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Fire History in the Cherokee Nation of Oklahoma

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Abstract The role of humans in historic fire regimes has received little quantitative attention. Here, we address this inadequacy by developing a fire history in northeastern Oklahoma on lands once occupied by the Cherokee Nation. A fire event chronology was reconstructed from 324 tree-ring dated fire scars occurring on 49 shortleaf pine (*Pinus echinata*) remnant trees. Fire event data were examined with the objective of determining the relative roles of humans and climate over the last four centuries. Variability in the fire regime appeared to be significantly influenced by human population density, culture, and drought. The mean fire interval (MFI) within the 1.2 km^2 study area was 7.5 years from 1633 to 1731 and 2.8 years from 1732 to 1840. Population density of Native American groups including Cherokee was significantly correlated (r=0.84) with the number of fires per decade between 1680 and 1880. Coincident with the Removal of the Cherokee and other native peoples from the eastern United States and immigrations into northeast Oklahoma, the MFI decreased to 1.8 years. After 1925 fire intervals were considerably lengthened (MFI=16 years) due to fire suppression and decreased fire use until the recent prescribed burning by The Nature Conservancy. Many of the historic fire years that were previously shown to be synchronous across Missouri and Arkansas during drought years were also fire years at this site. Overall the frequency of fires was weakly associated with drought compared to human population density.

Keywords Ozarks · Frequency · Humans · Missouri · Arkansas · Drought

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Introduction

Throughout North America the quantitative association between historic fire regimes and humans has been limited by the quality and availability of data on Native American populations and their many fire cultures (Delcourt and Delcourt 1997). Fire history information has provided increased perspective on fire regimes and baseline data applicable to understanding the ecology and management of fire and forests (Rudis and Skinner 1991; Lafon 2005; Abrams and Nowacki 2008). Compared to these applications rarely have fire history data been used to gain perspective on human ecology (Kaye and Swetnam 1999; Guyette *et al*. 2002; Fulé *et al*. 2011).

In the last decade there has been increased interest in documenting the fire history of Oklahoma's diverse vegetation, landscapes, and people. Studies reconstructing historic fire years have utilized dated fire scar injuries on oak trees at Cross Timbers sites located throughout east central and southwestern Oklahoma (Shirakura 2006; Clark *et al*. 2007; Stambaugh *et al*. 2009; DeSantis *et al*. 2010; Allen and Palmer 2011). Currently no fire histories exist in the eastern mountainous regions of Oklahoma (i.e., Ozarks, Ouachitas) despite it having one of the highest modern fire occurrence densities in the eastern U.S. (Source: U.S. Geological Survey, www.geomac.gov; period 2002–2011). The nearest comparable fire histories (i.e., considering topography and oak-pine forest types) are located in the Arkansas Ozarks approximately 200 km east (Guyette *et al*. 2006a). Because historic fire frequencies can be spatially variable it is difficult to extrapolate results from other locations, particularly those with different histories of human occupancy and climate.

Human Occupation of the Western Ozark Highlands (~1600 CE to Present)

During the last four centuries the western Ozark Highlands region has been either repeatedly visited or permanently occupied by multiple human groups including Osage, Caddo, Delaware, Cherokee, and Euro-Americans (Mathews 1961). As early as 1541, portions of the western Ozarks were within the boundaries of the expanding Osage territory (Burns 2004). From about 1630 to 1830 the region was likely occupied by both the Osage and Caddo Native American groups (Vogt 1974). Other Native American groups had left the region by the latter half of the 18th century (Vogt 1974; Bailey 2010). Although Osage villages were concentrated primarily in the Missouri and Arkansas Ozarks, they also utilized the western Ozarks and plains portion of their territory for annual game and bison hunts (Rollings 1992). The Illinois River trail was one of two significant trails utilized by the Osage for travelling between Arkansas and Oklahoma hunting grounds (Burns 2004; Nuttall 1999).

Displaced from their ancestral lands in the east (Georgia, Tennessee, North Carolina) by native and European encroachment pressures, the people of the Cherokee Nation began moving westward relatively early (before 1775; Goodwin 1977). By 1817, the "Western Cherokee", those that had been settling in Arkansas since the 1790s, were venturing into northeastern Oklahoma and encountering resistance from the Osage. Conflicts continued between the two tribes through 1825 (Goins and Goble 2006). In 1828, a treaty led to the exchange of Cherokee lands in Arkansas for lands in Indian Territory in Oklahoma (which included the study site). Between 1829 and 1838, the Western Cherokee occupied an area of northeastern Oklahoma by building cabins, clearing land for cultivation, raising livestock and hunting bison (Jones and Faulk 1984). In 1838, most of the remaining Cherokee in more eastern regions were forced to relocate to northeastern Oklahoma along what came to be known as the Trail of Tears. Approximately 5,000 Cherokee were already living in lands west of the Mississippi when about 14,000 surviving emigrants from the East arrived (McLoughlin 1993; Goins and Goble 2006).

Many emigrants arrived in the new territory destitute and struggled to survive in an unfamiliar climate and environment (McLoughlin 1993). The decades following the arrival of Cherokee were marked by turmoil as the reunited tribe struggled to establish social, economic and political stability (Goins and Goble 2006). Conflicts with other Plains tribes were common and the Civil War was particularly devastating for the Cherokee (Rafferty 1980). The construction of railroads in the 1870s and 1880s ushered in a new era of trials for the Cherokee, ultimately leading to unconstrained white settlement of the Cherokee territory and the end of Cherokee sovereignty in 1898 (McLoughlin 1993).

The objective of this study was to reconstruct and describe the historic fire regime at a site in Oklahoma that was within the historic boundaries of the Cherokee Nation. The second objective was to examine the potential influences of human ignitions and climate on the fire regime. We hypothesized that: 1) past increases in human population density corresponded with increases in fire frequency, and 2) drought conditions were associated with increased fire severity and occurrence of fires.

Methods

Study Location

The study was located in northeastern Oklahoma on lands that were received via treaty by the Cherokee Nation in the decades before 1887. Presently the lands are part of the Nickel Family Nature and Wildlife Preserve—a 6,880 ha area managed by The Nature Conservancy since 2000. The study area lies in the Cookson Hills on the western edge of the Ozark Highlands with lands further westward transitioning into the Cross Timbers physiographic region (Küchler 1964). The topography is rugged and dissected, with steep cherty slopes and narrow ridges and valleys. Approximately 20 to 50 % of the region has slopes over 8° (Rafferty 1980). Dominant forest types include mixed oak-hickory (*Quercus-Carya*) and mixed oak-pine (*Quercus-Pinus echinata* Mill.) forests that occasionally occur as woodlands and may contain small prairie openings. The Illinois River flows southward along the western boundary of the Preserve (Fig. 1). The climate is humid continental, with a mean maximum temperature of 22 ° C and a mean annual precipitation of 122 cm (PRISM Data, period 1971–2000; Daly *et al*. 2004).

Site Selection

We surveyed much of the Nickel Preserve and identified areas that had abundant dead remnant shortleaf pine (*Pinus echinata*) trees. Study sites were chosen based on the density of remnant trees, their condition, and presence of fire scars (Fig. 2). Study sites included one primary site and four smaller sites (i.e. "clusters"). The primary site was located at Tully Hollow (TLY; Fig. 1) covering an area of approximately 1.2 km^2. Clusters were located from 4 to 10 km away from Tully Hollow and each encompassed approximately 1 to 3 ha areas. At all sites we exhaustively collected all available fire scarred pine wood which primarily came from preserved stumps of trees that were cut during the 19th century. Data from the four clusters (DOG, PMK, CDH, TEL; Fig. 1) were combined with the Tully Hollow data to describe the historic extent of fires.

Sample Collection and Processing

Shortleaf pine was preferred over other tree species because of its potential for: 1) providing long fire scar records, 2)

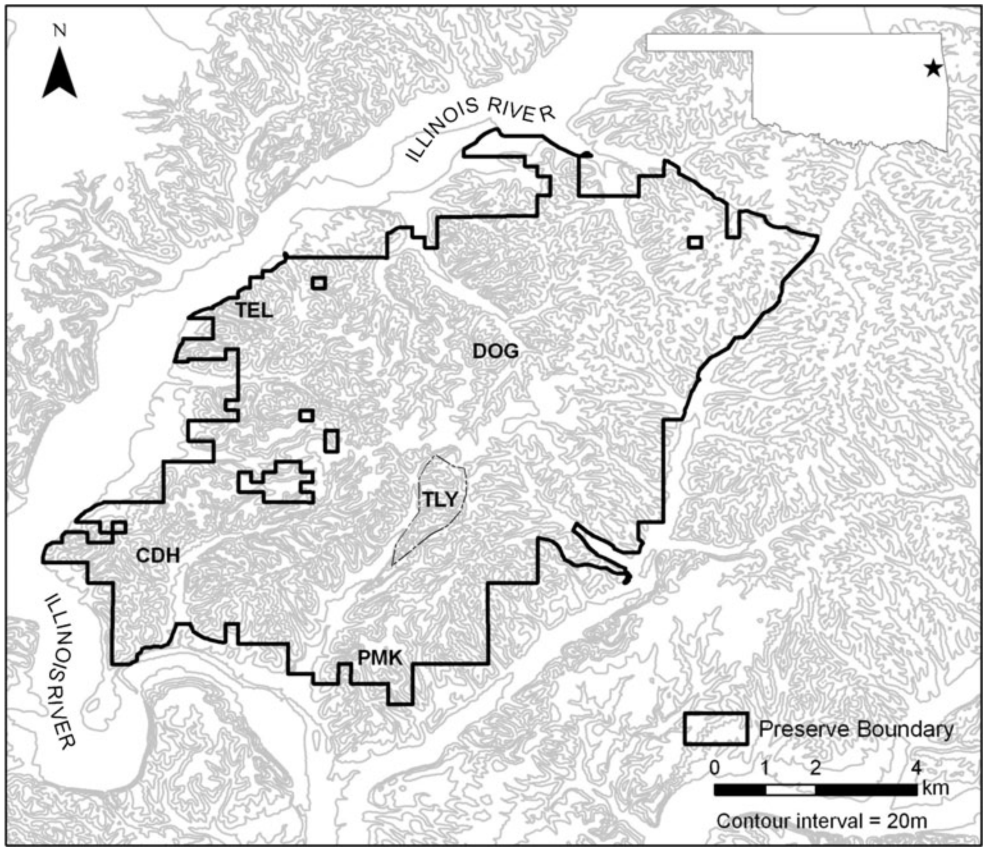

Fig. 1 Topographic map of The Nature Conservancy's Nickel Preserve and the locations of fire history sites. One primary fire history site consisting of 34 trees was collected at Tully Hollow (TLY, area depicted by dashed line). Other smaller fire history "clusters" were located in Pumpkin Hollow (PMK), Dog Hollow (DOG), Cedar Hollow (CDH), and Tell Hollow (TEL)

having charcoal associated with basal scars, and 3) recording multiple and frequent fire events (Stambaugh *et al.* 2005). Location (coordinates), slope, and aspect were recorded for each tree sampled. Samples consisted of 20 to 30 cm thick cross-sections cut from the base of trees using a chainsaw. In the laboratory we sanded surfaces of cross-sections with successively finer sandpaper (80 to 1200 grit) until the cellular detail of tree rings and fire scars were revealed. Tree-ring width series were measured on all trees at a precision of 0.01 mm. Ring-width series from each sample were plotted and visually crossdated using standard dendrochronological techniques (Stokes and Smiley 1968). Crossdating utilized existing shortleaf pine master ring-width chronologies developed from the Boston Mountains of Arkansas (Stambaugh and Guyette 2005) and a new master chronology was constructed for the study site. Computer program COFECHA (Holmes *et al.* 1986; Grissino-Mayer *et al.* 1996) was used to check the accuracy of crossdated ring-width series.

Fire scars were identified by the presence of cambial injury, callus tissue and traumatic resin canals. We dated fire scars to the year and, if possible, the season of cambial injury based on the position of the injury within or between rings (Kaye and Swetnam 1999). We used computer program FHX2 (Grissino-Mayer *et al.* 1996) to plot fire scar chronologies and calculate summary statistics. Mean fire intervals (MFIs) were calculated as the mean number of years between fire events (Dietrich 1980). Percentages of trees scarred in each fire year were calculated and used as a proxy of fire severity. From the fire event chronology we developed a time series of the average number of fires per decade. This coarse-resolution fire frequency dataset was developed to more closely match the resolution of human population density data.

Humans and Fire

Long-term human population density is often difficult to estimate because of factors such as rapidly changing population, area of occupancy, seasonal residence, and unknown populations. Compared to many regions where fire histories have been documented this study region has an exceptional record of Native American population that is attributed to its location, early records of land allotments by treaties (1700–1900), and descriptions of different tribal groups. During the early period (~1630 to 1780) covered by this study's fire scar record the region was occupied by the Osage and others. The Osage claimed their original territory in what is now northeast Oklahoma, southwest Missouri, northeast Arkansas and southeast Kansas (Vogt 1974). The fire history study areas represent a small portion of the large region occupied by the Osage at relatively low population densities (Guyette *et al.* 2002).

Fig. 2 Remnant shortleaf pine (*Pinus echinata*) tree with charcoal and fire injuries on a scar face. This tree had 28 fire scars during the period 1739 to 1914

Cherokee migration and population are particularly important to this study because Cherokee lived in and near the study area for nearly two centuries (Rafferty 1980). Associations among Cherokee migration, population, and fire history data have been described in previous studies (Guyette and Stambaugh 2005; Guyette *et al*. 2006a). Cherokee population estimates were derived from the regions of southeast Missouri, northwest Arkansas (Royce 1899; Gilbert 1996), and northeast Oklahoma (Morris *et al*. 1986). During the winter of 1811–1812 many Cherokee moved from Missouri to Arkansas. During this time their population in northwest Arkansas (and probably northeast Oklahoma) increased to about 4,500 (Stevens 1991). In 1828, the Cherokee moved further west into the region of northeastern Oklahoma. In 1838, approximately 14,000 Cherokee were forcefully removed from their homelands in the eastern United States along the Trail of Tears to northeast Oklahoma. From decadal population estimates we used linear interpolation to derive annual estimates of Cherokee population in eastern Oklahoma. Decadal population estimates were based on 13 historic population estimates of Cherokee and Osage that were derived from multiple sources (Royce 1899; Vogt 1974; Rafferty 1980; Morris *et al*. 1986; Gilbert 1996).

Reconstructed Drought

Reconstructed Palmer Drought Severity Index (PDSI) (Cook *et al*. 2004) data were obtained from the National Climate Data Center. We calculated an annual average regional drought condition for our study region from the two nearest PDSI grid points in the western Ozark region (grid points: 192, 193). To be comparable to the resolution of human population data we smoothed drought indices using a 7-year moving average following the same methods used to calculate fires per decade.

Data Analysis

Summary statistics describing fire frequency and percentage of trees scarred were calculated for the full period of record and for five sub-periods that corresponded to changes in human population and culture (Table 1). The frequency of fire years were plotted by drought condition to examine whether fire events appeared normally distributed or skewed to drier or wetter conditions. Correlation analysis was used to determine if drought was significantly related to percentages of trees scarred. In addition, correlation and multiple linear regression analysis were used to determine whether drought or human population density explained more of the variance in fire frequency during the period associated with Osage and Cherokee occupation. The fire event record was combined with comparable fire history records from Missouri and Arkansas (Guyette *et al*. 2006a; Stambaugh and Guyette 2008) to determine which years corresponded with regionally synchronous fire years and whether these years were drier than normal. SAS/STAT (2002) software was used to perform statistical summaries, analysis of means, and regression and correlation analyses.

Results

A total of 324 fire scars on 49 shortleaf pine remnant stumps and trees were identified and dated at the five study sites (Fig. 2). The majority of sample trees (n=34) were located at Tully Hollow (Fig. 3). At Tully Hollow the mean fire interval ranged from 1.7 to 17 years between 1633 and 1925 (Table 1). Although the period after 1925 is only represented by 2 trees at Tully Hollow we believe the dramatic decrease in fire frequency is accurate based on the lack of fire scars or charcoal (i.e., lack of physical evidence for recent fires) on the trees which comprise the current forest. The percentage of trees scarred during fire years ranged from 5 to 48 %. Nearly all (98 %) fires occurred in the dormant season.

Table 1 Fire history and cultural information for five time periods. Time periods reflect major cultural eras related to changes in human population, cultures, and fire frequency. Mean fire intervals (MFIs) were are given for the entire Nickel Preserve study area (NP) and for extent of Tully Hollow (TLY) site. MFIs for the entire Nickel Preserve were based on the combined fire records for Tully Hollow and the four additional cluster sites (data in Fig. 2). Due to low sample sizes at 4 of the sites and few sites overall, the mean fire interval statistics for the entire Nickel Preserve are conservative estimates and likely do not represent all fires within the area. Drought is the reconstructed PDSI (Cook *et al*. 2004)

Cultural eras	Time period	NP MFI	TLY MFI (range)	Mean % trees scarred, (# fires)	Mean # fires per decade	Ethnic Groups	Correlation coefficients (drought x %trees scarred)
Native American	1650–1780	na	5 (1–17)	13.4[1],(15)	2	Osage, Wichita, Caddo	−0.211
Native American migration I	1780–1830	2.2	2.5 (1–4)	9.5, (21)	4	Osage, others	−0.30*
Native American migration II	1830–1889	1.3	1.7 (1–4)	11.0, (35)	6.3	Cherokee	−0.06
Euro- American settlement	1890–1925	1.7	2.2 (1–4)	19.2, (17)	4.6	Cherokee, Euro-American	−0.01
Fire suppression	1925–1992	5	17 (8–30)	na	0.5	Euro-American	0.02

[1] Dates for this analysis were 1731–1780 because of limited sample depth before 1731. *=$p<0.05$. Study area sizes are: Tully Hollow (TLY) approximately 121 ha, Nickel Preserve (NP) approximately 6880 ha

Overall, three climate-fire associations were found: 1) fire years were slightly more common in dry years (Table 2), 2) years with fires occurring throughout the study area were synchronous with regional droughts, and 3) anthropogenic ignitions were more important than drought conditions in determining the fire frequency between 1680 and 1880. During 1680 to 1880 twenty-four fire years (34 %) occurred during wetter than normal conditions (PDSI>0), while forty-seven fire years (66 %) occurred during drier than normal conditions (PDSI<0). Based on occurrences of fires at Tully Hollow and the smaller "cluster" sites, widespread fires occurred within the study area in 1753, 1772, 1780, 1786, 1801 and 1808—all of which were drought years with average PDSI values of −2.2. Drought explained about 10 % of the variance in fire frequency.

The importance of anthropogenic influences on the fire regime was evident in the large differences in correlations between drought and fire variables compared to human variables and fire variables (Tables 1 and 2). Correlations between fire frequency and human population density were much higher than between fire frequency and drought (Table 2). By far the most important variable affecting fire frequency in the early portion of the record (prior to 1880) was the population density of Native Americans which was positively correlated with fires per decade (Table 2). A significant regression model was developed describing fires per decade from Native American population density (Figs. 4, 5 and 6):

$$\text{Fires per decade} = 7.7 + 1.14 * \text{popdensity} \quad (1)$$

where:

Fires per decade = the number of fires per 10 year period at Tully Hollow,
popdensity = natural log of the sum of Osage and Cherokee population per 28,000 km^2,
r^2=0.75, p<0.001,
period: 1680 to 1880

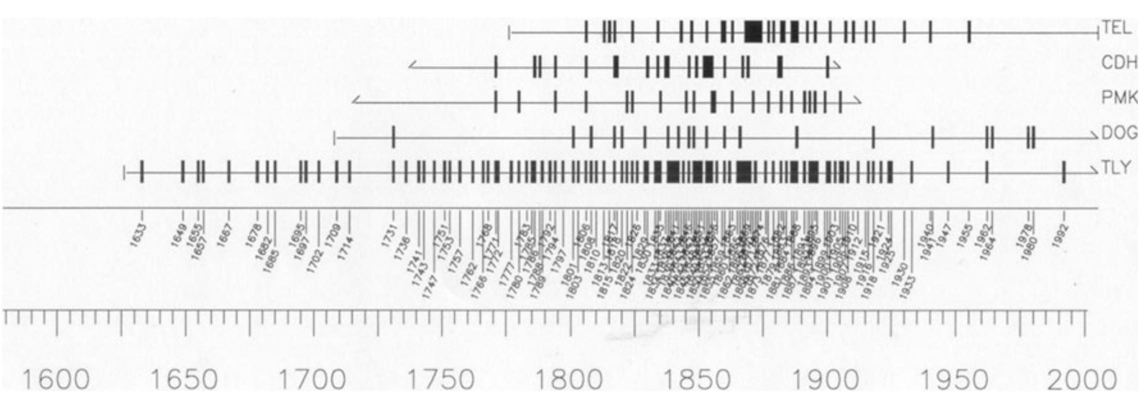

Fig. 3 Composite fire scar history diagram of all five Nickel Preserve sites. Each horizontal line represents the length of the fire scar record at the collection site. Bold vertical marks represent fire scars. The preserve-wide composite fire scar chronology (bottom axis) indicates the presence of a fire at one or more of the study sites

Table 2 Correlation coefficients among fires per decade and the percent of trees scarred with population and drought variables (1680–1880). Ln is the natural log of population

Population and climate variables	Fires per decade	Percent trees scarred
Population density (Osage+Cherokee)	0.74[a]	0.16[a]
Ln (population density) (Osage+Cherokee)	0.80[a]	0.17[a]
Drought (reconstructed)	−0.06	−0.14*
Drought (reconstructed, % scarred fire years)	−0.02	−0.33*[b]

*statistically significant at $p<0.05$

[a] significance levels for population density and fire variable correlation coefficients are not given because of the high autocorrelation in population time series

[b] natural log of percent trees scarred during fire years.

Although it is difficult to address the statistical significance of these autocorrelated series (i.e., moving averages and annual population interpolation), the strength of the correlation between fires per decade and population density was robust (r=0.81) and has been found significant at other sites using similar analyses (Guyette *et al.* 2002; Guyette *et al.* 2006a). The addition of PDSI (Cook *et al.* 2004) as a predictor variable of fires per decade also resulted in a significant model, but with little additional explanatory power. This model was given as:

$$\text{Fires per decade} = 8.08 + 1.42 * \text{popdensity} + 0.47 * \text{PDSI} \quad (2)$$

where:

Fires per decade = the number of fires per 10 year period at Tully Hollow,
Popdensity = natural log of the sum of Osage and Cherokee population per 28,000 km^2,
PDSI is the 7 year average of the reconstructed Palmer Drought Severity Index,
r^2=0.78, p <0.00, partial r-squares are 0.75 for population and 0.03 for drought,
intercept and model are significant (p<0.01),
period: 1680 to 1880.

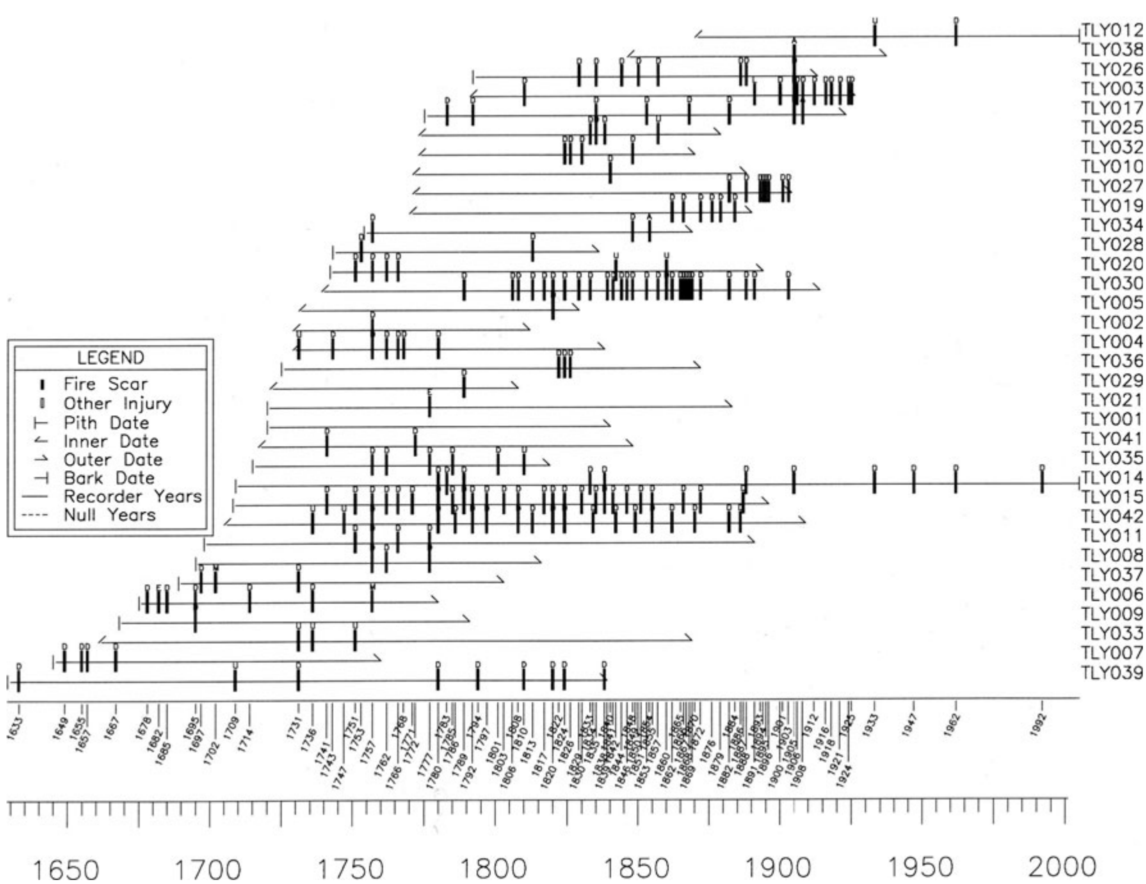

Fig. 4 Tully Hollow fire history chart showing fire scar dates of 34 individual trees and a fire scar composite chronology for the site. Each horizontal line represents the length of the fire scar record of a live shortleaf pine tree or remnant. Each bold vertical mark represents a fire scar year. The letters above the vertical marks indicate the season of fire (D = dormant season, M = middle earlywood, A = latewood, U = undermined seasonality). The composite fire scar chronology with all fire scar dates is shown at the bottom of the figure

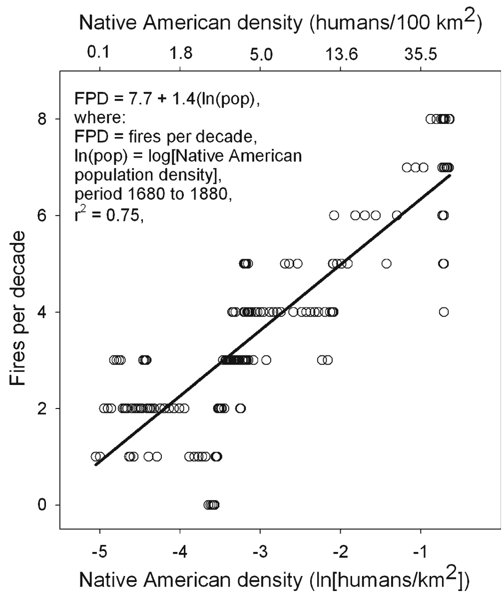

Fig. 5 Scatterplot and regression (black line and text) illustrating the association between natural log of Native American population density and the number of fires per decade (FPD) between 1680 and 1860. The top axis gives the non logarithmic population densities per 100 km^2

Discussion

The fire scar record showed to be similar to those documented in the Ozarks of Arkansas and Missouri. Widespread fire years at the study site (1657, 1753, 1772, 1780, 1786, 1801, 1808) were also widespread in Missouri and Arkansas. These fires likely encompassed large areas, and had potential for high severity effects. Fires occurring during these years could have resulted from the interactions between drought and Native American migrations into the region, human conflicts, and attempts to use fire to culture or condition the landscape for subsistence. Also, it is plausible that more accidental fires resulted from greater human population density and movements, particularly during drought conditions.

Fire frequency at a decadal scale can be affected by anthropogenic ignitions and climate variability. Drought can enhance the probability of burning by decreasing fuel

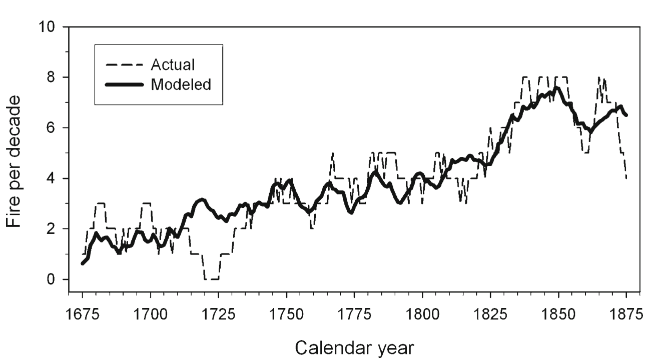

Fig. 6 Time series of the actual number of fires per decade and model predictions based on population and drought (Eq. 2)

moisture and increasing the probability of ignitions and fire spread. Prolonged drought (5 year+) may also ultimately decrease the probability of burning by reducing fuel production and consequently fire spread. In ignition saturated environments fuel production is a limiting factor controlling the frequency of fire (Guyette *et al*. 2002; Stambaugh *et al*. 2006).

Fire frequency at the Tully Hollow site before the forced movement of Native Americans onto lands in northeast Oklahoma (~ prior to 1820) was comparable to other sites with similar forest types and at similar latitudes (Table 3). Considering the possibility that all fires were not detected by fire scar history reconstructions (i.e., not all fires may result in fire scars) it is not known whether the MFIs in Table 3 are significantly different. Only the Granny Gap site in the Lower Boston Mountains of Arkansas had a more frequent history of burning than Tully Hollow (Table 3) and this site, like Tully Hollow, was directly adjacent to a trail (Hoffman 1995).

Fires were least frequent between about 1925 and 2000 (Figs. 2 and 3). The pattern of significantly reduced fire frequency during the 20th century is comparable to most sites in the eastern U.S., however contrast to some sites immediate to the west in the Cross Timbers (Clark *et al*. 2007; DeSantis *et al*. 2010; Stambaugh *et al*. 2009). This difference could be the result of many interacting factors such as climate, topography, human population, fuels, or culture. The drier climate to the west is a major factor in the decrease in forest cover and the increase in grasslands. More rapid fire spread in the expansive grasslands could be an important factor distinguishing the fire environment of this site from those of the Cross Timbers. Additionally, fire suppression campaigns in the 20th century may have had differing effects on cultural burning practices in the Cross Timbers and rangelands versus more forested regions of the Ozarks. Certainly, active open land burning currently occurs in many grassland regions of Oklahoma and Kansas, particularly for purposes of range management.

Many of the fire years at the study site matched fire years at other fire history sites in the central and western Ozark region of Arkansas and Missouri (Guyette *et al*. 2006a). This network of Ozark fire history data (~40 sites) suggests that fires during the late 18th century (1753, 1772, 1780, 1786, 1801, and 1808) were regionally extensive and associated with annual droughts and probably anthropogenic activities related to eastern Native Americans (Table 4). It is likely not possible to determine to what degree these synchronous fire years were produced by single large events, multiple localized events, or a combination. The rough topography of the Ozark Highlands can significantly limit fire spread and long-term rates of fire occurrences (Stambaugh and Guyette 2008) therefore, for large fires to have occurred there likely existed drought conditions and/or multiple ignitions. The area and era of these extensive fires corresponds to the movement and possible culturing of the Ozark landscape by Native Americans

Table 3 Early Native American period (~1650–1830) mean fire interval (MFI) at Tully Hollow compared with those of other mixed oak forest, woodland, and savanna ecosystems between 32°N and 37°N latitude

Site name	Location	Period	Forest cover	MFI (yrs)	Data source
Tully Hollow	East OK	1650–1830	Mixed oak-pine forest, woodland, savanna	5.0	This study
Saltwell Hollow	Middle TN	1700–1810	Mixed oak forest, woodland	6.0	Guyette and Stambaugh 2005
Land Between the Lakes	West KY	1700–1810	Mixed oak forest, woodland	6.6	Guyette *et al*. 2008
Caney Mountain	South MO	1702–1821	Mixed oak forest, woodland, savanna	5.2	Guyette and Cutter 1991
Granny Gap	North AR	1680–1820	Mixed oak-pine forest, woodland	4.6	Guyette and Spetich 2003
Purtis Creek	East TX	1690–1820	Oak woodland, savanna	6.7	Stambaugh *et al*. 2011
Wichita Mountains	Southwestern OK	1720–1820	Oak-cedar woodland, prairie	6.6	Stambaugh *et al*. 2009

(Jurney and Stahle 2004). We estimate that fires between 1748 and 1810 in the Ozarks could have burned over a total area (as estimated by the number of sites with fire scars) equal to three times the size of the Ozarks during this 62 year period. In this scenario an area the size of the Ozarks (~12,950,000 ha) would have burned about every 21 years. As has been documented in recent fires in drought conditions crown fires and stand replacing effects are possible. The fact that trees at the study site lived to document these fire years suggests that no complete stand replacing fires occurred at the site during the period of record.

Anthropogenic Fire Regime Thresholds

In anthropogenic fire regimes thresholds can exist whereby increased humans populations (and ignitions) fail to increase the frequency of fire (Guyette *et al*. 2002; Guyette *et al*. 2006b). At this threshold point the landscape is saturated with ignitions and fuel availability becomes the limiting variable affecting fire frequency. Based on the relationship between population density and fire frequency at this site the fire regime crossed this threshold (i.e., from ignition-dependent stage to a fuel-limited stage; sensu Guyette *et al*. 2002) circa 1850 at a human population density of 0.49 humans per km^2. This compares with a threshold value of about 0.64 humans per km^2 that was reached in the Missouri Ozarks at the same time by early Euro-American subsistence settlers. A threshold value of about 0.26 (humans per km^2) in the interior Boston Mountains of Arkansas was reached earlier (1820) with increases in Cherokee population density. It is important to note that estimates of human populations and their landscape density are coarse and small differences in threshold values of population density may not be significant. However, these data suggest that the threshold values may vary by place, time period, and cultural group. Also, although differences in population and topography are known to influence regional fire frequency (i.e., achievement of a threshold), the additional influences of vegetation type and climate on fire regime thresholds are not known.

Conclusions

The use of fire by humans is ubiquitous in ancient and modern cultures (Pyne 1982; Delcourt and Delcourt 1997). The use of fire by Native Americans for many purposes has been previously documented and discussed (Fowler and Konopik 2007; DeVivo 1991) with intentional burning of landscapes occurring for reasons including wars and conflicts and for the purposes of culturing of plant communities

Table 4 Percent of study sites burned at other Ozark locations during major fire years at the study sites. Rank is by the mean percentage of all sites in the Ozark region (right hand column). Drought is reconstructed Palmer Drought Severity Index (PDSI) for the Ozark region (Cook *et al*. 2004). More negative PDSI values indicate increasing drought severity

Percent of study sites burned					Drought (PDSI)	Rank	Ozark region
Fire Year	Oklahoma Ozarks	Lower Boston Mtns. (AR)	Interior Boston Mtns. (AR)	Missouri Ozarks			
1780	40 %	100 %	33 %	50 %	incipient dry, −0.99	1	56 %
1808	40 %	66 %	66 %	26 %	near normal, −0.46	2	49 %
1786	20 %	66 %	66 %	23 %	mild drought, −1.14	3	44 %
1772	25 %	100 %	0 %	27 %	extreme drought, −4.45	4	38 %
1801	40 %	0 %	66 %	31 %	extreme drought, −4.33	5	34 %
1753	25 %	0 %	66 %	39 %	mild drought, −1.78	6	32 %

and encouraging and driving game (DeVivo 1991; Rollings 1992; Williams 2002). For Cherokee, though fire was an import aspect of their spiritual culture and (Corkran 1963; Swanton 1995) there is little documentation of their cultural burning practices and fire uses.

Historic fire scar chronologies are potentially a new source of information for understanding human ecology, specifically human-fire-environment interactions. As more studies of fire history consider the interconnectedness of humans, fires, and landscapes it may be possible to better document the spatial and temporal changes in human populations and understand historic fire uses. Excellent opportunities are likely to exist in regions such as the Ozarks where anthropogenic ignitions appear to be dominant over the course of a least the last four centuries if not longer (Jurney 2012). Documenting new fire history sites is important because they both expand the spatial extent of the existing paleofire information and reveal unique and complex human-fire-environmental conditions of the region—data needed for understanding the scope and variability of anthropogenic fire regime dynamics.

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