

THE CHANGING FORESTS OF CENTRAL OKLAHOMA: A LOOK AT THE COMPOSITION OF THE CROSS TIMBERS PRIOR TO EURO-AMERICAN SETTLEMENT, IN THE 1950S, AND TODAY

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ABSTRACT

Prior to Euro-American settlement, the Cross Timbers of the Southern Plains marked the edge of “civilization,” beyond which lay a prairie ecosystem ruled primarily by Plains Indian tribes. War, trade, and pasture for cattle brought an increased Euro-American presence by the middle of the 19th century. In the early 1870s a large portion of what was to become the state of Oklahoma was surveyed by the General Land Office (GLO). Although these surveys were not conducted for ecological purposes, they have provided information on pre-settlement vegetation that has been invaluable for researchers seeking to reconstruct the historical landscape. Perhaps the most beneficial information for historical ecologists and biogeographers comes from data on bearing trees recorded by GLO surveyors, which have given present-day researchers a good idea of the species composition of Cross Timbers forests during this time. When compared to modern studies of the Cross Timbers, it documents a change in species composition over time, believed to be the result of fire suppression and perhaps the beginning of a wetter climate cycle. In central Oklahoma, this has meant a shift from forests dominated by *Quercus marilandica* and *Quercus stellata* (with the former being more abundant) to forests containing an equal abundance of these two species, and an increase in *Carya texana*, *Juniperus virginiana*, and other mesophytic and invasive woody species.

INTRODUCTION

Cross Timbers Overview

The Cross Timbers are a mosaic of riparian forest, woodland, and grassland that extends from southeastern Kansas, through Oklahoma, and into north-central Texas (Dyksterhuis 1948 and 1957, Rice and Penfound 1959, Omernik 1987, Hoagland et al. 1999, Francaviglia 2000; Figure 1). The Cross Timbers encompass an estimated 4.8 million ha in this region (Kuchler 1964). Slightly more than half of the total area (2.5 million ha) is located in Oklahoma, where it comprises a larger area than all other forest types in Oklahoma combined (Duck and

Fletcher 1945; Rice and Penfound 1959; Dwyer and Santelman 1964). As a result, the Cross Timbers are the most studied forest type in Oklahoma.

These studies note the importance of *Quercus stellata* (post oak) and *Q. marilandica* (blackjack oak) in Cross Timbers stands. Combined, these two species constitute over 90% of the canopy cover and 50% of the basal area (Rice and Penfound 1959, Kennedy 1973). *Q. marilandica* is the more xeric and fire-tolerant of the two species (Brown and Davis 1973; Givnish 1981; Dooley 1983; Dooley and Collins 1984). Stem density (number of

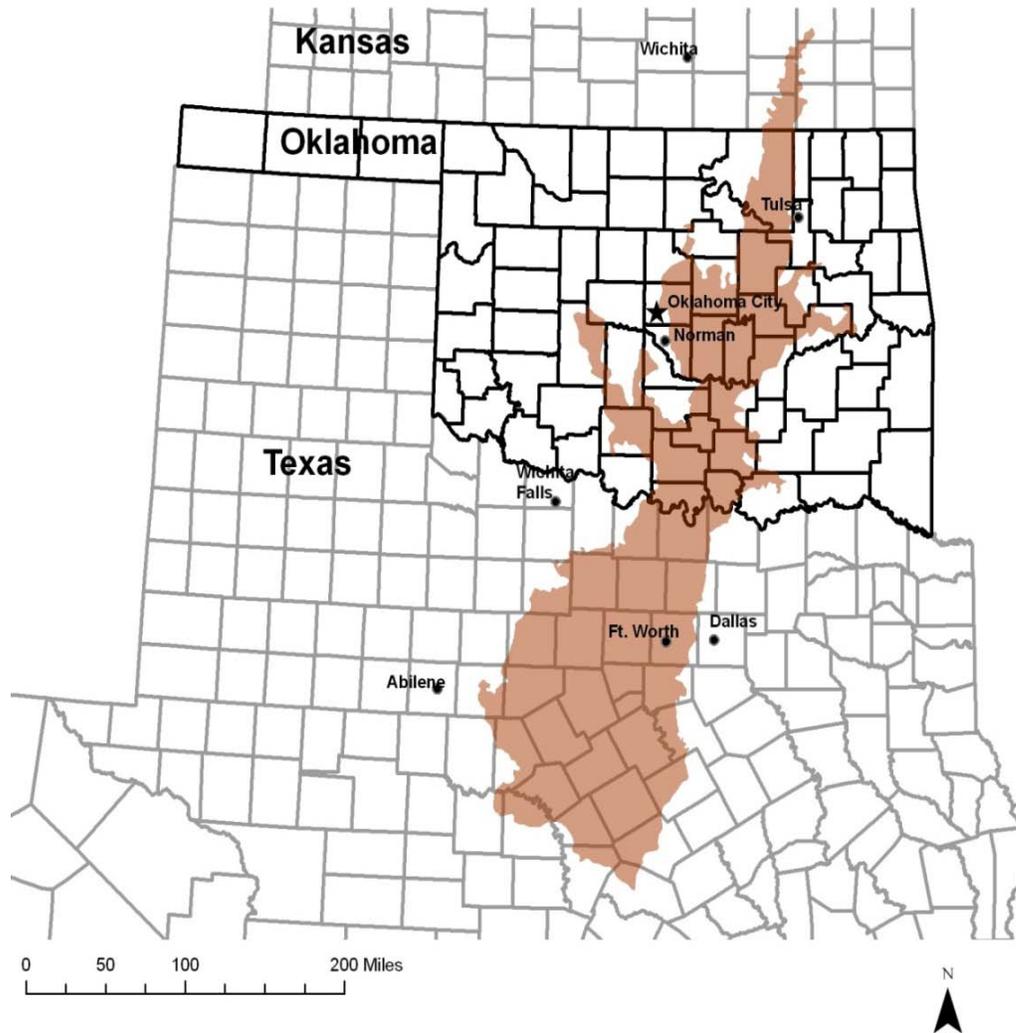


Figure 1 The present-day Cross Timbers (from Omernik, 1987).

stems per unit area) is correlated with slope, aspect, and/or geographic location, but the ratio of *Q. stellata* to *Q. marilandica* has generally ranged from 2:1 to 3:1, (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 and, therefore, basal area values of the two species are roughly equivalent in these instances (Luckhardt and Barclay 1938, Rice and Penfound 1955, 1959).

Woody species of secondary importance include *Carya texana* (black hickory), *Quercus*

velutina (black oak), and *Juniperus virginiana* (eastern redcedar) (Coppock et al. 1955, Hale 1955, Rice and Penfound 1955 and 1959, Penfound 1963, Johnson and Risser 1972, Hoagland et al. 1999). The herbaceous understory of the Cross Timbers, which becomes more prevalent in the woodland aspect, is similar to the surrounding prairie (Dyksterhuis, Kuchler 1964 and 1974). *Schizachyrium scoparium* (little bluestem) dominates most Cross Timbers stands, but *Andropogon gerardii* (big bluestem) and *Sorghastrum nutans* (Indiangrass) may be co-dominant (Kuchler 1964).

The Changing Cross Timbers

Three major factors influencing the Cross Timbers region today are urban fringe development, woody plant encroachment, and the “mesophication” of *Quercus*-dominated portions of the Cross Timbers (Coppedge 2001a; Dillard et al. 2006, DeSantis et al. 2010). Urban fringe development (UFD) is currently more geographically ubiquitous in the mainland United States than any other human activity that negatively impacts ecosystems (Czech et al 2000). UFD produces some of the highest local extinction rates and often eliminates most of the native species (Vale and Vale 1976, Luniak 1994, Kowarik 1995, Marzluff 2001, McKinney 2002). Biological communities around these areas are increasingly homogenized (McKinney 2004), producing a “distinct and rapid trajectory of vegetation change towards historically unprecedented and simplified conditions” in some regions (Schulte et al. 2007).

In their study of landscape structure and change within a forest-prairie ecotone, Boren et al. (1997) indicated that increased human activity in densely populated rural areas surrounding urban centers in northern Oklahoma lowered biodiversity, increased homogeneity, and resulted in greater patch fragmentation than a rural landscape with a low-density population. Fragmentation was higher in forested areas than in grasslands in each year of their twenty-four year study, in both low- and high-density areas.

In Oklahoma, the main culprit in woody plant expansion is *Juniperus virginiana* (eastern redcedar), a native species that has advanced beyond its pre-settlement range and density in the Great Plains and portions of the Cross Timbers (Engle et al. 1997, Coppedge et al. 2001b, Briggs et al. 2002, Horncastle et al. 2005). Encroachment at a rate of 300,000 acres per year in Oklahoma (Drake and Todd 2001) by *J. virginiana* has many negative consequences, including displacement of native plant species (Engle

et al. 1997, Cooper 1998, Coppedge et al. 2002), wildlife species (Engle et al. 1997, Smith 2001, Guthery 2001, Coppedge et al. 2002), a decrease in livestock forage production (Stritzke and Bidwell 1989, Engle and Stritzke 1992, Engle et al. 1997), and a deterioration of water quality (Thurov and Carlson 1994, Cooper 1998).

In a recent study, DeSantis et al. (2010) make the contention that drought and fire suppression are changing the woody species composition of relatively undisturbed portions of the Cross Timbers in Oklahoma. They indicate that woodland portions of the Cross Timbers “appear to be in transition to closed-canopy mesophytic forest stands with less *Quercus* and more shade-tolerant tree species.” In their study, they draw heavily on the work of Nowacki and Abrams (2008), who coined the term “mesophication,” which they define as a process “whereby microenvironmental conditions (cool, damp, and shaded conditions; less flammable fuel beds) continually improve for shade-tolerant mesophytic species and deteriorate for shade-intolerant, fire-adapted species.” According to the authors, this process is widespread in the forests of North America as a result of fire suppression.

This study sought to characterize Cross Timbers forest and woodland in an urban area in central Oklahoma, focusing specifically on Cross Timbers vegetation that had undergone little visible disturbance (i.e. few invasive species present, trees of varying ages). The area chosen for this was the southeast sector of Oklahoma City, the least developed portion of the city. As a baseline for comparison, General Land Office (GLO) Public Land Survey (PLS) bearing tree data from the 1870 to 1873 survey were analyzed. This analysis relied on results produced in Thomas (2010), which contradict previous analyses of the Cross Timbers in Oklahoma (Shutler and Hoagland 2004, Fagin 2009), but are in line

with primary historical sources along with past and present research on the woody plant composition of the Oklahoma Cross Timbers.

STUDY AREA

The southeast sector of Oklahoma City is almost equally divided between Oklahoma and Cleveland counties in central Oklahoma, with a portion falling in Pottawatomie County (Figure 2). Average temperature is around 15° C, ranging from

an average January low of -3° C to an average July high of 34° C. Average annual precipitation ranges between 91 and 99 cm, and winds from the south and southeast predominate (OCS 2009).

Cross Timbers forest and woodland in the study area is found on the Darnell-Stephenville soil series, which is made up of moderately deep, well-drained, moderately permeable upland soils with slight to moderate slopes (Fisher and Chelf 1969).

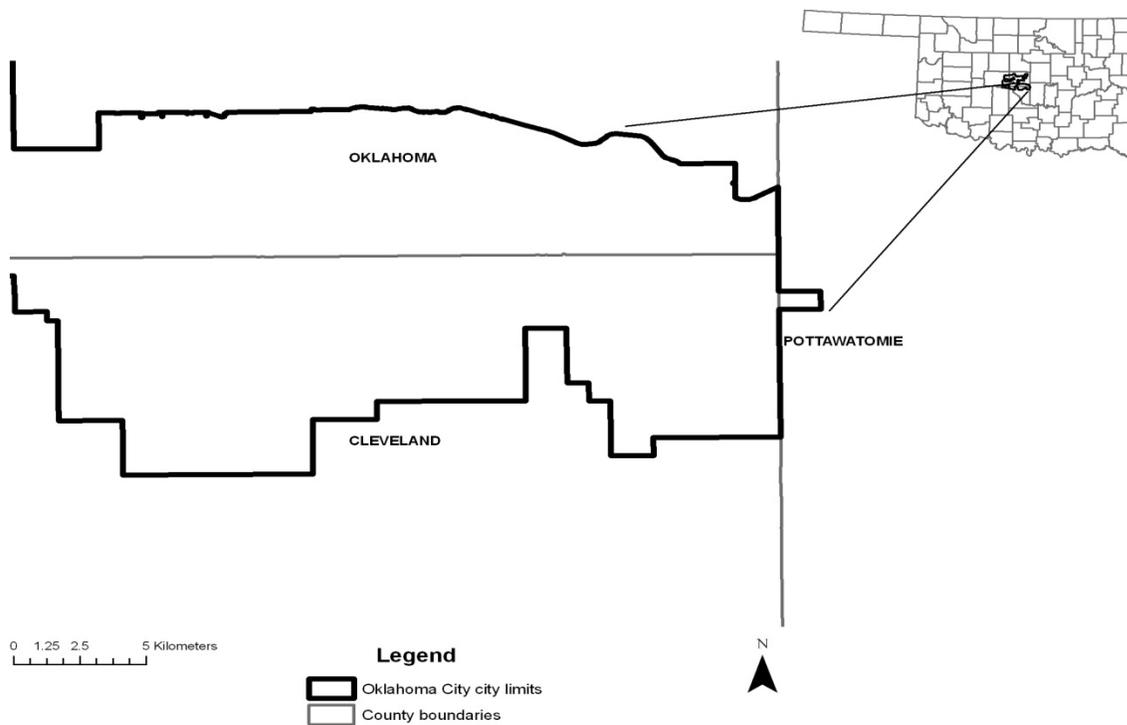


Figure 2 Study area – southeastern Oklahoma City.

METHODS

The Public Land Surveys

The PLS, conducted in the United States beginning with the Land Ordinance of 1785, subdivided land into square townships six miles on a side, which were further subdivided into thirty-six sections of

one square mile (Stewart 1935). Surveyors would travel along the section lines, erecting monuments at the intersections of section lines and making notes about the landscape, soil, and vegetation in order to draw an accurate plat of the township following the survey (Bourdo 1956). Surveyors were also instructed to list tree species encountered in

order of predominance at the end of each section line, known as “ranked timber observations” (Bourdo 1956, Grimm 1981).

In order to facilitate the relocation of a section corner, at the intersection of section lines the surveyors would record the distance, direction, species, and diameter of four near and “durable” trees. One tree was recorded in each quadrant formed by the intersection of the section lines (Grimm 1981). These were known as bearing trees

and were inscribed by the surveyors. Two trees were also marked as bearing trees at the half-mile interval between the intersections of section lines (Bourdo 1956, Fagin and Hoagland 2002, Figure 3).

Since the 1873 bearing tree data was not taken in individual plots, relative frequency (RF) was not calculated, and relative basal area (RBA) and relative density (RD) were combined to provide an importance value (IV).

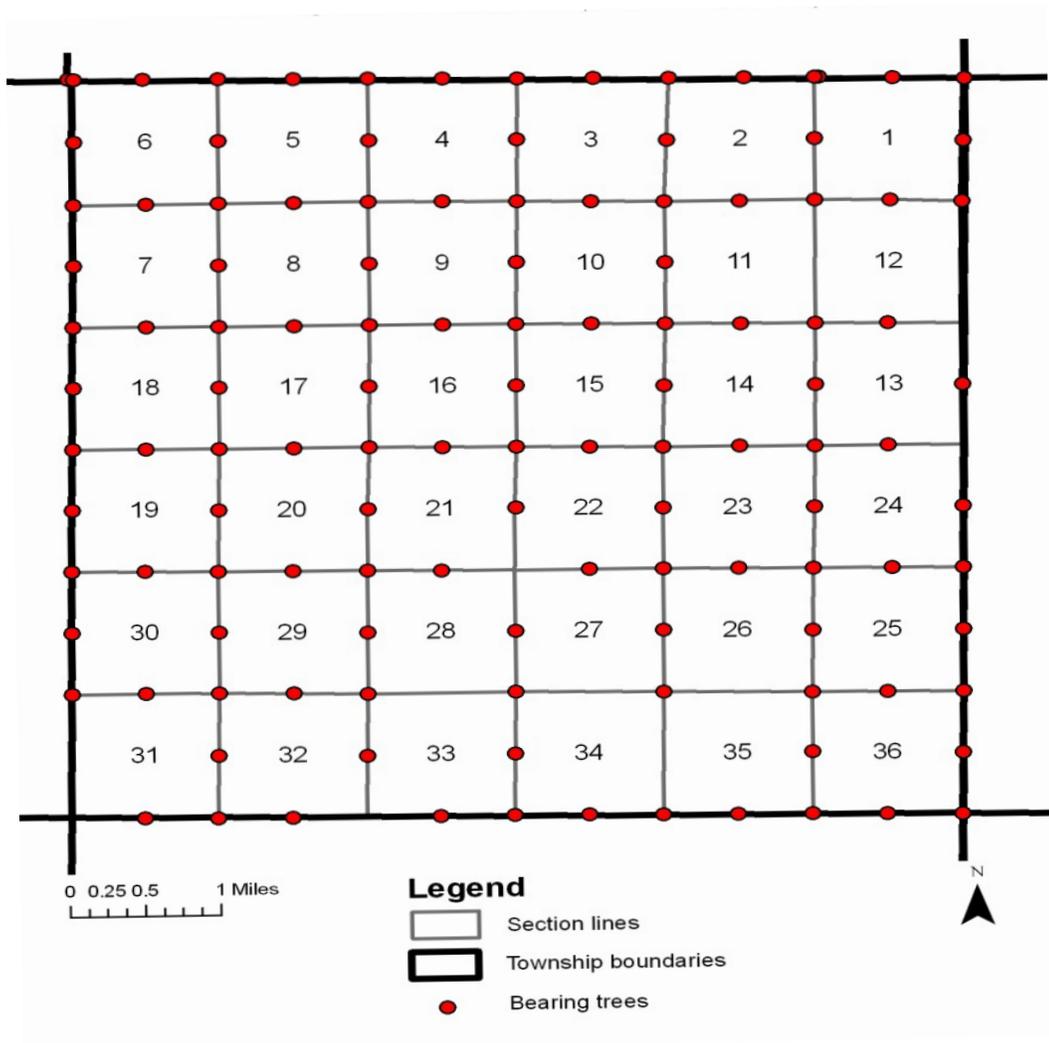


Figure 3 Bearing trees noted at the intersection of section lines and at halfway points along the section lines.

Contemporary vegetation

The first stage of analysis was the interpretation and delineation of forest vegetation in the study area using four Digital Orthoquarter Quads (DOQQs) from June 2006. Each DOQQ was imported into Arcmap GIS and joined into a complete coverage. The resulting layer was reviewed and forest vegetation delineated, resulting in a map of either “potential” or “probable” undisturbed Cross Timbers.

Ground-verification of the preliminary map began in the winter of 2007 and consisted of two phases. First, sites were visited to determine the accuracy of the initial disturbance designations of potential or probable. Sites that were verified as or upgraded to probable were then considered for the collection of quantitative vegetation data pending contact with and approval of the landowner. Following the verification of the accuracy of these designations, field studies commenced in order to characterize the structure and species composition of forest/woodland vegetation at these sites, using twenty-by-twenty meter plots. Where possible, multiple plots were established at a site. However, collection of quantitative data even at “probable” sites was somewhat limited by low quality of vegetation and access restrictions. Each tree and shrub was identified to species (nomenclature follows the US Department of Agriculture-Natural Resources Conservation Service [USDA-NRCS 2006]) and stems exceeding 7.5 cm diameter-at-breast-height (DBH) were measured within plots, so that this data could be compared to the PLS bearing tree data, as few trees below this size were marked by GLO surveyors. Basal area (BA) was calculated for each species in each plot using the formula $\text{Area}=\pi r^2$. Relative Basal Area (RBA) was calculated as:

$$\left(\frac{\sum \text{BA}_{\text{species 1}}}{\sum \text{BA}_{\text{all species}}}\right) \times 100 = \text{RBA}$$

Density (D) was defined as the number of stems for each species occurring in a plot. Relative density (RD) was calculated as:

$$\left(\frac{\sum D_{\text{species 1}}}{\sum D_{\text{all species}}}\right) \times 100 = \text{RD}$$

Frequency was defined as the number plots in which a species occurred. Relative Frequency (RF) as calculated as:

$$\left(\frac{\sum \text{FREQ}_{\text{species 1}}}{\sum \text{FREQ}_{\text{all species}}}\right) \times 100 = \text{RF}$$

An importance value (IV) was calculated for each species in order to determine which trees were stand dominants:

$$\text{IV} = \text{RBA} + \text{RD} + \text{RF}$$

RESULTS

Public Land Survey

A total of 608 trees were recorded by PLS surveyors within the study area. Ten different species were recorded. Of these, 397 individuals were *Q. marilandica* and 182 were *Q. stellata*. Fourteen stems of *Ulmus sp.* were recorded, but no other species was recorded more than three times. *Q. marilandica* had a total basal area of 9.76 m², *Q. stellata* 16.37 m². No other species had a total basal area over 1 m². The highest importance values for 1873 bearing tree data were scored by *Q. marilandica* at 100.89 and *Q. stellata* at 89.65 (Table 1). The importance values of other species marked as bearing trees were very low. *Ulmus sp.* had an importance value of 3.29, *Carya texana* 2.87 and *Populus deltoides* 1.20. Public land surveyors also reported finding *Fraxinus nigra* (black ash), a species native to northeastern North America and not found in Oklahoma. It is likely that different common names applied to species at the time resulted in this anomaly.

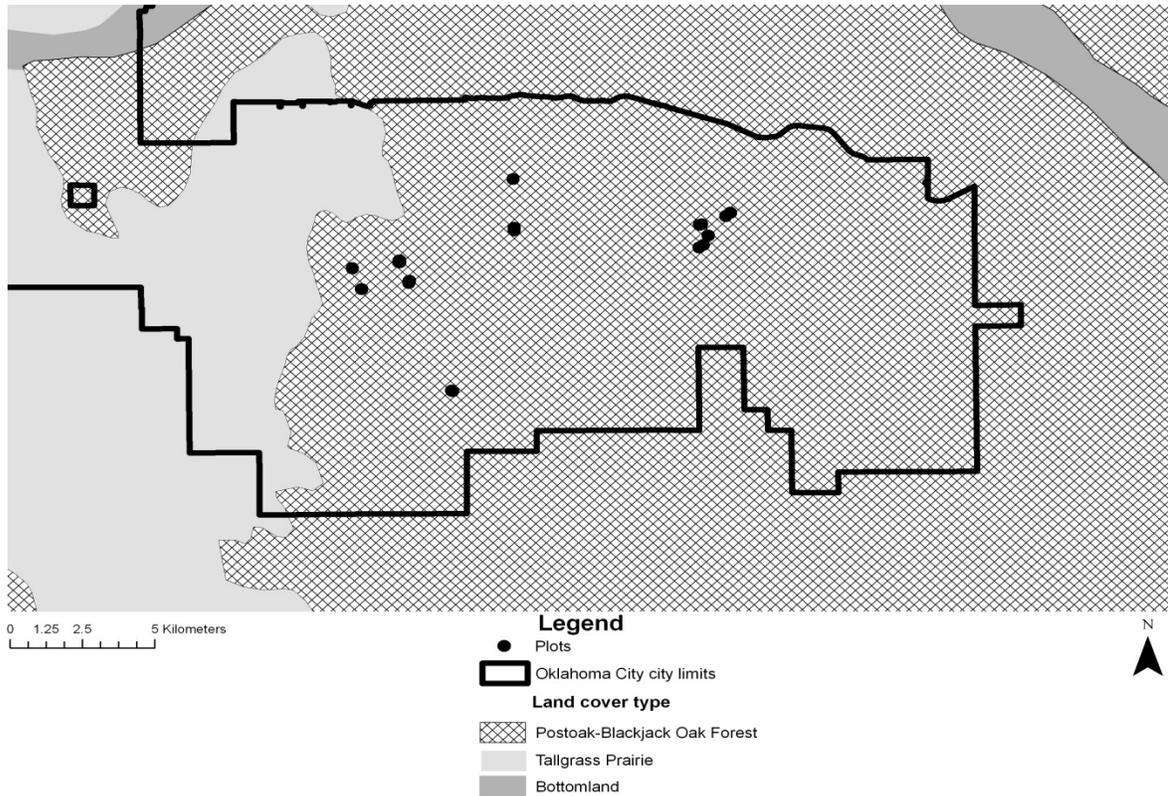


Figure 4 Locations of vegetation plots on sites within the study area.

Contemporary Vegetation

Vegetation was quantified using a total of twenty-two plots (some in close proximity) on about ten sites (Figure 4). A total of 944 stems with a diameter of at least 7.5 cm were sampled. Stem diameters ranged from the minimum of 7.5 cm to 55.5 cm, with a mean diameter of 15.21 cm and a median diameter of 13 cm. Eighteen woody plant species were encountered (Table 2). The most common were *Quercus marilandica* (blackjack oak), *Quercus stellata* (post oak), *Carya texana* (black hickory), and *Juniperus virginiana* (eastern redcedar), respectively. Four hundred and two stems of *Q. marilandica* were recorded, ranging in diameter from 7.5 cm to 42 cm, with a mean diameter of 14.3 cm and a median diameter of 13 cm. Three hundred ninety-four stems of *Q. stellata* were recorded, ranging in diameter from 7.5 cm to 55.5 cm, with a mean diameter of 16.49 cm and a median

diameter of 14.5 cm. Forty-two stems of *C. texana* were recorded, ranging in diameter from 7.5 cm to 44 cm, with a mean diameter of 17.55 cm and a median diameter of 16.25 cm. Twenty-four stems of *J. virginiana* were recorded, ranging in diameter from 7.5 cm to 22 cm, with a mean diameter of 12.46 cm and a median diameter of 12 cm.

The highest importance values were scored by *Q. stellata* at 115.26 and *Q. marilandica* at 96.33 (see Table 2). *C. texana* at 20.12 and *J. virginiana* at 14.49 fell far below these two dominant oaks. Other notable species include *Ulmus rubra* (Slippery elm) at 9.45 and *Celtis occidentalis* (common hackberry) at 6.31.

Plot total basal area values ranged from 0.66 m² to 1.88 m² (mean 0.95 m², median 0.88 m², standard deviation 0.28 m²). The highest basal area values were reported for trees dominant in the Cross Timbers in the following order: *Q. stellata* > *Q. marilandica* >

C. texana. *Q. stellata* had the highest frequency (22), followed by *Q. marilandica* (19), *J. virginiana* (10), and *C. texana* (9) (see Table 2). Mean basal area for *Q. stellata* was 0.506 m²/plot, median basal area 0.38 m²/plot (range = 0.057 m² to 1.876 m², standard deviation 0.474 m²), mean basal area for *Q. marilandica* was 0.343 m²/plot, median basal area 0.305 m²/plot (range 0.0 m² to 0.765 m², standard deviation 0.252 m²), mean basal area for *C. texana* was 0.064 m²/plot, median basal area 0.0 m²/plot (range 0.0 m² to 0.506 m², standard deviation 0.168 m²), and median basal area for *J. virginiana* was 0.017m²/plot, median

basal area 0.004 m²/plot (range 0.0 m² to 0.133 m², standard deviation 0.038 m²).

Plot density values ranged from 20 to 65 (mean = 42.91, median = 43, standard deviation = 15.16). The highest density values were for *Q. marilandica* with 21.16 stems/plot (range 0 to 56, median 25, standard deviation 16.3), *Q. stellata* with 17.91 stems/plot (range 1 to 56, median 17.5, standard deviation 17.16), *C. texana* with 4.67 stems/plot (range 0 to 13, median 0, standard deviation 3.84), and *J. virginiana* with 2.4 stems/plot (range 0 to 11, median 1, standard deviation 3.10).

Table 1 Species scores for bearing trees that fell within the boundaries of the study area from the 1873 PLS data. DEN = total number of stems, BA = total basal area in study area (m²), RD = relative density, RBA = relative basal area, and IV = importance value.

<u>1873 Bearing trees</u>	DEN	BA (m ²)	RD	RBA	IV
<i>Quercus marilandica</i>	397	9.76171	65.29605	35.59868	100.8947
<i>Quercus stellata</i>	182	16.3742	29.93421	59.71289	89.6471
<i>Ulmus sp.</i>	14	0.270201	2.302632	0.98536	3.287992
<i>Carya texana</i>	2	0.697738	0.328947	2.544488	2.873435
<i>Populous deltoides</i>	3	0.194575	0.493421	0.70957	1.202991
<i>Salix sp.</i>	3	0.04915	0.493421	0.179239	0.67266
<i>Juglans nigra</i>	3	0.020775	0.493421	0.075762	0.569183
<i>Fraxinus nigra</i>	2	0.016214	0.328947	0.059129	0.388076
<i>Celtis occidentalis</i>	1	0.032429	0.164474	0.118261	0.282735
<i>Cercis canadensis</i>	1	0.00456	0.164474	0.016629	0.181103

Table 2 Species scores for woody plants in the twenty-two plots sampled. FRQ = frequency, RF = relative frequency, BA = total basal area in study area (m²), MPLT = median basal area/plot (m²), RBA = relative basal area, DEN = total number of stems, MSTM = average density/plot, RD = relative density, and IV = importance value.

Species	FRQ	RF	BA	MPLT	RBA	DEN	MSTM	RD	IV
<i>Quercus stellata</i>	22	22.92	10.6	0.481	50.61	394	17.91	41.74	115.26
<i>Quercus marilandica</i>	19	19.8	7.112	0.374	33.95	402	21.16	42.58	96.33
<i>Carya texana</i>	9	9.38	1.319	0.147	6.3	42	4.67	4.45	20.12
<i>Juniperus virginiana</i>	10	10.42	0.321	0.032	1.53	24	2.4	2.54	14.49
<i>Ulmus rubra</i>	5	5.21	0.445	0.089	2.12	20	4	2.12	9.45
<i>Celtis occidentalis</i>	4	4.17	0.183	0.046	0.87	12	3	1.27	6.31
<i>Quercus muhlenbergii</i>	3	3.13	0.202	0.067	0.96	14	4.67	1.48	5.57
<i>Morus alba</i>	4	4.17	0.173	0.043	0.83	4	1	0.42	5.42
<i>Carya illinoensis</i>	3	3.13	0.196	0.065	0.94	4	1.33	0.42	4.48
<i>Prunus mexicana</i>	3	3.13	0.101	0.034	0.48	4	1.33	0.42	4.03
<i>Cercis canadensis</i>	3	3.13	0.033	0.011	0.16	5	1.67	0.53	3.81
<i>Viburnum rufidulum</i>	3	3.13	0.051	0.017	0.24	3	1	0.32	3.69
<i>Morus rubra</i>	2	2.08	0.102	0.051	0.49	7	3.5	0.74	3.31
<i>Prunus angustifolia</i>	2	2.08	0.052	0.026	0.25	5	2.5	0.53	2.86
<i>Celtis laevigata</i>	1	1.04	0.028	0.028	0.13	1	1	0.11	1.28
<i>Sideroxylon lanuginosum</i>	1	1.04	0.013	0.013	0.06	1	1	0.11	1.21
<i>Quercus macrocarpa</i>	1	1.04	0.01	0.01	0.05	1	1	0.11	1.19
<i>Diospyros virginiana</i>	1	1.04	0.005	0.005	0.02	1	1	0.11	1.17

DISCUSSION

Two previous studies that have utilized PLS bearing tree data from the Cross Timbers of central Oklahoma provide apt comparison here. Shutler and Hoagland (2004) reported that PLS surveyors sampled 6886 stems in Carter County in the early 1870s, with *Quercus stellata* (2,648 stems) and *Quercus velutina* (1,740 stems) being the two most abundant species by far, and only 18 stems of *Quercus marilandica* recorded. Fagin (2009) reported that PLS surveyors sampled 2,578 trees in the Arbuckle Mountains of south-central Oklahoma in the early 1870s, recording 1,234 stems of *Q. stellata* and 529 stems of *Q. velutina*. These reports would indicate that the composition of Cross Timbers forests in central Oklahoma were drastically different than they are today. However, Thomas (2010) demonstrated that the stems labeled as “black oak” by the PLS surveyors and assumed to be *Q. velutina* in these studies were almost certainly *Q. marilandica*. “Black oak” was another common name for blackjack oak, and references to *Q. velutina* are almost completely absent from any historical accounts of the Cross Timbers. “Blackjack oak” (*Q. marilandica*), on the other hand, is almost universally present in these accounts.

Even so, it still appears that in south-central Oklahoma *Q. stellata* was twice as abundant as *Q. marilandica* during the first PLS in Oklahoma in the early 1870s. The 2:1 ratio of *Q. stellata* to *Q. marilandica* at the time seems to demonstrate that the Cross Timbers of south-central Oklahoma contained more mesophytic vegetation than the Cross Timbers found in Oklahoma and Cleveland counties in central Oklahoma, where a ~ 1:2.2 ratio of *Q. stellata* to *Q. marilandica* was reported by the PLS surveyors in the early 1870s. *Carya texana* was also much more abundant in south-central Oklahoma as well, with 118 stems reported by Fagin (2009), but only two recorded by PLS surveyors in Oklahoma

and Cleveland counties. This further lends credence to the idea that the Cross Timbers in Carter County and the Arbuckle mountains contained more mesophytic vegetation than those in Cleveland and Oklahoma counties, perhaps as a result of protection from prairie fires, as prairie fires select for fire-tolerant species in environments that would ordinarily trend toward a more mesophytic species composition (Thomas 2010).

In their study of the upland forests of Oklahoma, Rice and Penfound (1959) sampled three sites in Oklahoma County and three sites in Cleveland County (for their sampling methods see Hoagland and Hough 2008). In Oklahoma County they recorded 39 stems of *Q. stellata* and 137 stems of *Q. marilandica*. In Cleveland County they recorded 66 stems of *Q. stellata*, 129 stems of *Q. marilandica*, 10 stems of *C. texana*, and 7 stems of *Q. velutina* (Hoagland and Hough 2008). This ~1:2.5 ratio of *Q. stellata* to *Q. marilandica* is much more in line with the ~1:2.2 ratio recorded by PLS surveyors in the early 1870s than with the ~1:1 ratio recorded in the current study.

However, with the reports of *C. texana* and *Q. velutina* by Rice and Penfound (1955, 1959), we begin to see the results of the “mesophication” of the Cross Timbers noted by this study and by DeSantis et al. (2010). As mentioned in the introduction, this mesophication process is believed to occur as a result of fire exclusion, which “can alter stand structure and create microclimatic conditions that are more beneficial to mesophytic woody species” (DeSantis et al. 2010). In his study, DeSantis (2010) re-sampled 30 forest stands originally sampled by Rice and Penfound (1959) and noted substantial increases in the abundance of *C. texana*, *Juniperus virginiana*, and *Q. stellata*, while *Q. marilandica* declined in abundance. These results are consistent with this study, as we recorded a large increase in *C. texana* and the fire-intolerant *J. virginiana* since the 1870s PLS, and the replacement of

Q. marilandica by the less fire-tolerant *Q. stellata* as the most important species in the Cross Timbers of central Oklahoma.

CONCLUSION

It is apparent from this study and other studies conducted in the Cross Timbers and in *Quercus* forests worldwide that the dominance of *Quercus*, especially those species at the xeric end of the spectrum, is in decline. Fire exclusion seems to be a plausible mechanism, and with the pace of urban, suburban, and ex-urban development the urgency and necessity of fire exclusion will only continue to expand in coverage. Thus, there will likely be nothing to check the mesophication trend in *Quercus*-forests, save greatly altered land management practices. Noting these trends, future studies might attempt to document what changes in woody species composition mean for other flora and fauna found in *Quercus*-dominated forests. Documenting changes such as these might increase the urgency for conservation and preservation practices in the Cross Timbers ecoregion.

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