Vegetation Patterns in Carter County, Oklahoma, 1871

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The cross timbers is a region of forest, woodland, and grassland vegetation occupying much of central Oklahoma. The dominant trees in the region are *Quercus stellata* and *Q. marilandica*. Although several contemporary studies of the cross timbers exist, historical data sources have not been used in the analysis of species composition and vegetation structure. This study employed Public Land Survey data from 1871 to analyze pre-settlement vegetation of the cross timbers of Carter County, Oklahoma. It was determined that historically forest vegetation predominated in the study area. Dominant tree species were *Q. stellata* and *Q. velutina*. Some of the structural indices were not congruent with contemporary studies of cross timbers vegetation.

INTRODUCTION

The cross timber region is a mosaic of forest (woody vegetation with interlocking crowns), woodland (woody vegetation lacking interlocking crowns), and grassland vegetation extending from southeastern Kansas through Oklahoma and into north central Texas (Dyksterhuis 1948, Hoagland et al 1999). Forest and woodland vegetation is characterized by the predominance of two species of woody plants: *Quercus stellata* and *Quercus marilandica*. Grasslands are dominated by species such as *Andropogon gerardii, Panicum virgatum, Schizachyrium scoparium, and Sorghastrum nutans* (Hoagland et al 1999). At an estimated 2.5 million hectares, the cross timbers are the most broadly distributed woody vegetation type in Oklahoma (Rice and Penfound 1959, Dwyer and Santlemann 1964).

Several authors have studied the composition and structure of woody vegetation in the cross timbers. *Quercus stellata* and *Q. marilandica* constitute up to 90% of the canopy cover and 50% of the basal area in cross timber stands (Rice and Penfound 1959, Kennedy 1973). The stem ratio of *Q. stellata to Q. marilandica* ranges from 2:1 to 3:1, depending on slope, aspect, and / or geographic location (Luckhardt and Barclay 1938, Kennedy 1973). Although stem density of *Q. marilandica* may surpass *Q. stellata* on south-facing slopes, *Q. marilandica* rarely exceeds 30 cm in diameter, so basal area values of the two species are roughly equivalent (Luckhardt and Barclay 1938, Rice and Penfound 1955, 1959).

There has been no quantitative analysis of historical vegetation patterns in the cross timbers. The only insight to be gained is from passing references in 19th century travel accounts. For example, Washington Irving (1956) wrote in 1832 "I shall not easily forget the mortal toil, and the vexations of flesh and spirit, that we underwent occasionally, in our wanderings through the Cross Timber. It was like struggling through forests of cast iron." This description implies densely forested stands. Randolph Marcy wrote: "At six different points where I have passed through it [the cross timbers], I have found it characterized by these peculiarities; the trees, consisting primarily of post-oak and black-jack, standing at such intervals that wagons can without difficulty pass between them in any direction" (Foreman 1947). Although these descriptions may seem contradictory, both are possible in a mosaic of forest, woodland, and grassland.

The objective of this study was to map the distribution of cross timbers and stand composition in 1871. Because woody vegetation has increased at the expense of grasslands due to fire suppression and land use practices (Archer 1995, Engle et al 1997), restoration ecologist and conservation biologists are interested the extent of forest and grassland vegetation in pre-settlement times. So what was the distribution of forest versus grassland in 1871? What was the species composition of cross timbers stands in 1871? And in particular, given their dramatic increase in abundance during the 20th century, what was the historical distribution of *Juniperus* spp.?

These questioned were addressed by using data gathered during the Public Land Surveys (PLS) of Oklahoma conducted in 1817. The PLS represents the only quantitative pre- and early settlement data source available for reconstructing vegetation patterns (Fagin and Hoagland 2003). Although the intent of the PLS was not to gather ecological data, these data have been useful for evaluating historical vegetation distribution and land-use (Bourdo 1956, Brothers 1991, Whitney and DeCant 2001). In addition, PLS data can serve as a reference for the comparison of change in vegetation over time and have been instrumental in aiding land managers and restoration ecologists (Galatowitsch 1990).

Study Area

Carter County is located in south-central Oklahoma (Fig. 1). Prior to statehood, the study area was part of Pickens County, Chickasaw Nation, Indian Territory (Morris et al 1986). Carter County is located in the Subtropical Humid (Cf) climate zone (Trewartha 1968). Summers are warm and

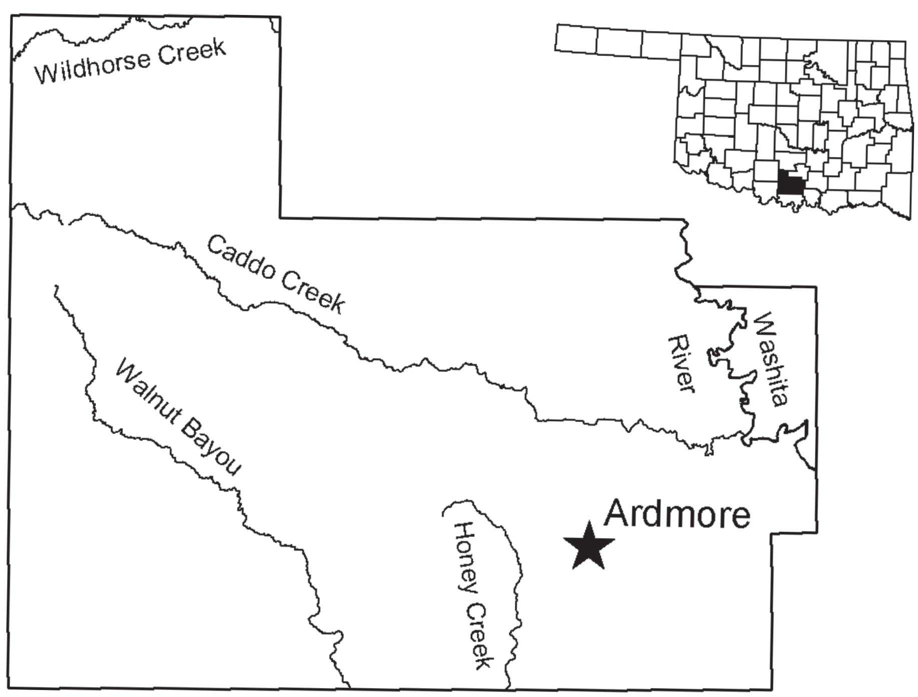

Figure 1.

humid, with an average annual temperature of 28˚C. Winters are relatively short and mild with an average temperature of 3˚C. Mean annual precipitation is 91 cm (Oklahoma Climatological Survey 2004). The county lies within the Arbuckle Mountains and Redbed Plains Physiographic Provinces. The Arbuckle Mountains are steep-sided limestone and conglomerate hills formed during the Ouachita Orogeny of the Pennsylvanian era (Curtis and Ham 1979). The Red Bed Plains cover the majority of Carter County and are underlain by Permian shales and sandstones that form gently rolling hills and broad, flat plains. The surface geology is composed of shales and conglomerates of the Van Noss group.

Quercus stellata–Q. marilandica forest and woodlands form the predominant woody vegetation type (Rice and Penfound 1959). Secondary woody plant species in the cross timbers include *Carya texana*, *Juniperus virginiana*, *Q. velutina*, and *Ulmus alata*. Woody understory species include *Sideroxylon lanuginose*, *C. canadensis*, *Cornus drummondii*, *Prunus mexicana*, *Symphoricarpos orbiculatus*, *Rhus copallina*, and *R. glabra* (Hoagland et al 1999, Hoagland 2000).

MATERIALS AND METHODS

The PLS was established to aid the United States government in the orderly disposition of publically held lands (Stewart 1935). Ehud Darling initiated the PLS in Oklahoma in 1871 (Hoagland, forthcoming). Surveyors were instructed to partition the land into 36-mi^2 (93.20 km^2) townships, which were further subdivided into 1-mi^2 (2.59 km^2) sections (Stewart 1935). There are two types of data available in the PLS records that are useful for analysis of historic vegetation. First are the plats that were mapped following the survey of a township. In the field, surveyors recorded the occurrence of various land cover types, such as forest, grassland, or agricultural fields. Surveyors also documented the general character of the soil, location of prominent physical features, natural disturbances, such as windfalls, fire, and erosion (Hutchison 1988) as well as the location of human settlements, sawmills, coal mines, quarries, lime kilns, roads, and cattle trails. These data were mapped on the township plat.

The second dataset consists of quantitative data gathered for tree species encountered during the survey. At the point where section lines intersected, surveyors identified the nearest tree in each section and recorded its identity, distance, direction, and diameter. At each quarter section point, surveyors gathered the same data, but only for the two nearest trees (Stewart 1935, Hutchison 1988).

Data analysis

Analyses were conducted to ascertain the spatial distribution of land cover types and to calculate indices of vegetation composition. To analyze distribution of land cover types, the 26 township plats constituting Carter County were digitized by using ArcInfo GIS. Plats were obtained from the archives branch of the Oklahoma Department of Libraries in Oklahoma City. All information digitized from a plat was attributed to one of the following data layers: vegetation (forest, grassland, and wetland), hydrology (streams, rivers, springs, and ponds), agriculture (cultivated fields), transportation (roads, trails, and railroads), and settlement (residences, schools, and other cultural features). Once a township had been digitized, each data layer was edited, attributed, and joined with adjacent plats.

FRAGSTATS (McGarigal and Marks 1994), a landscape ecology software package, was used to determine landscape composition, defined here as the number of occurrences and area occupied by each land cover type. FRAGSTATS indices used in this study were class area, number of patches, and mean patch size. Class area is a measure of the total area occupied by a particular land cover type. Number of patches is a measure of individual occurrences of a given land cover type. Mean patch size averages the area occupied by each land cover (McGarigal and Marks 1994).

Vegetation data were analyzed by using the tree species, diameter, and distance data extracted from surveyors notes for all 26 townships. When analyzing bearing tree data, the matter scale must be considered. Bearing tree data were collected at intervals of 0.5 mi (0.8 km) making these data suitable for broadscale analysis, not fine scale or site level analysis (Delcourt and Delcourt 1974, Schulte and Mladenoff 2001). Therefore, indices of vegetation composition were calculated at the township scale. In doing so, it is understood that finer scale vegetation patterns as related to environmental gradients might be masked, but the objective of this study was to analyze broad scale variation in vegetation composition.

Table 1. Metrics for land cover types.

	Area (km^2)	Mean Area (km^2)	Number of Patches
Forest	172,436	2,873	60
Grassland	42,677	224	190
Wetlands	664	12	55
Cultivation	97	4	23
Other	23	23	1

Bearing tree data were used to determine stand composition and dominance, stem density, and basal area. Once bearing tree data were extracted from surveyors records, density, frequency, and basal area for each species in a township was calculated. Stem density was calculated following Cottam and Curtis (1956); basal area was calculated according to Wenger (1984). Frequency was the number of times a species was recorded in a township by a surveyor. The relative values of these three metrics were then summed into an importance value.

RESULTS

Forest and woodland vegetation was predominant in Carter County in 1871 (Table 1), occupying 79.9% of the study area (Fig.

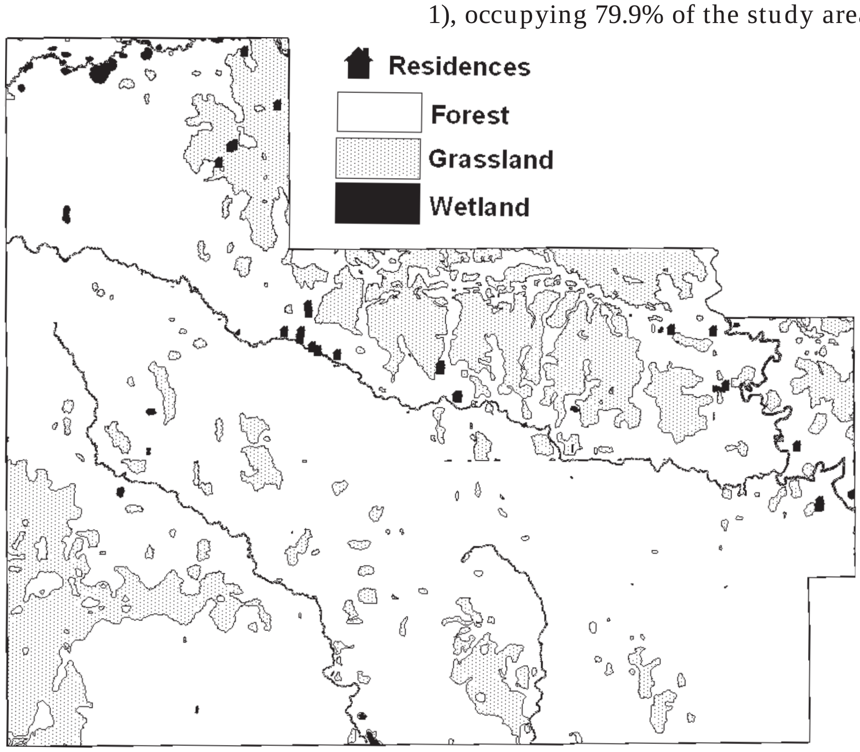

Figure 2.

2). The number of patches and mean patch size of wetlands and cultivated land were substantially lower then the forest and grasslands. Although there were fewer forest patches than grassland patches, mean forest patch area was greater (Table 1). Forest patches ranged in size from 0.54 to 170,690 ha, and grassland patches ranged from 0.04 ha to 10,658 ha in area. Wetlands were a minor component of the landscape in 1871 and were most abundant along Wildhorse Creek in the northwest corner of the study area. Wetland patch area ranged from 0.05 to 172 ha ($\bar{x}$ = 12 ha).

Table 2. Importance values for tree species calculated from township data recorded by surveyors of the Public Land Survey in 1971. Scientific binomials were determined from common names provided by surveyors.

Attributed Latin binomial	Surveyors identification	Frequency	Mean IV*
Acer negundo	Box Elder	4	0.47
Carya illinoensis	Pecan	19	4.10
Carya spp.	Hickory	17	3.39
C. texana	Black Hickory	4	0.33
Celtis spp.	Hackberry	16	1.90
Cercis canadensis	Red Bud	1	0.02
Crataegus berberifolia	Red Haw	1	0.02
Crataegus spp.	Hawthorn	1	0.03
Frazinus spp.	Ash	14	1.86
Gleditsia triacanthos	Honey Locust	1	0.07
Gymnocladus diocia	Coffee bean	2	0.04
Juglans nigra	Black Walnut	9	7.8
J. spp.	Walnut	12	1.30
Juniperus spp.	Cedar	1	0.25
Morus spp.	Mulberry	4	0.11
Platanus occidentalis	Sycamore	4	0.43
Populus deltoides	Cottonwood	19	7.19
P. spp.	Poplar	1	0.02
Prunus spp.	Plum	21	0.02
Quercus alba	White Oak	21	47.46
Q. macrocarpa	Bur Oak	20	18.46
Q. marilandica	Blackjack	4	0.48
Q. palustris	Pin Oak	9	1.04
Q. rubra	Red Oak	15	4.65
Q. spp.	Oak	2	0.18
Q. spp.	Scrub Oak	1	0.15
Q. spp.	Sweet Oak	1	0.08
Q. stellata	Post Oak	26	129.26
Q. velutina	Black Oak	26	65.86
Salix spp.	Willow	7	0.33
Sideroxylon lanuginosum	Shittum	2	0.16
Ulmus spp.	White Elm	4	0.06

*IV = importance value

Human impact, defined as cultural features and landscape modifications, was limited. There was a total of 23 cultivated patches covering a 97 ha at a mean patch size of 4.2 ha. In addition, only 28 residences were mapped in 1871. There were 234 km of roads and 15 km of railroad.

The PLS reported 34 taxa of woody plants (Table 2). However, some species reported by the surveyors do not presently occur in the Arbuckle Mountains. For example, *Q. palustris, Q. alba, and Q. rubra* are common in eastern Oklahoma, but have not been reported from Carter County or the Arbuckle Mountain region. It is possible, though, that red and pin oak refer to *Q. shumardii* or *Q. buckleyi* and white oak may refer to *Q. muehlenbergii*. A Latin binomial for sweet oak could not be ascertained.

Surveyors sampled a total of 6,886 stems in 1871. Of those, the most commonly sampled were *Q. stellata* (2,648 stems) and *Q. velutina* (1,740 stems). Only 18 stems of *Q. marilandica* the co-dominant species in crosstimbers stands, were reported. Basal area values ranged from 5.4 to 39.8 m^2/ha for townships, with a countywide average of 19.6 m^2/ha. Mean basal area values were highest for *Q. stellata* (7.8 m^2/ha) and *Q. velutina* (5.0 m^2/ha). Again, *Q. marilandica* scored low for mean basal (0.24 m^2/ha) and was recorded in only four townships. Stem densities ranged from 66 stems/ha to 565.3 stems/ha, with a mean value of 124.4 stems/ha (Table 2). The highest stem density values were scored in three townships of eastern Carter County.

Importance values were highest for members of the genus *Quercus* (Table 2). The highest importance value was scored by *Q. stellata* (129.26), followed distantly by *Q. velutina* (65.86) and *Q. alba* (47.46). *Quercus stellata, Q. velutina,* and *Ulmus* spp., were found in every township. Despite the frequent occurrence of *Ulmus* spp., the average importance value was low.

DISCUSSION

The number of woody taxa reported by the PLS was lower than that of floristic studies from the region. For example, Dale (1956) reported a total of 90 taxa of trees and shrubs in the Arbuckle Mountain, which includes the northern portion of Carter County. Hoagland and Johnson (2001) reported 72 species of woody plants from the Chickasaw National Recreation Area, a National Park Service facility in adjacent Murray County. However, an accurate count of woody plants encountered by the surveyors is not possible because many taxa were identified only to the genus level. For example, the surveyors frequently recorded the presence of elm. However, four species of *Ulmus* (*U. alata, U. americana, U. crassifolia,* and *U. rubra)* occur in the study area and occupy both upland and bottomland habitats.

As noted earlier, cross timbers stands are characterized by the dominance of *Q. stellata* and *Q. marilandica* (Hoagland et al 1999). In this study, the highest importance values were scored by *Q. stellata* followed by *Q. velutina* and *Q. alba*. *Quercus marilandica* was reported only from four townships, and its importance value was significantly lower than for *Q. stellata.* This pattern of dominance is not consistent with values reported in previous studies of the cross timbers (Rice and Penfound 1955, 1959). Misidentification of common species could affect dominance values. Although it is possible to confuse *Q. stellata* for *Q. alba* and, to a lesser degree, *Q. marilandica* for *Q. velutina.* This does not appear to be the case in this study, however, because surveyors reported these congeners as occurring together in several townships.

Carya texana, a secondary species in cross timbers forests (Hoagland et al 1999), had an importance value less than 1.0 and was only reported from five townships. Interestingly, though, Rice and Penfound (1959) did not report an average basal area value for *C. texana* in Carter County. Because the majority of surveyor entries for *Carya* spp. are at the genus level only, this may not accurately reflect the contribution of *C. texana* in study area. Two species of hickory occur in Carter County: *C. texana* and *C. cordiformis*.

Rice and Penfound (1959) reported the average basal area for all species sampled in Carter County as 12.2 m^2/ha. Based on the PLS data, basal area in Carter County averaged 19.6 m^2/ha and mean basal area values were highest for *Q. stellata* (7.8 m^2/ha) and *Q. velutina* (5.0 m^2/ha). *Quercus marilandica* basal area ranged from 0.08 m^2/ha to 0.47 m^2/ha, averaging 0.24 m^2/ha. Rice and Penfound (1955) reported a basal area value for *Q. stellata* of 8.6 m^2/ha and for *Q. marilandica* 2.6 m^2/ha. Interestingly, they did not report the basal area of *Q. velutina*. However, at a cross timbers site in Cleveland County, the basal area of *Q. marilandica* was 5.3 m^2/hectare, *Q. stellata* was 5.0 m^2/ha, *Carya* spp. was 1.3 m^2/ha, and *Q. velutina* was 0.32 m^2/ha (Rice and Penfound 1959).

There is also a discrepancy between the PLS data and more recent studies reporting *Q. stellata* to *Q. marilandica* stem ratios. The ratios calculated from PLS data do not correspond to 2:1 or 3:1 ratios reported by Luckhardt and Barclay (1938). Based on the data collected by the PLS surveyors, the ratio of *Q. stellata* to *Q. marilandica* is on the order of 147:1. The reason for this discrepancy is unclear, but could be a result of differences in sampling methods.

In the PLS data, four individuals of *Juniperus*, all from one township (T3SR2E) within the Arbuckle Mountain province were reported. Two *Juniperus* species occur in the region: *Juniperus asheii* and *J. virginiana* (Little 1996). Both species are aggressive grassland invaders (Rice and Penfound 1959, Johnson and Risser 1975). Because the surface geology of Arbuckle Mountains is composed of limestone, it is reasonable to conclude that these four individuals were *J. asheii*, a calciophile.

There has been a dramatic increase in abundance of *Juniperus* spp. in the study area since 1871. At present, *J. asheii* and/or *J. virginiana* occupied 25,642 ha in Carter County (Engle et al 1997). Historically, *Juniperus* spp. may have persisted in the Arbuckle Mountains, where rugged topography could impede the movement of fire, thus providing refuge.

Analysis of the land cover map for Carter County indicates little human impact in 1871. However, it is important to note that, following removal from eastern United State to Indian Territory in the 1830s, members of the Chickasaw tribe assembled in small communities within the study area. Individual Chickasaws were permitted to cultivate or graze as much land as they wished, although the Chickasaw small farmer was mostly a subsistence farmer (Graebner 1943). By the 1850s fields ranged from three to ten acres which would occasionally provide surplus food to sell (Hale et al 1991).

Analysis of PLS data from the cross timbers of Carter County provided several important insights. The spatial distribution of land cover types, as mapped on the plats, clearly indicates a predominance of forest/woodland vegetation. Also, the PLS indicate an extremely low abundance of *Juniperus* spp. However, what appears to be misidentification of several tree species limites the utility of these data in the analysis of species composition.

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