest extended beyond the mapped boundary of this division to Silver Creek in the east.

Mississippi Bottomlands

The Mississippi Bottomlands, an alluvial plain subject to frequent flooding, supported forests that were very different from the oak/hickory forests of the surrounding uplands.

The major species found in the land survey in the Mississippi American Bottomlands are elm , willow, cottonwood (Fig 6), sycamore, boxelder, hackberry, and ash (Fig 7). Nearly all of the box elder and cottonwood were close to the Mississippi. In contrast, elm was found both in the Mississippi Bottomlands and in many upland sites.

Western Forest and Prairie Division

This division supported white oak, "black" oak (Fig 4), hickory (Fig. 5). The quarter section corners from the center of this division all contain black jack oak (Fig. 5). This latter species has an unusual distribution because it also occurs in a small area to the west of Silver Creek and in scattered sites throughout the study area (Fig. 5).

Ozark Division

The Ozark Division had a forest similar to the Mississippi Borderlands division. In the Ozark Division white oak was found at nearly every quarter section corner (Fig. 4). "Black" oak was also common (Fig. 4)

Sugar Maple

Sugar maple (*Acer saccharum*; Fig. 6) was not confined to a particular environmental division but was found in greatest abundance along the Kaskaskia River. The surveyors found a few isolated specimens of these species in other locations.

Statistical Analyses of Tree Distributions

The chi-squared test (Table 1) was used to determine if the most abundant tree species in the data set were distributed randomly with respect to Schwegman's (1974) physiographic divisions. Most tree species show a significantly non-random distribution with respect to division. A few species, like sugar maple and black jack oak, had distributions among divisions which did not differ significantly from random.

When the percentage of tree species occupying particular regions is examined (Fig. 8), the affinities of species for particular regions is apparent. These percentages represent the proportion of particular species compared with the total number of trees in the physiographic division. White oak, black oak, and hickories are found in all physiographic divisions. Pin oak is most abundant in the Southern Till Plains. Elm, ash, hackberry, boxelder and cottonwood are most abundant in the Bottomlands. Post oak is most abundant in the Western Prairie and Forest division.

DISCUSSION

Ecotone Between the Mississippi Borderlands and Southern Till Plain

This pre-settlement vegetation survey reveals an ecotone between a forest of hickory, white oak, red oak and black oak and a forest of pin oak, post oak, and overcup oak dividing the study area (Fig 3). For most of its length in our area the ecotone follows Silver Creek. This creek also separates areas of contrasting topography. To the west of the creek the land has highly dissected loess ravines. To the east it is flat, loess-covered glacial till plain. The creek itself follows a meandering course through a relatively broad, shallow valley.

A likely explanation for the existence of the ecotone at Silver Creek is contrasting fire frequency on either side of the creek. The flat areas to the east of the creek were covered by prairie. They are marked by the Piasa soil association (Fig. 3) which developed under grasslands. The Piasa soil is also poorly permeable having ponded water on it in spring (Goddard and Sabata 1986). The areas of prairie were surrounded by a fire-tolerant woodland of pin oak, post oak, and overcup oak. Presumably, prairie fires burned into these areas. Silver Creek probably functioned as an efficient fire break. To the west of the creek the dissected topography provided additional firebreaks allowing the growth of a forest of less fire tolerant trees -- white oak, red oak, black oak, and hickory.

King and Johnson (1977) also emphasized the association among topography, fire frequency and the geographic distributions of tree species in Illinois. In their study of the pre-settlement vegetation of the Sangamon River drainage in Illinois, they found that forested survey corners were more likely to be found on sloping sites. Flat land supported prairie. We found a similar relationship. The Ozark, Mississippi Borderlands, and Western Prairie and Forest divisions all have areas of steep slopes whereas the Southern Till

Plains division has large areas of flat land of the type that supported prairie in the Sangamon River drainage (King and Johnson 1974).

Telford (1926) noted the prevalence of post oaks on well-drained soils and pin oaks on poorly drained soils in the Southern Till Plains. These forests called the "Illinois flatwoods" have a tree density intermediate between savanna and forest (Taft et al. 1995). Taft et al. (1995) find the post oak flatwoods to be associated with poorly permeable soils with clay pans and frequent fires. Our maps show the natural distribution of the flatwoods. Guyette and Cutter (1991) emphasize in their study of fire history in southern Missouri that post oak is very resistant to scarring by ground fires. Their observation suggests that the flatwoods were very fire tolerant.

The ecotone between the Mississippi Borderlands that we have found from the land survey data marks the western border between the Prairie Peninsula and Braun's (1964) Mississippi Valley Section of the Oak-Hickory Forest. Our location for the boundary is somewhat to the east of Schwegman's (1974) location, but consistent with his interpretation of the physiographic regions of Southern Illinois.

Flood Plain Forests

The Mississippi Bottomlands, in contrast with the surrounding uplands, contained species that are either common in flood-plains (e.g. *Salix* and *Populus*) or fire intolerant, moisture demanding genera (e.g. *Fraxinus* and *Ulmus*). Their presence in the Bottomlands suggests that fire frequencies there were low. Fowler's (1989) map of the pre-settlement Mississippi Bottomlands shows it to have been a complex of wetlands and oxbow lakes. In modern times, levee construction and draining have erased most of these wetland types.

The Geographic Distribution of Sugar Maple

One result of the European colonization of southwestern Illinois has been a sharp decline in fire frequency (Ebinger 1986). A number of investigators (Anderson and Adams 1978; Ebinger 1986; Shotola et al. 1992) have suggested that a major result of this change is enhanced survival of sugar maple and the eventual replacement of oak/hickory forest by sugar maple at many sites. Sugar maple is rare as a bearing tree in our data set. It occurs in abundance only along the Kaskaskia River. In modern times, it has colonized old-growth woods. Grimm (1984) suggested that sugar maple is susceptible to periodic ground fires because its seedlings survive for a long time in the forest understory until a light gap releases them. The seedling population of maples would be susceptible to even a small ground fire that would not affect larger oaks. An anthropogenic decrease in fire frequency would enhance the survival of the seedlings.

CONCLUSION

The presettlement land survey data for Southwestern Illinois show a strong relationship between tree species distributions and topography. The computer-generated maps show a clear ecotone between the oak-hickory forests on the uplands adjacent to the Mississippi River and the pin oak and post oak woodlands surrounding the prairies to the east of the river. The distributions of these forest types are consistent with the hypothesis that differences in fire frequency influenced by topography controlled tree species distributions in pre-settlement Southwestern Illinois.

LITERATURE CITED

Anderson, R.C. 1991. Presettlement forests of Illinois. Proceedings of the Oak Woods Management Workshop. G.V. Burger, J. Ebinger and G.S. Wilhelm eds. Eastern Illinois University, Charleston, Ill. pp 9-19.

Anderson , R.C. and D.E. Adams 1978. Species replacement patterns in Central Illinois white oak forests. In P.E. Pope ed. Central Hardwoods Conference II Purdue University, West Lafayette, Indiana. pp 284-301.

Anderson, R.C. and M.R. Anderson 1975. The presettlement vegetation of Williamson County, Illinois. Castanea 40:345-363.

Bourdo E.A., Jr. 1956. A review of the General Land Office Survey and of its use in quantitative studies of former forests. Ecol. 37:754-768.

Braun, E.L. 1964. Deciduous Forests of Eastern North America Hafner Publishing Co., New York. 596 pp.

Curry, B. and L.R. Follmer 1992. The last interglacial-glacial transition in Illinois 123-25 ka. In Clar, P.V. and Lea P.D. eds. The Last Interglacial-Glacial Transition in North America. Geological Society of America Special Paper 270

Ebinger, J. 1986. Sugar maple, a management problem in Illinois forests. 79:25-30.

Fowler, M. L. 1989. The Cahokia Atlas: A Historical Atlas of Cahokia Archaeology. Studies in Illinois Archaeology 6. Illinois Historic Preservation Agency, Springfield, Ill. 243 pp.

Fralish, J.S., F.B. Crooks, J.L. Chambers, and F.M. Harty. 1991. Comparison of presettlement, second-growth and old-growth forest on six site types in the Illinois Shawnee Hills. Amer. Midl. Nat. 125:294-309.

Goddard, T.M. and L.R. Sabata. 1986. Soil Survey of Madison County, Illinois. United States Department of Agriculture, Soil Conservation Service. Washington, D.C. 254 pp.

Grimm, E.C. 1984. Fire and other factors controlling the Big Woods vegetation of Minnesota in the mid-nineteenth century. Ecol. Monogr. 54:291-311.

Guyette, R.P. and B.E. Cutter. 1991. Tree-ring analysis of fire history of a post oak savanna in the Missouri Ozarks. Natural Areas Journal 11:93-99

King, F.B. and J.B. Johnson. 1977. Presettlement forest composition of the central Sangamon River basin, Illinois. Trans. Ill. Acad. Sci. 70:153-163.

Mohlenbrock R.H. 1982. Illustrated Flora of Illinois: Flowering Plants, Basswoods to Spurges. Southern Illinois University Press, Carbondale. 234 pp.

Patterson, M.J. 1989, Pre-settlement Vegetation of Madison and St. Clair Counties, Illinois. M.S. Thesis, Southern Illinois University, Edwardsville, 140 pp.

Rodgers, C. and R.C. Anderson 1979. Presettlement vegetation of two prairie peninsula counties. Bot. Gaz. 140:232-240.

Schwartz, M.W. 1994. Nautral distribution and abundance of forest species and communities in Northern Florida. Ecol. 75:687-705.

Schwegman, J.E. 1974. Comprehensive Plan for the Illinois Nature Preserves System, Part 2: The Natural Divisions of Illinois. Illinois Nature Preserves Commission. 32 pp.

Shotola, S.J., G.T. Weaver, P.A. Robertson, and W.C. Ashby. 1992. Sugar maple invasion of an old-growth oak-hickory forest in southwestern Illinois. Am. Midl. Nat. 127: 125-138.

Taft, J.B., M.W. Schwartz and L.R. Phillippe 1995. Vegetation ecology of flatwoods on the Illinoisan till plain. J. of Veg. Sci. 6:647-666.

Telford, C.J. 1926. Third report of a forest survey of Illinois. Illinois Natural History Survey Bulletin 16:1-102.

Transeau, E. N. 1935. The prairie peninsula. Ecol. 16: 99-112.

Wallace, D.L. 1978. Soil Survey of St. Clair County, Illinois. United States Department of Agriculture, Soil Conservation Service. Washington, D.C. 114 pp.

Table 1: Chi-squared results. The null hypothesis is that individuals of a species are evenly distributed among the 5 physiographic regions. The degrees of freedom vary because some regions had < 5 individuals of a particular species.

Species	degrees of freedom	chi squared	Probability
Celtis spp.	1	98.4	P<.1%
Q.alba	4	87.0	P<.1%
Q.stellata	2	81.9	P<.1%
P.deltoides	1	81.5	P<.1%
A.negundo	1	75.5	P<.1%
Q.velutina /rubra	4	73.4	P<.1%
Q.palustris	2	59.1	P<.1%
Fraxinus spp.	2	48.3	P<.1%
Ulmus spp.	3	46.1	P<.1%
Carya spp.	4	34.2	P<.1%
Q.marilandica	2	3.3	P>5%
A.saccharum	1	1.5	P>5%

Figure 1. Environmental divisions of southwestern Illinois Redrawn from Schwegman (1974). Inset shows location of study area.

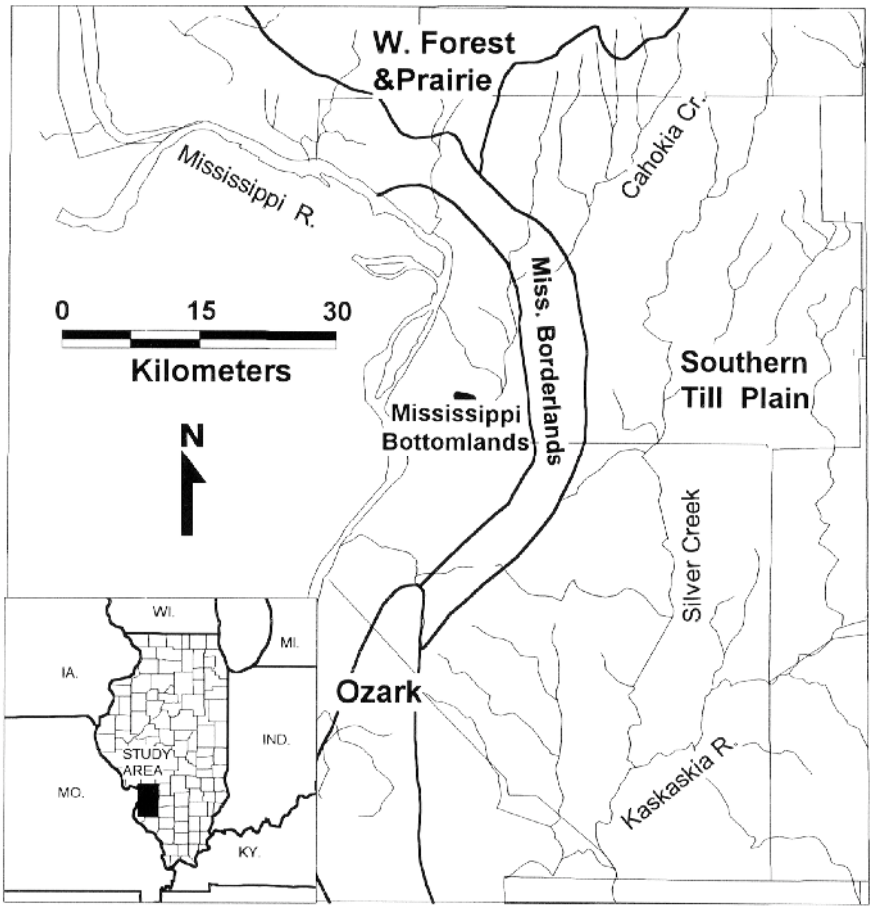

Figure 2. Location map of all quarter section corners with trees.

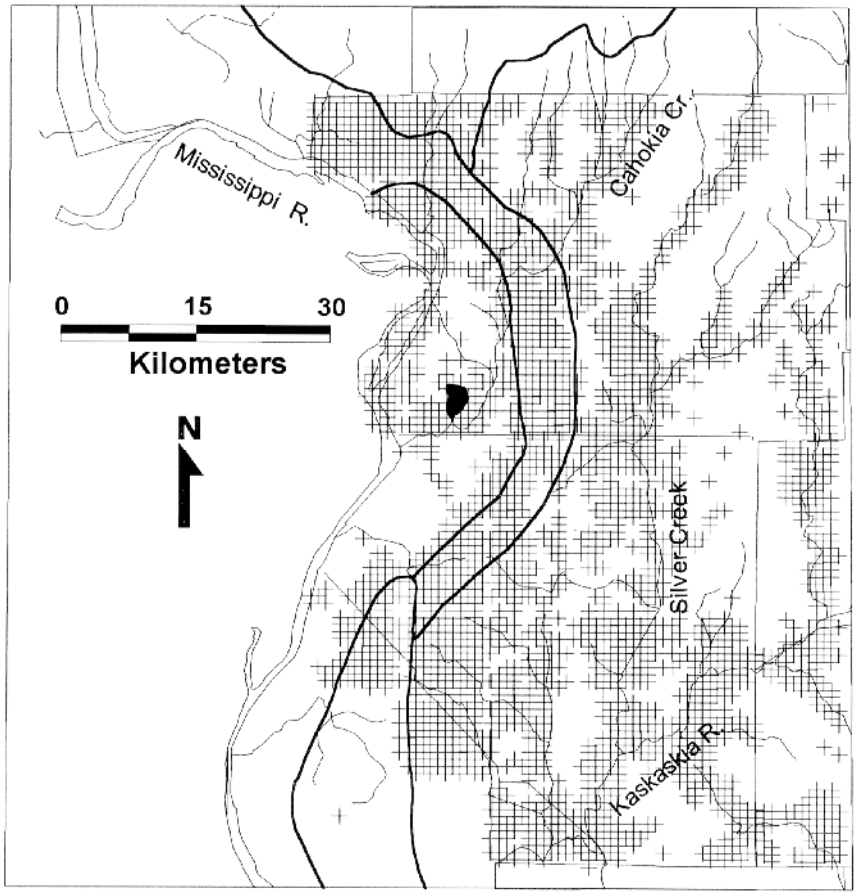

Figure 3. Location map of all , post oak (*Q. stellata*), overcup oak (*Q. lyrata*) and pin oak (*Quercus palustris*) trees in the study area. Ecotone between pin oak-post oak-overcup oak woodlands and white oak-red oak-black oak forest indicated by heavy line. Piasa soil association shown by shaded regions.

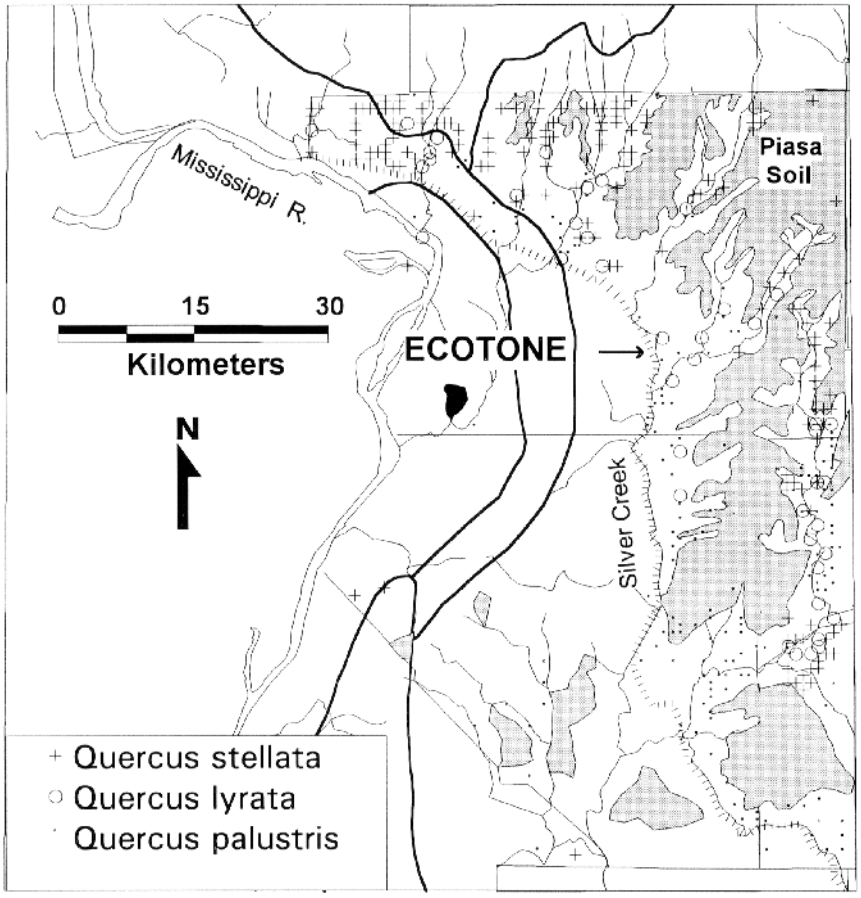

Figure 4. Location map of all black or red oak (*Q. rubra* /*Q. velutina*), and white oak (*Quercus alba*) trees in the study area.

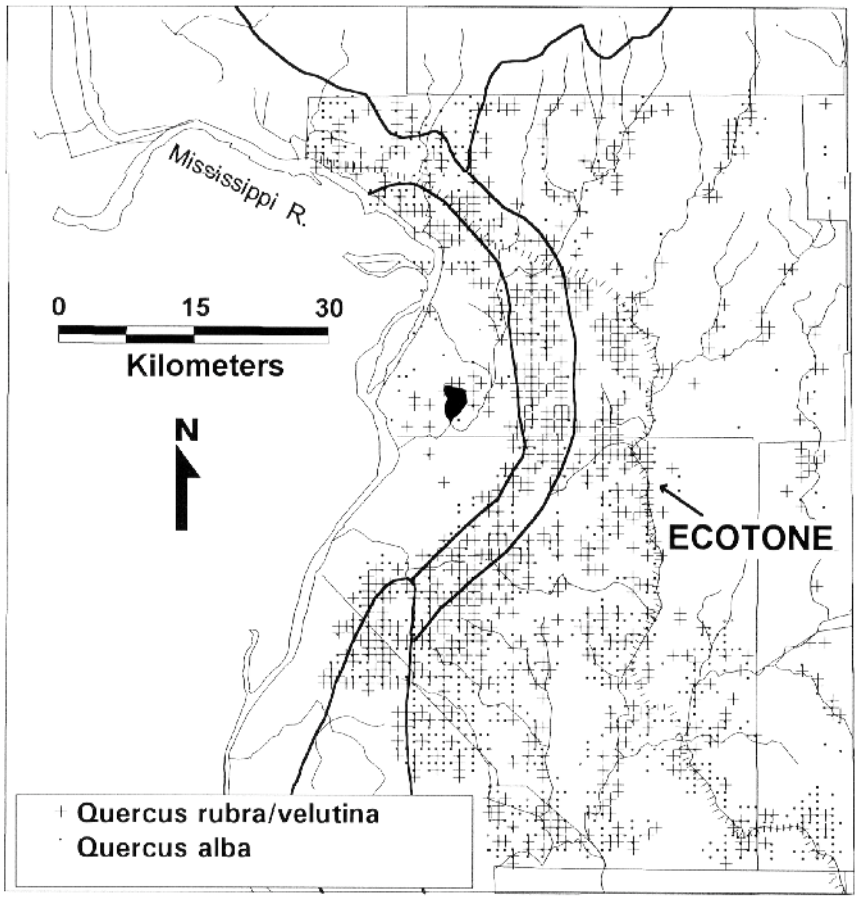

Figure 5. Location map of all black jack oak (*Quercus marilandica*) and hickory (*Carya* spp.) trees in the study area.

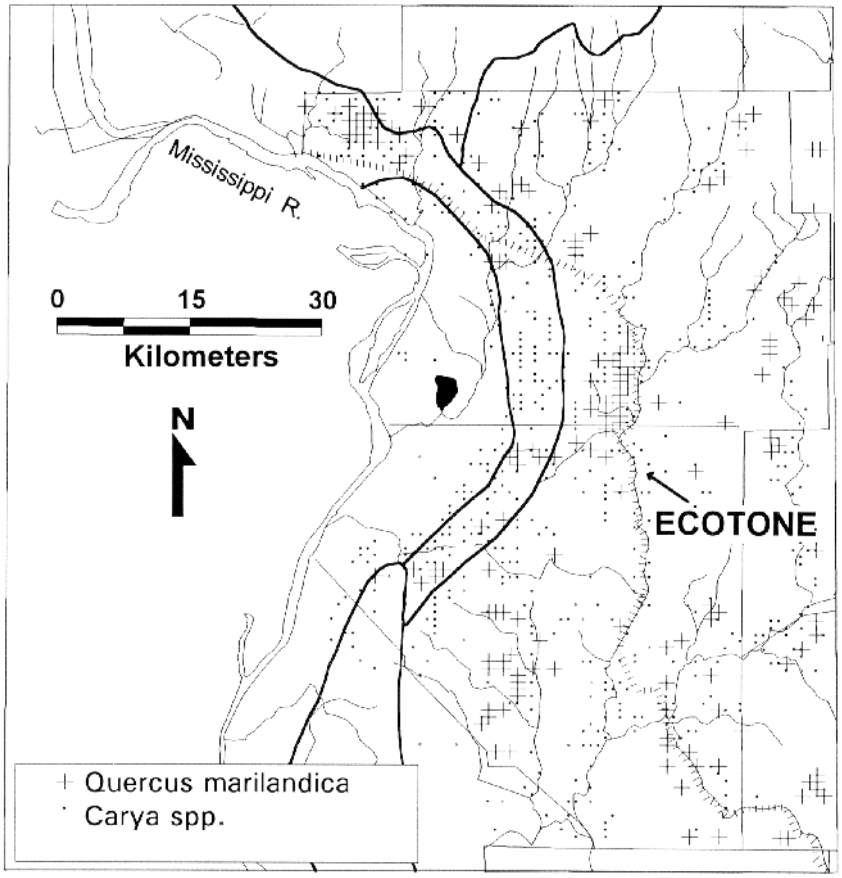

Figure 6. Location map of all sugar maple (*Acer saccharum*), cottonwood (*Populus deltoides*), willow (*Salix* spp.) and elm (*Ulmus* spp.) trees in the study area.

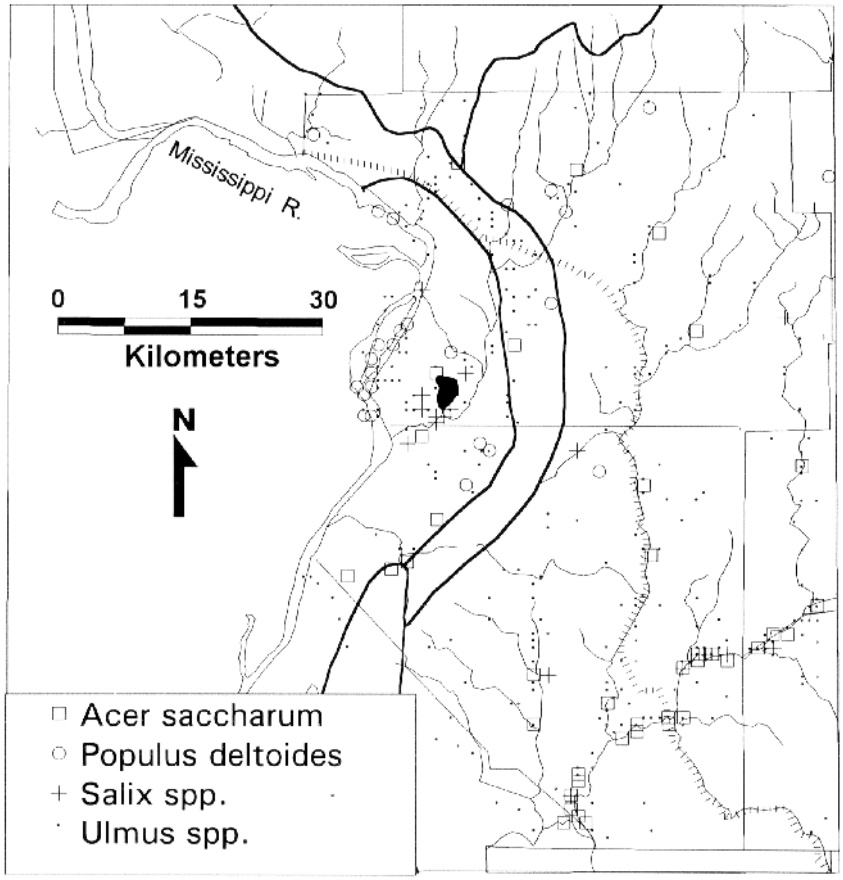

Figure 7. Location map of all sycamore (*Platanus occidentalis*), ash (*Fraxinus*), hackberry (*Celtis* spp.), and box elder (*Acer negundo*) trees in the study area.

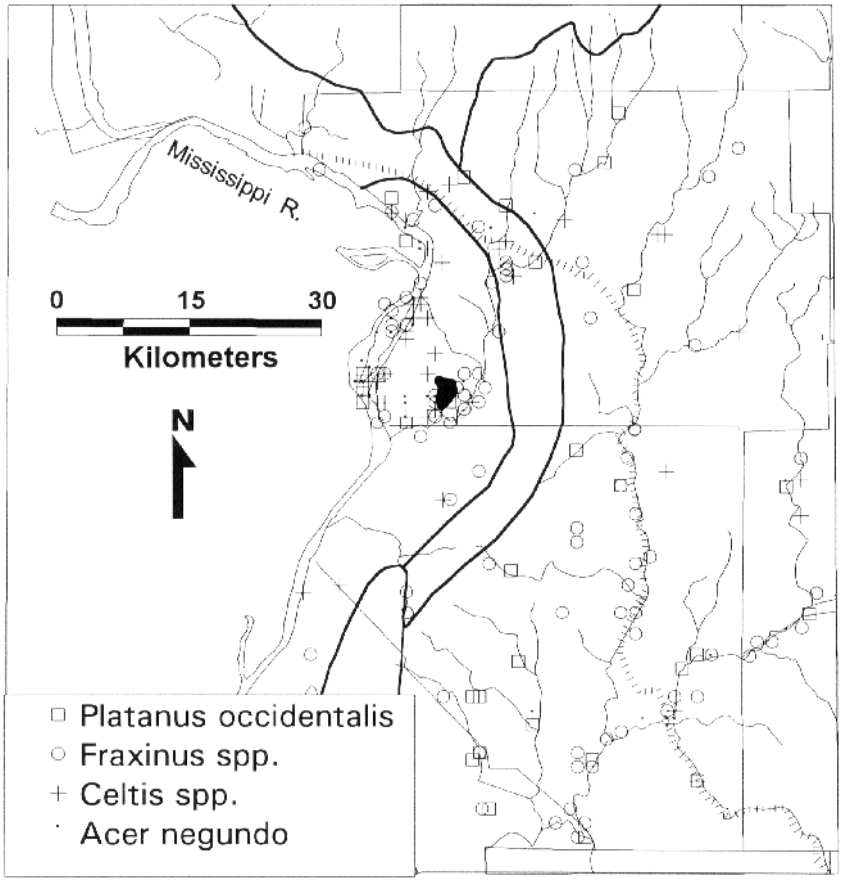

Figure 8. Percent abundances of trees in the physiographic regions.