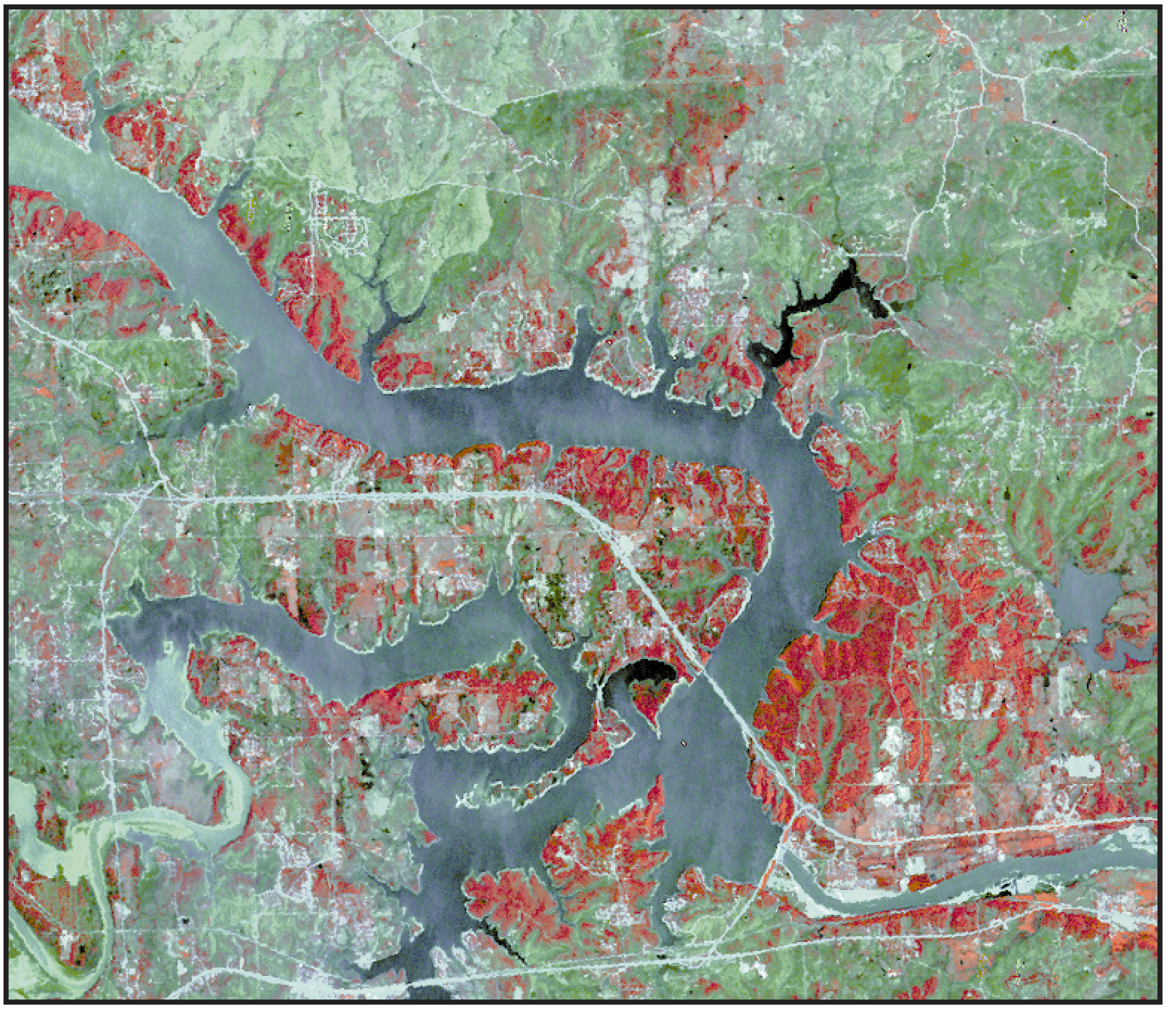
AMQUA 2000



CLIMATE HISTORY RECORDED BY THE ANCIENT CROSS TIMBERS

Fieldtrip, May 21, 2000

Ancient Cross Timbers Project
Tree-Ring Laboratory
University of Arkansas

CLIMATE HISTORY RECORDED BY THE ANCIENT CROSS TIMBERS

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INTRODUCTION

The Cross Timbers are a complex mosaic of upland deciduous forest, savanna, and glade communities that highlight the broad ecotone between the eastern forests and the grasslands of the southern Great Plains (Figure 1). The Cross Timbers are dominated by post oak and blackjack oak (*Quercus stellata* and *Q. marilandica*), and may have acquired their name from the earliest pioneers who were obliged to cross the north-south oriented belts of dense upland forest and prairie in their westward travels across northcentral Texas, eastern Oklahoma, and southeastern Kansas. The presettlement Cross Timbers may have covered some 7,909,700 hectares (30,526 square miles; Kuchler 1964), and consisted largely of low-stature oaks that were not suited for timber production.

The entire Cross Timbers formation is noncommercial for timber production and has never experienced large-scale industrial logging (commercially sustainable forests are defined by the U.S. Forest Service as forests that produce at least 1.4 cubic meters of wood volume per hectare per year, and recent surveys in the Oklahoma Cross Timbers indicate that the annual volume increment is usually only 1.1 cubic meters, Rosson 1994). The Cross Timbers grown on level terrain have been widely cleared for agriculture, but undisturbed tracts of ancient Cross Timbers are still common on steep, rocky terrain where deforestation for farming or grazing was not economically justified. Consequently, the Cross Timbers may be the least disturbed forest ecosystem that survives in the eastern United States. In fact, because these undisturbed ancient Cross Timber ecosystems often grade from dense forest to open savanna to countless small glades, the largest amount of unplowed, ungrazed, largely undisturbed glade grasslands that still survive in the southcentral United States may actually be found within the ancient forest-glade mosaic of the Cross Timbers.

The surprising abundance of ancient forests in the Cross Timbers of Oklahoma is not widely appreciated by public or private landowners. Admittedly, the ancient Cross Timbers hardly fulfill our notions about what an old-growth forests should look like. Ancient forest stereotypes remain focused on large trees, even though tree-ring research has emphatically demonstrated that tree size does not necessarily equate with great age. The 5000-year old bristlecone pine of California are the oldest living organisms known, but are in fact massive shrubs growing in one of the most hyperarid forest environments on earth. The ancient post oak of the Cross Timbers tend to average only 5 to 15 meters in height (15 to 40'), and 30 to 60 cm in diameter (10 to 20"), and are often dismissed as second growth "brush" by casual observers. But thousands of these living post oak trees were old growth when the United States gained independence. These extensive remnants of the ancient Cross Timbers are the unaltered representatives of the largest single forest type in Oklahoma and are an important component of the native vegetation of the southcentral United States.

The Cross Timbers form the arid western fringe of the eastern deciduous forest, and the trees of this formation are stunted in part by limited soil moisture. The ancient post oak of the Cross Timbers have proven to be particularly valuable for the tree-ring reconstruction of past climate. These trees live up to 400 years and are highly sensitive to growing season rainfall amounts. Tree-ring chronologies from 21 post oak sites extending from Texas, across Oklahoma, and into Kansas and Missouri have been used with other chronologies to reconstruct the summer Palmer Drought Severity Index (PDSI) for the coterminus United States (Cook et al. 1999). These trees have also been used in reconstuctions of the Southern Oscillation Index (SOI; Stahle et al. 1998), El Nino/Southern Oscillation (ENSO) influences on reconstructed PDSI (Cole and Cook 1998), and the past occurrence of false spring over the southcentral USA (Stahle 1990).

The University of Arkansas Tree-Ring Laboratory has initiated the Ancient Cross Timbers Project (ACTS) to locate the last remaining stands of undisturbed Cross Timbers using predictive models, satellite imagery, and field survey. We have recently completed the randomized field testing of a predictive model covering most of eastern Oklahoma and estimate that at least 41,975 hectares (162 square miles) of ancient Cross Timbers still survive in this portion of the state. In some remote parts of eastern Oklahoma, ancient Cross Timbers woodland still dominate the landscape, and include entire mountains and ridgelines covered with undisturbed forest, savanna, and glade vegetation.

The AMQUA 2000 fieldtrip will visit the Frank Tract west of Tulsa, Oklahoma, which is an outstanding example of the ancient Cross Timbers now under consideration for a public access forest preserve. The Frank Tract is located above the confluence of the Arkansas and Cimarron Rivers, and was visited by Washington Irving in 1832. This fieldtrip guidebook will provide a brief overview of the remote sensing of ancient Cross Timbers in the area, the ecological and historical significance of the Cross Timbers at the Frank Tract, and the tree-ring record of past climate extremes.

ANCIENT FOREST DEFINITION

The ancient forests that survive on rugged, noncommercial terrain in the Cross Timbers of Oklahoma are authentic examples of what these forests looked like before European settlement. Because these original presettlement forests did not provide valuable timber, farming, or grazing lands, these steep Cross Timbers have not been substantially disturbed by man. Dendrochronological analyses of core samples from thousands of living trees demonstrate that these ancient Cross Timbers are dominated by post oak trees in the 200- to 400-year age class. In addition to the dominant post oak, several other tree species achieve remarkable old age in the Cross Timbers, including the 300- to 500-year old eastern red cedar (*Juniperus virginiana*) which can often be found wherever the ancient oak forests are broken by rocky blufflines, glades, or barrens.

Beyond the undeniable antiquity of the living trees, the undisturbed Cross Timbers also exhibit the classic stand architecture of ancient forests. This includes the heavy, twisted, and weathered canopies of old post oak, and the mosaic of age classes that populate these forests. Sapling, juvenile, mature, and ancient trees, standing-dead snags, and fallen logs in various stages of decomposition are all evident in undisturbed Cross Timbers, and are typical of ancient forests in general.

Based on these observations, and extensive first-hand experience in the ancient forests of Oklahoma and elsewhere in North America, we believe that the Cross Timbers may be the least disturbed forest ecosystem that survives in the eastern United States. In fact, the post oak-blackjack oak forests of the Cross Timbers may have remained largely unchanged on these steep, coarse-textured soils of the forest-prairie margin since the post-glacial thermal maximum some 6,000 years ago. We do not believe that the Native American inhabitants of this region have had a major impact on the ecology of the ancient forests in the uplands of the Cross Timbers. The ancient Cross Timbers survive primarily on the steepest and roughest terrain where food resource values are low. Prehistoric utilization of these areas appears to have been light because we rarely find the stone and ceramic artifacts of past societies which are so common in the river valleys and in other ecological settings of Oklahoma. Only the most xerophytic oak species are common on these steep sites, and these oak woodlands are well adapted to the low-intensity ground fires which occasionally sweep through the forest floor, whether initiated by man or lightning.

THE ANCIENT CROSS TIMBERS PROJECT

The Ancient Cross Timbers Project is designed to locate the last remaining stands of undisturbed ancient forest cover in the Cross Timbers biogeographic province of eastern Oklahoma, to identify and describe the largest and best situated areas for conservation management, and to develop a draft ecosystem management plan for the individual, corporate, and public owners of these unique native Oklahoma woodlands. With funding from the McGee Foundation in Oklahoma City, we have developed a GIS-based predictive model to identify the last remaining stands of ancient Cross Timbers in eastern Oklahoma. The logic behind our predictive model to locate ancient Cross Timbers is simple: the entire Cross Timbers forest formation in Oklahoma is noncommercial for timber production. Cross Timbers on level terrain have been widely cleared, but much of the Cross Timbers on steeper terrain was not molested. Therefore, still forested land on steep slopes in the Cross Timbers ecosystem of eastern Oklahoma often retain original vegetation cover and truly ancient trees typical of the presettlement forest of eastern Oklahoma. These forest-covered lands on steep slopes can be readily identified using both satellite remote sensing and a digital elevation model of topography. Our predictive model is targeted on these still-wooded slopes in eastern Oklahoma, but first excluding the Ozark Plateau and Ouachita Mountains in eastern Oklahoma, because the forest of the Ozarks and Ouachitas both include commercially valuable timber and therefore have been much more disturbed than the Oklahoma Cross Timbers.

The predictive model uses three recent Landsat Thematic Mapper (TM) "scenes" taken during April of 1997 or 1998. Each scene covers 185 x 170 km, with a 30% overlap between adjacent scenes (Jensen 1996). We are using the false color infrared composite of bands 4, 3, and 2 to discriminate between forest and nonforest landcover (see cover, and Figure 5 which outlines the areas of predicted to retain ancient Cross Timbers near Keystone Lake). April scenes are used because the greatest contrast between vegetation types in the infrared and near infrared portion of the spectrum is usually obtained during the spring season. The Landsat imagery has a 30 x 30m pixel size, but the DEM we are using has a 60m spacing between sample points. Nevertheless, this is more than sufficient to identify forest land covering more than 10 hectares (ha).

The final predictive model we have designed and are currently field testing can be succinctly stated as:

> Forest-covered land (Landsat TM bands 4, 3, 2) on slopes >8%, and in parcels >15 ha (>40 acres) in size, in the Cross Timbers biogeographic province of eastern Oklahoma (Figure 2).

The areas identified with this model cover 210 square miles (134,400 acres or 54,390 ha) of eastern Oklahoma. These areas predicted to retain ancient forest cover are found on the steep slopes and cuestas of eastern Oklahoma, including the Osage Hills, Shawnee Hills, and outliers of the Ouachita Mountains (Figure 2). We have completed the systematic ground truth of the predictive model by randomly selecting 50 locations within the predicted polygons (Figure 3). We measured undisturbed ancient forest cover on 77% of the land within the 50 randomly selected standard size sample plots (50 x 200 m), and therefore estimate that ancient Cross Timbers survive on 162 out of the 210 square miles of predicted polygons in eastern Oklahoma alone. Twenty-eight of the transects sampled were 100% covered with ancient Cross Timbers, and eight more had over 75% ancient forest cover (Figure 3). We know that the predictive model underestimates the true amount of ancient Cross Timbers still left in the study area because old growth forest does exist on slopes <8% and in parcels smaller than 40 acres. We also found many additional ancient woodlands on lands adjacent to our predicted polygons that were not classified as forest cover with the TM bands used for these particular dates (perhaps reflecting differences in leaf flush during the early growing season). In spite of these problems, this predictive model has identified vast areas of largely undisturbed upland forest and will be a valuable conservation management tool. For example, we have identified ancient Cross Timbers in the uplands on both sides of the north Canadian River, just upstream from Lake Eufaula. The value of the ancient Cross Timbers in this area is considerably leveraged by the presence of the riparian ecosystems along this unmanaged reach of the Canadian River, which includes important habitat for least terns, an endangered species. The Frank Tract near Tulsa is another ancient Cross Timbers area of key concern because of its ecological and historical significance, and given its proximity to Tulsa and Stillwater.

ECOLOGICAL AND HISTORICAL SIGNIFICANCE OF THE FRANK TRACT, OSAGE COUNTY, OKLAHOMA

One of the largest and most interesting tracts of undisturbed Cross Timbers found during this research is located on public and private property in the dissected uplands above Keystone Reservoir in Osage County (Figures 4 and 5; Therrell and Stahle 1998). This outstanding tract covers approximately 4 square miles, and includes some 2.7 square miles of largely undisturbed forest, savanna, and glade vegetation. The three principal landowners of this tract are the U.S Army Corps of Engineers (COE; which manages the buffer zone of lands surrounding Keystone Reservoir), the Tulsa Audubon Society (TAS; which owns a 108 acre bald eagle preserve), and Mr. Irvin Frank of Tulsa, Oklahoma, who owns over 1000 acres in the heart of this tract (i.e., portions of Sections 27, 28, 32 and 33, T20N, R10E). This important tract is currently under consideration for the development of public access forest preserve.

The truly ancient trees are perhaps the most distinguishing feature of the undisturbed vegetation on the Frank Tract. The oldest post oak tree ever documented is located in this ancient forest (400+ years old), and we have determined the age of literally thousands of post oaks throughout its natural range from the Great Plains to the Atlantic Ocean. The oldest eastern red cedar ever documented in Oklahoma are also found on the Frank Tract (individual cedars exceed 500 years in age). In fact, all tree species found on the Frank Tract include many individuals at or above the natural longevity for the respective species. These species include blackjack oak, black oak (*Q. velutina*), black hickory (*Carya texana*), ash (*Fraxinus americana*), and winged elm (*Ulmus alata*), and shrub species in the genus *Vaccinium*.

The longevity of trees on the Frank Tract is certainly impressive, but the variety and integrity of the undisturbed plant communities found on this tract was emphasized by several professional botanists who visited this area during the October 27, 1995, fieldtrip of the Natural Areas Conference. The Frank Tract is dissected by several steep ravines that drain into the Arkansas River (now partially impounded by Keystone Reservoir). These ravines fragment the landscape into a wide variety of slopes and exposures, which dramatically modulate the intensity of solar radiation, evapotranspiration, and available soil moisture. The interesting mosaic of undisturbed vegetation cover on the Frank Tract reflects the variety of microenvironments associated with this complex terrain. Most of the major plant associations typically found in the Cross Timbers of Oklahoma are present on the Frank Tract in a nearly pristine condition. We know of no other single area of largely undisturbed terrain in eastern Oklahoma that presents such a broad cross-section of the vegetation types found in the Cross Timbers.

At least eleven vegetation associations can be identified at the Frank Tract based only on the dominant plant types (see Roe 1998 for an annotated checklist of vascular flora at the Frank Tract). These associations include: post oak-blackjack oak-hickory forests, post oak and red cedar forests on rocky soils, red cedar dominated blufflines, red cedar and black oak rocky ravines, black oak slopes, Shumard oak stands, sycamore lined ravines, post oak savannas, blackjack oak barrens, numerous grassy glade openings, and an un-plowed tallgrass prairie community on the ridge top. The tallgrass prairie and some of the post oak savanna, which are both found on more level soils on or near the ridge tops, are the only communitites at the Frank Tract with clear evidence for human disturbance. However, this disturbance appears to have been confined to grazing and the development of dirt roads and clearings associated with oil exploration. It is the general consensus of most professional ecologists who have visisted this site that both the tallgrass prairie and the post oak savanna communities can be restored with fire management.

The Cross Timbers are largely noncommercial for timber production, but the Frank Tract includes sizable individuals of red cedar, black oak, and post oak which might have been logged elsewhere. One could reasonably question why the diverse forests found on this tract have survived even selective logging. One possible explanation could be the relative isolation of the area by the very rugged terrain and the Arkansas River. The main channel of the River was located immediately against the base of the steep hillslopes on the western edge of the Frank Tract. The late settlement of Oklahoma could certainly be another factor. Oklahoma was only opened to settlement in 1889, and much of rural Oklahoma was depopulated during the depression, drought, and Dust Bowl of the 1930'3. Consequently, the native vegetation on rugged, remote, and relatively-inaccessible terrain often escaped heavy utilization during the two generations of settlement prior to the Depression.

The Frank Tract is located on the highest and most rugged uplands immediately above the confluence of the Arkansas and Cimarron Rivers. Lookouts on the Frank Tract present commanding views of the historical crossing of the Arkansas River often used by early exploration parties and pioneers. An important 19th century military road crossed the Arkansas just upstream from the confluence with the Cimarron, and then traveled westward through the upland prairies north of the Cimarron (the Dawson Road, Tomer and Brodhead 1992). The most famous crossing was made by the American writer Washington Irving in 1832, who appears to have crossed the Arkansas less than one mile north of the confluence, perhaps right across the Frank Tract. Irving (1835) described the Cross Timbers in general, and the terrain surrounding the Frank Tract in particular, in his book *A Tour on the Prairies* published in 1835. Irving's journey is celebrated in Oklahoma history and by the numerous place names associated with his visit, including "Bear's Glen" which is located just west of the Frank Tract across the Arkansas River.

In 1849 and 1850 Samuel Washington Woodhouse attended the boundary survey of the Creek Nation in Indian Territory and described the native fauna of the presettlement Cross Timbers (Tomer and Brodhead 1992). Woodhouse identified buffalo, elk, deer, black bear, gray wolf, coyote, fox, cougar, bobcat or ocelot, skunk, prairie dogs, jack rabbit, skunk, raccoon, opossum, turkey, greater prairie chicken, wood duck, white pelican, Bonaparts gull, Carolina rail, and many other birds, small mammals, and reptiles in the Cross Timbers ecosystem of 1849-50. He also described large flocks of passenger pigeons, numerous flocks of Carolina parakeets along the Arkansas River, and ivory-billed woodpeckers.

The undisturbed forest and glade vegetation of the Frank Tract provides excellent wildlife habitat, particularly due to its diversity, isolation, and proximity to the (impounded) Arkansas and Cimarron Rivers. The Tulsa Audubon Society has purchased 108 acres adjacent to the Frank Tract for an American bald eagle preserve. As many as 50 to 60 bald eagles have roosted on winter evenings in the deep ravines adjacent to Keystone Reservoir (Mr. John Kennington, TAS, personal communication). The number of eagles roosting on the Audubon Tract has gone down to perhaps 20 or 30 per night during the past few years, and this may in part reflect dispersal of the eagles into other roosting habitat along the Arkansas.

PALEOCLIMATIC VALUE OF THE ANCIENT CROSS TIMBERS

Drought and Wetness

The post oak trees of the Cross Timbers record regional and large-scale weather and climate extremes spanning the past 350 years. A network of precipitation-sensitive post oak chronologies has been developed from living trees and historic building timbers along the eastern margin of the southern Great Plains. These proxies provide an accurate history of past moisture anomalies, including several prolonged dry periods comparable to the 1930's Dust Bowl and 1950's drought.

One of the longest post oak chronologies has been developed from the ancient trees above Keystone Lake, Oklahoma (Figure 6). This chronology is highly correlated with growing season precipitation (March through June), and documents several decade-long climate extremes that appear to have had profound ecological and human consequences during the mid-19th century. The period from 1813 to 1850 in northcentral Oklahoma was the wettest episode in the past 350 years (above average tree growth was recorded for 32 out of 37 years, Figure 6). This coincides with a wet era across the central Great Plains region that Merlin Lawson (1974) has referred to as "the monsoon." The prolonged wetness of this monsoon era over northcentral Oklahoma culminated in 1826, which was the highest single year of post oak growth from 1650 to 1995 (Figure 6). The spatial pattern of reconstructed summer PDSI for 1826 is illustrated in Figure 7 (Cook et al. 1999), which documents widespread wetness over the western USA, particularly over the central Great Plains. The PDSI reconstructions for 1826 also indicate dryness over the Great Lakes and Northeast, a spatial anomaly pattern consistent with a classic reverse-Pacific North America circulation pattern.

Elliott West (1995) describes the dramatic growth in Native American population on the central High Plains between 1820 and 1850, drawn to the region by the abundant resources and the Santa Fe trade. Bison populations in this area were enormous prior to 1850 when several observers described the herds as "immense" and "innumerable" (West 1995). However, the favorably wet episode of the early 19th century ended with the prolonged drought and "environmental crisis" of the 1850's (West 1995). West describes a series of perverse interactions between climate, environment (especially in the "Big Timbers," the critical habitat islands along the major river corridors across the Great Plains), and human impacts during the 1850's that contributed to the disappearance of the bison from the central High Plains and the collapse of the Native American societies. The decade-long drought from 1855-1865 is well documented in tree-ring reconstructions of the summer PDSI (Cook et al. 1999). The most severe tree-ring reconstructed drought over the Southern Plains during this 1850's envirnomental crisis occurred during 1851. The drought anomaly map for 1851 is illustrated in Figure 7, and when compared with the reconstructions for 1826 provides vivid illustration of the extraordinary climatic changes that occurred over the Southern Plains from the early- to mid-19th century. It is also interesting to point out that the 1850's drought at Keystone appears to have been more severe than either the 1930's Dust Bowl or the 1950's drought (Figure 6), which of course had profound socioeconomic and environmental impacts. However, all three of these 19th and 20th century droughts were exceeded by the protracted drought which extended from 1785-1812 over northcentral Oklahoma, when tree growth at the Keystone Lake site was above average for just 3 out of 28 years (Figure 6).

ENSO

A reasonably strong teleconnection between ENSO and winter-spring precipitation has been detected over the Cross Timbers. Many post oak chronologies in this region record the long-range influence of El Nino and La Nina extremes, and have been used in conjunction with tree-ring data from Mexico and Indonesia to develop a reconstruction of the SOI back to A.D. 1706 (Stahle et al. 1998). Warm events in the eastern equatorial Pacific are usually associated with winter-spring wetness over the southern Great Plains, the Southwest, and northern Mexico. This classic teleconnection pattern is evident in the tree-ring reconstructions of summer PDSI over the coterminus USA for the year 1793 (Figure 8). Grove (1998) discusses archival evidence for the global impact of the ENSO event of 1789-1793, and asserts that it may have been one of the most severe ENSO events on record. The tree-ring reconstructions certainly indicate that there were strong climatic anomalies over the Southern Plains and Southwest consistent with warm ENSO conditions in 1793 (Figure 8).

False Spring

Ancient post oak of the Cross Timbers provide accurate proxies of regional and large-scale climate, but they also record the episodic impact of past wildfires and spring freeze events. Severe subfreezing temperatures during the growing season can damage the new shoot, bud, and cambial tissues of woody plants, and can seriously retard growth or even kill the organism. Freezing of the active cambial layer where the differentiation of xylem and phloem cells occurs will result in distinctive anatomical damage referred to as a "frost ring." Frost rings in oaks can be identified upon microscopic examination by the underlignified and deformed trachieds, irregular layers of collapsed vessels, and abnormal parenchyma cells (Figure 9). Frost injuries are common in the annual rings of deciduous oaks of the Cross Timbers, and a well replicated chronology of 70 frost ring years from 1650 to 1980 has been developed from 42 post oak collection sites across the southcentral USA (Stahle 1990). "False spring" conditions are responsible for frost ring damage to oaks of the Cross Timbers, which paradoxically include both an abnormally warm winter which prematurely advances tree growth in early spring, followed by an outbreak of severe subfreezing air in which minimum temperatures fall to or below -5°C (23°F). False spring therefore reflects both climatic and meteorological extremes, and is associated with widespread ecological and agricultural impacts (Figure 10). The Weekly Weather and Crop Bulletin (March 28, 1955) reported that the fruit crop was completely destroyed across the southern United States during the false spring event of 1955, and that *all* crops were killed or severely damaged from Texas to the Carolinas.

Major circulation changes over North America often occur from the warm to cold phase of false spring. An upper level trough over Southern California and a surface high over the Southeast favor warm air advection into the Southern Plains region during the extended warm phase (Figure 11 and 12). This pattern is then reversed by a deep upper level trough over the central to northeastern USA and a strong surface ridge usually extending from Canada to Mexico during the cold phase (Figure 11). The resulting cold air advection into the southcentral and eastern USA often causes heavy damage to crops and native vegetation, including the formation of anatomically distinctive frost rings in post oak. False spring often occurs during La Nina events, and appears to reflect an ENSO influence on above average temperatures over the Southern Plains, but well below average temperatures over Alaska and Canada. The warm winters over the Southern Plains favor the premature growth of plants, while the extreme cold air over Canada can be advected by deep low pressure disturbances into the Southern Plains to terminate false spring.

False spring occurrence has been nonrandom over the past 331 years (Figure 13). Several periods with a particularly high incidence of frost rings stand out: 1740-1745, 1810-1828, and 1920-1936, Figure 13). There were also several episodes free of any frost damage, including the 18-year long period from 1751-1769. No severe false spring events have occurred over the southcentral USA from 1975-2000, which might reflect the general absence of La Nina events, the secular warming of minimum temperatures, or both.

CONCLUSIONS

In spite of the relative abundance of ancient Cross Timbers in Oklahoma, the conservation value and scientific significance of these interesting undisturbed forests has been seriously under-appreciated. The Cross Timbers is the largest single forest type in Oklahoma, but to our knowledge there is not one single park or conservation area in the entire state specifically devoted to the recognition and protection of an ancient Cross Timbers forest. The Frank Tract and adjacent COE and TAS lands represent one of the most outstanding and diverse examples of the Cross Timbers vegetation type. Given its accessibility and proximity to Tulsa, the Frank Tract could serve as an focal point for the larger Cross Timbers ecosystem, and could help raise public and professional awareness concerning this authentic but little-known component of Oklahoma's natural heritage.

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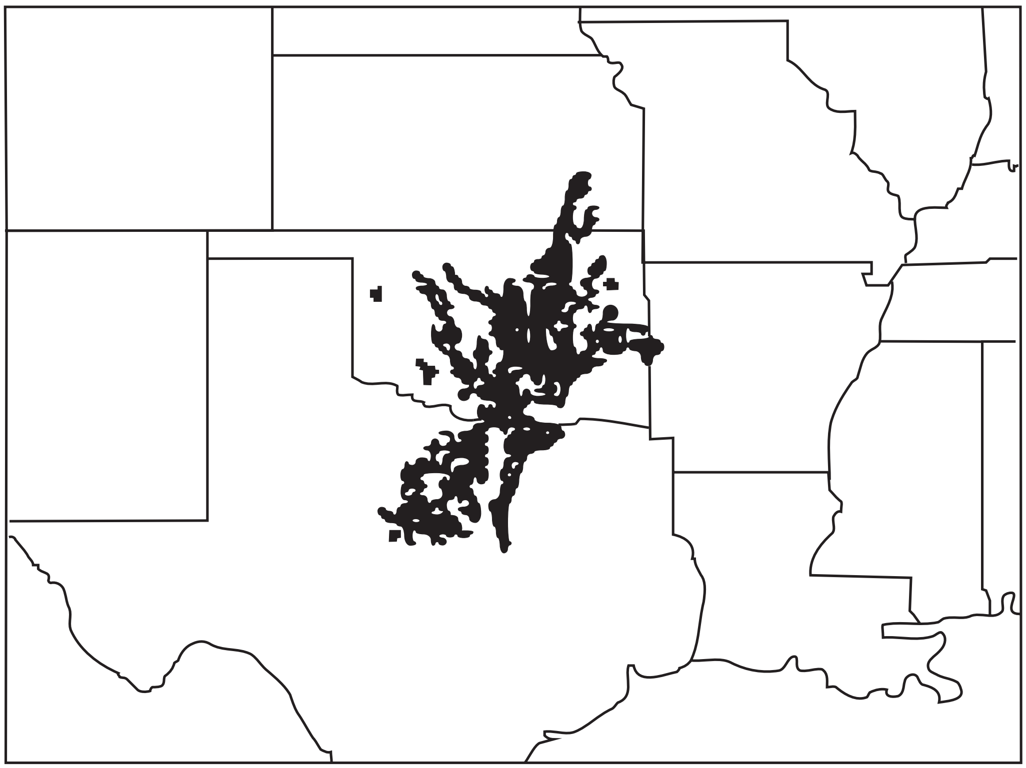


Figure 1. The potential natural distribution of the Cross Timbers forest type along the eastern margin of the southern Great Plains. This map was digitized from Kuchler (1964) and only includes Kuchler's type 75 ("Cross Timbers: Quercus-Andropogon"), which covers an estimated 7,909,700 hectares (30,526 square miles). Because this entire formation is composed largely of noncommercial forest, it may be the least disturbed forest type still left in the eastern United States.

Ancient Cross Timbers Project

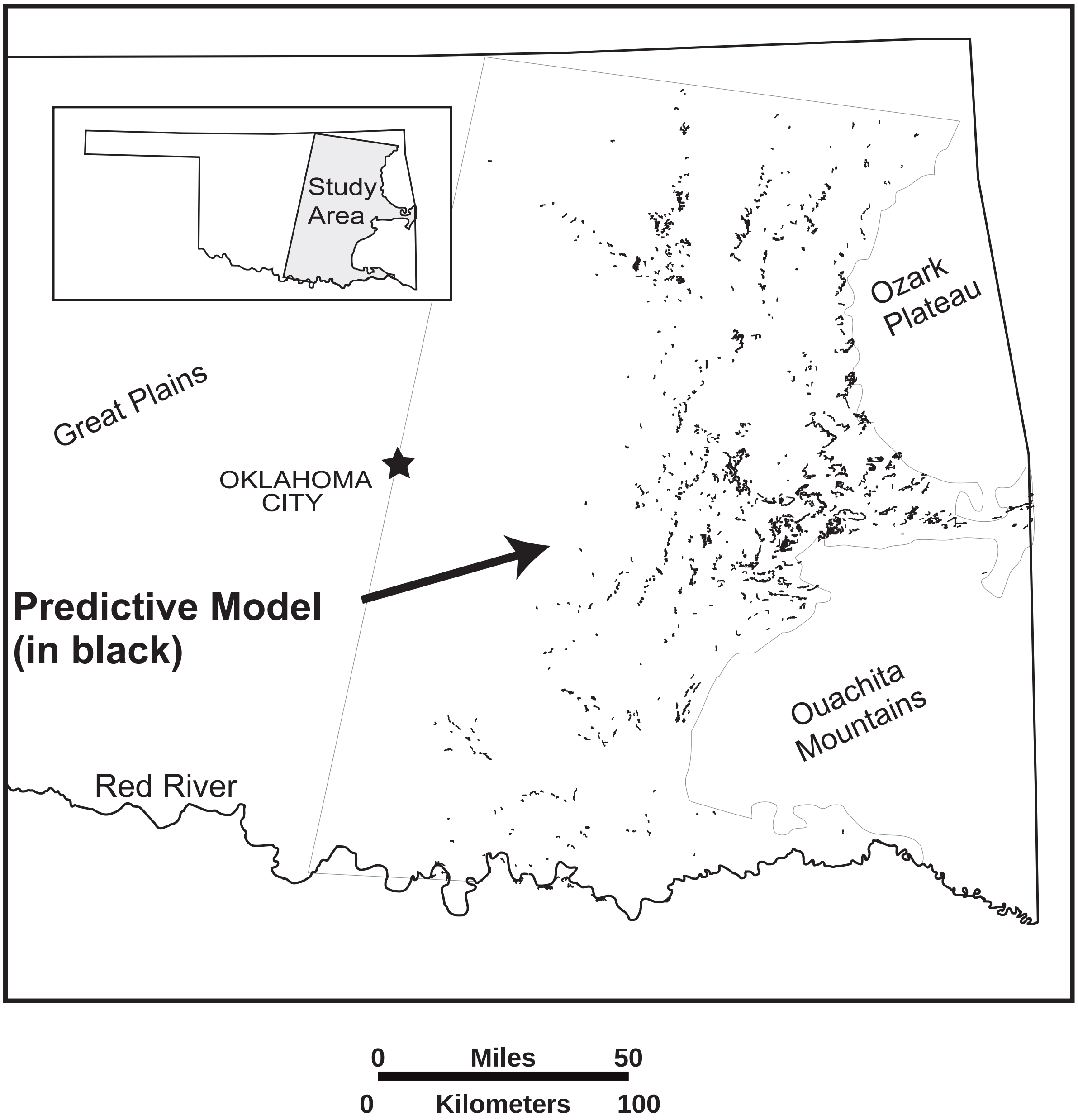


Figure 2. The 210 square miles of ancient Cross Timbers identified with our predictive model is shown in black. The predictive model is based on still forested land found on slopes >8% and in parcels >15 ha in size. The model generally identifies the slopes of mountains and cuestas that are still forested in eastern Oklahoma, and we are quite certain that it understates the true extent of old growth Cross Timbers in Oklahoma.

Ancient Cross Timbers Project

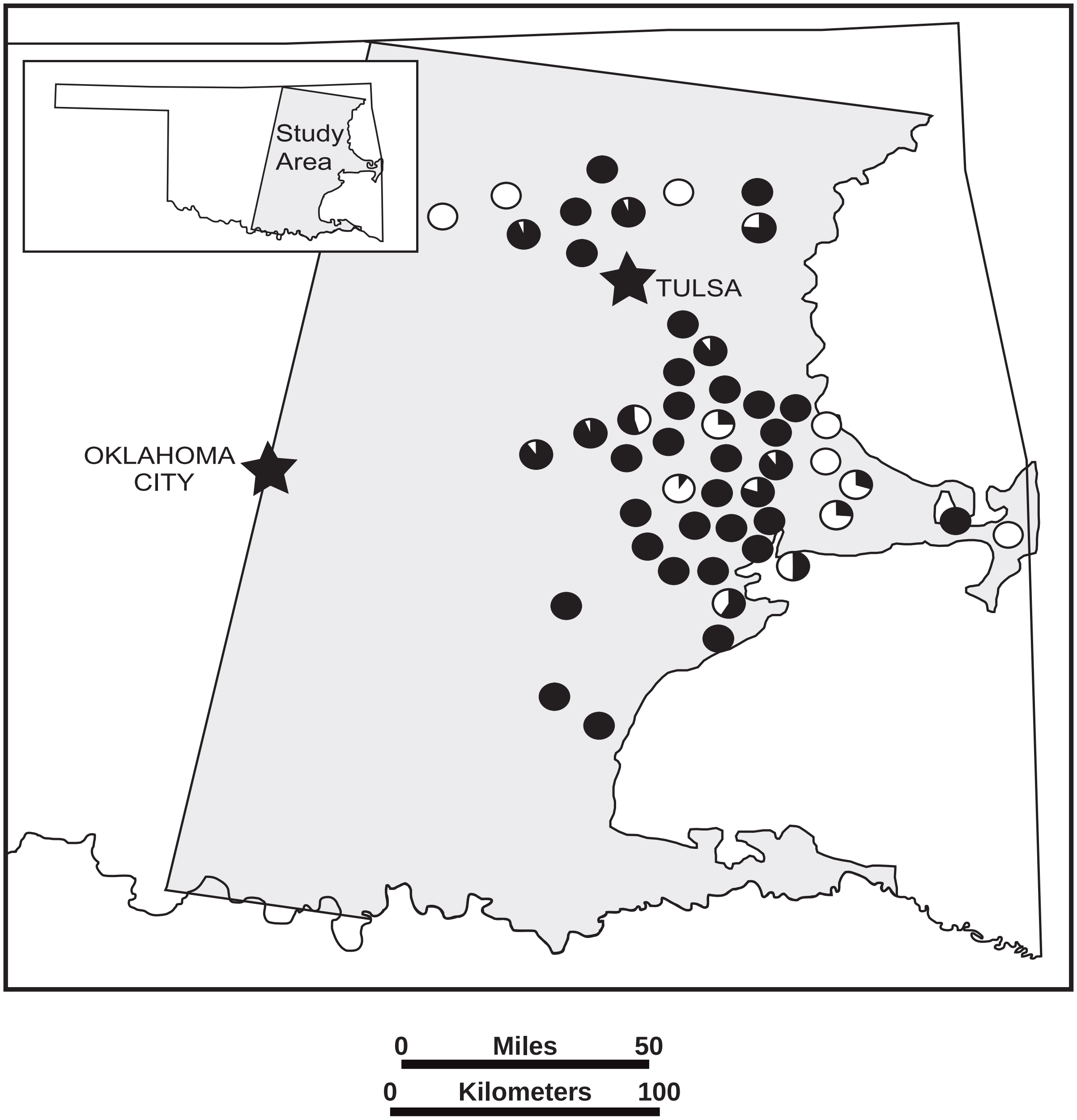
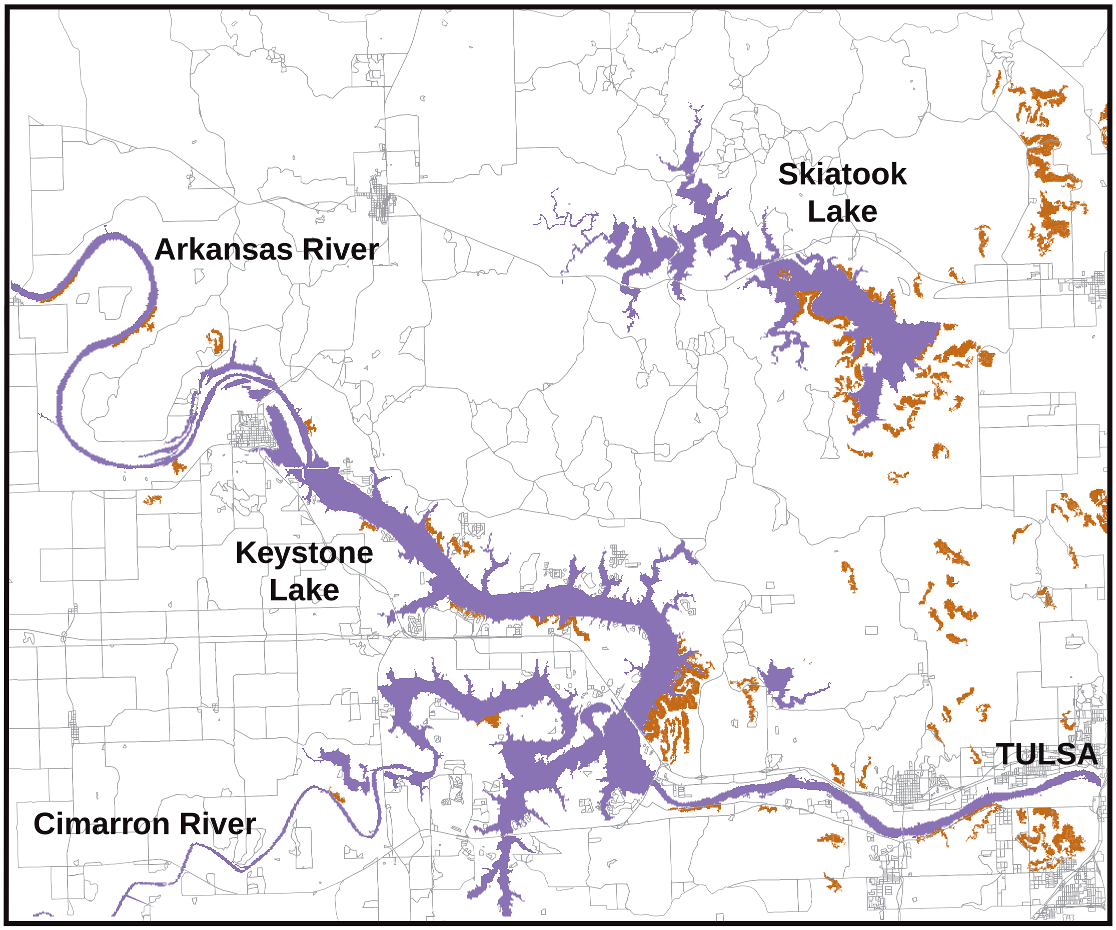


Figure 3. The ancient Cross Timbers predictive model (Figure 2) was tested at 50 randomly-selected belt transects (50 x 200m, locations indicated by the circles). The percent cover within each standard size transect was measured for four cover types: undisturbed ancient Cross Timbers, cull, second growth, and cleared land. The circle symbols are scaled to the percent ancient Cross Timbers cover found within each transect, from 0% (open circle) to 100% ancient forest (closed circle). Note the concentration of ancient Cross Timbers in eastcentral Oklahoma.

Keystone Lake Region-
Northcentral Oklahoma



Red = Predicted Old Growth Cross Timbers
Black =Roads

0 Miles 10

0 Kilometers 10

Ancient Cross Timbers Project

Figure 4. The predicted areas of ancient Cross Timbers northwest of Tulsa are illustrated in red. The Frank Tract is located on the southeast margin of Keystone Lake.

Keystone Lake
Northcentral Oklahoma

Landsat Thematic Mapper Imagery
Yellow Areas = Predicted Old Growth Cross Timbers

0 Miles 2

0 Kilometers 5

Ancient Cross Timbers Project

Figure 5. Landsat TM image for the Frank Tract. The ancient Cross Timbers predictive model is outlined in yellow. Forest cover is indicated by red. Many of the forested areas outside of the predictive

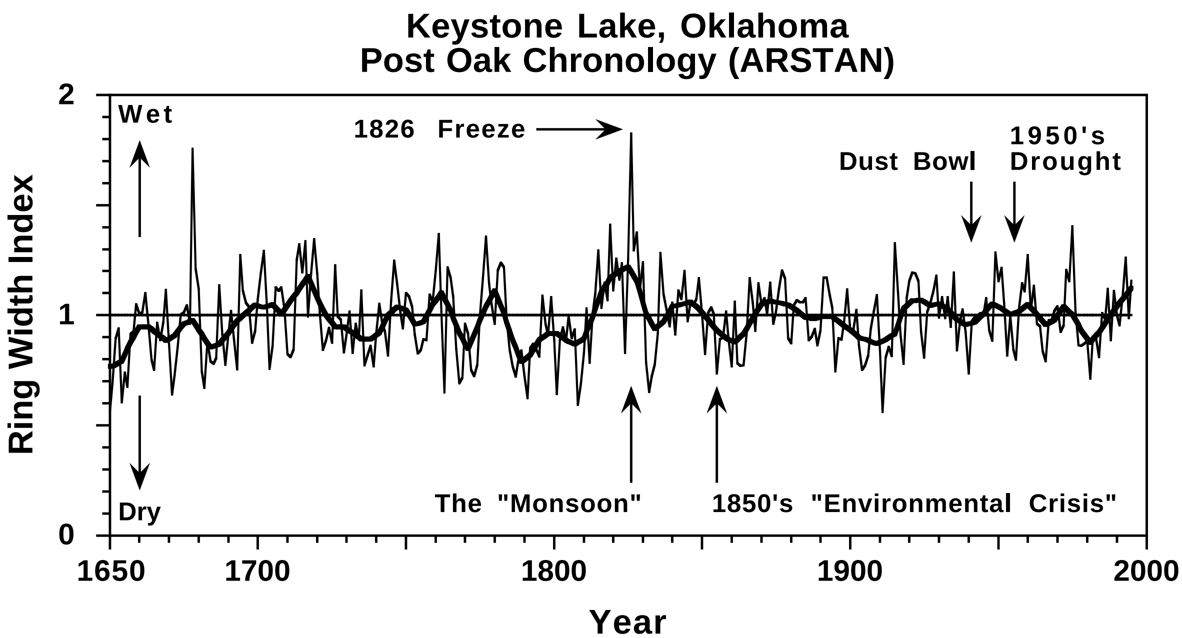


Figure 6. The standardized ring width chronology for post oak from the Frank Tract above Keystone Lake, Oklahoma. This chronology is positively correlated with spring precipitation (March-June), and several interesting climatic extremes are illustrated (see text).

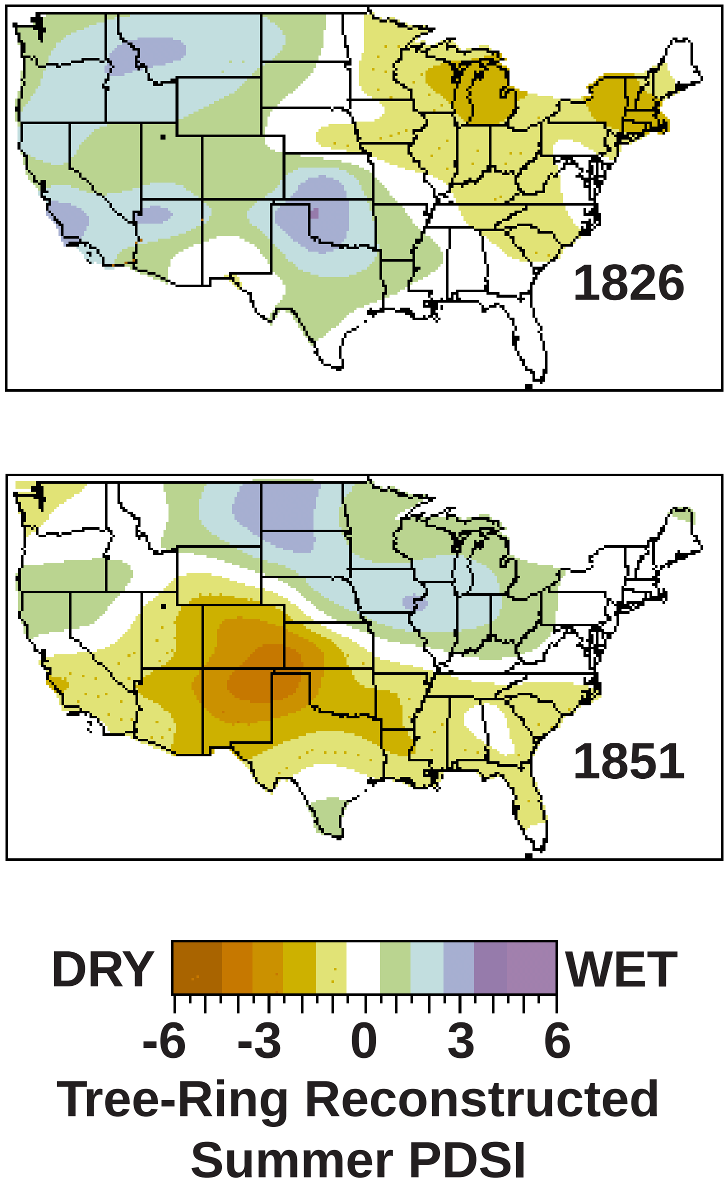


Figure 7. Tree-ring reconstructed summer (JJA) PDSI for 1826 and 1851 (Cook et al. 1999). These two years represent the opposite extremes of dramatic 19th century climatic changes that appear to have had a major impact on the ecology and human societies of the Southern Plains.

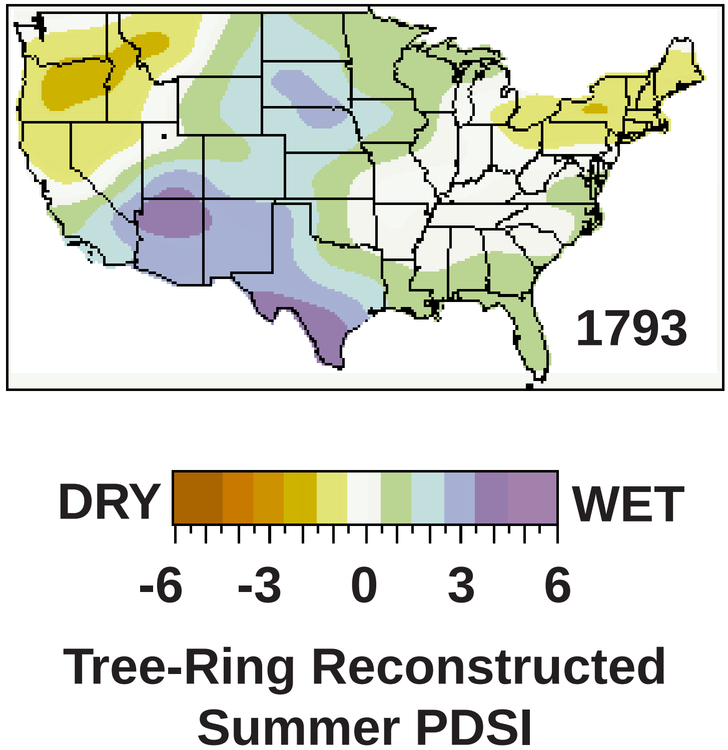


Figure 8. Tree-ring reconstructed summer PDSI for 1793 (Cook et al. 1999), which may have been one of the most intense El Nino events in recent centuries (Grove 1998). The reconstructed moisture gradient across the Cross Timbers and southern USA is the typical cool-season precipitation response to warm ENSO events.

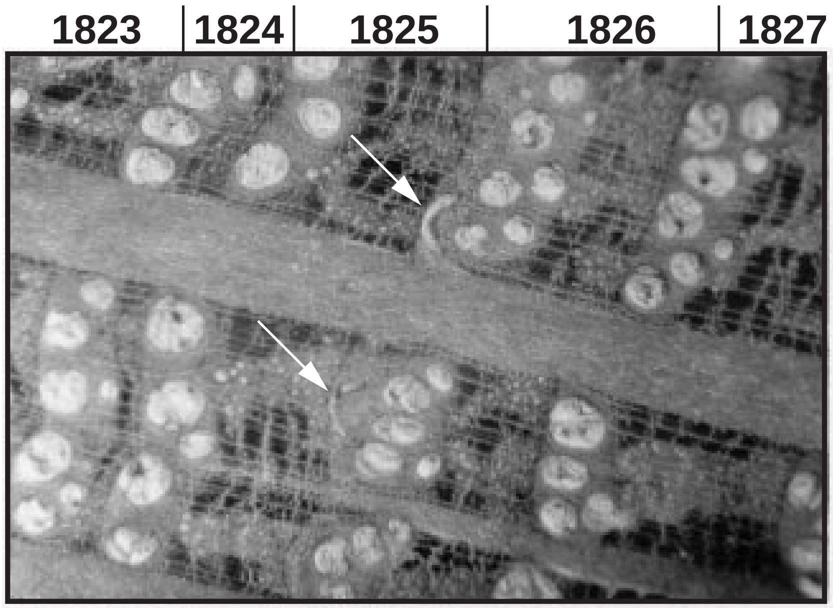


Figure 9. This polished transverse surface of a post oak specimen from Bluestem Lake, Oklahoma, illustrates the abnormal earlywood anatomy of a severely frost damaged ring for 1826 (Stahle 1990). Radial growth proceeded from left to right in this image, beginning with the large-diameter vessels of the earlywood, and ending with the dense fibre cells and terminal parenchyma of the latewood. The rings for 1824, 1825, and 1827 are not damaged and the earlywood vessels begin immediately adjacent to the latewood of the previous ring. The frost damaged ring for 1826 begins with a zone of traumatic growth, and note in particular the lunate vessels (arrows) which were collapsed by extracelluar freezing during the severe late-season frost of 1826. A band of normal vessel were then formed after the freeze event. Frost injury was more intense and widespread in 1826 over the southcentral USA than during any other year from 1650 to 1980. A broad medullary ray transects the annual rings from left to right in this image.

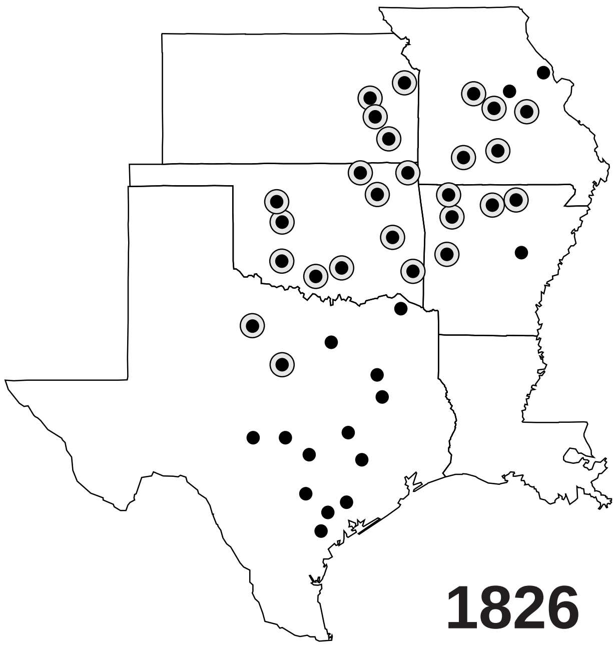


Figure 10. The spatial pattern of frost injury to post oak in 1826 and 1828. The distribution of all available tree-ring collection sites that date to 1826 and 1828 is indicated by the solid dots, and those sites with a statistically significant incidence of frost damage are indicated by the circled dots. The most intense frost ring event over the southcentral USA from 1650 to 1980 occurred in 1826. The false spring episode of 1826 implies a highly amplified large-scale atmospheric circulation over North America, with prolonged late-winter warmth and the subsequent outbreak of severe subfreezing temperatures over the central USA. Record wetness across the Southern Plains (Cook et al. 1999; Figure 7) and unprecedented flooding on the Red River of the North in Manitoba are also reported for 1826 (St. George 2000). The spatial pattern of frost damage in 1828 is very similar to 1826, and there are many vivid first-hand accounts of the damaging false spring event of 1828 (Stahle 1990). David Ludlum's (1968) summary of the warm phase of false spring in 1828 is particularly graphic: "The winter season of 1827-1828, or more truly the lack of it, constituted an outstanding event in the meteorological history of the eastern half of the United States. The wide geographical extent and the unbroken duration of the warmth appeared to be unique in the American experience. The consistent above normal zone extended from the Gulf of Mexico to Canada and westward encompassed all settled sections of the United States." At Little Rock, Arkansas, peach trees blossomed at Christmas of 1827, but these record warm conditions were abruptly terminated in early April of 1828 by a subfreezing airmass that destroyed fruit trees and crops across the South (Stahle 1990).

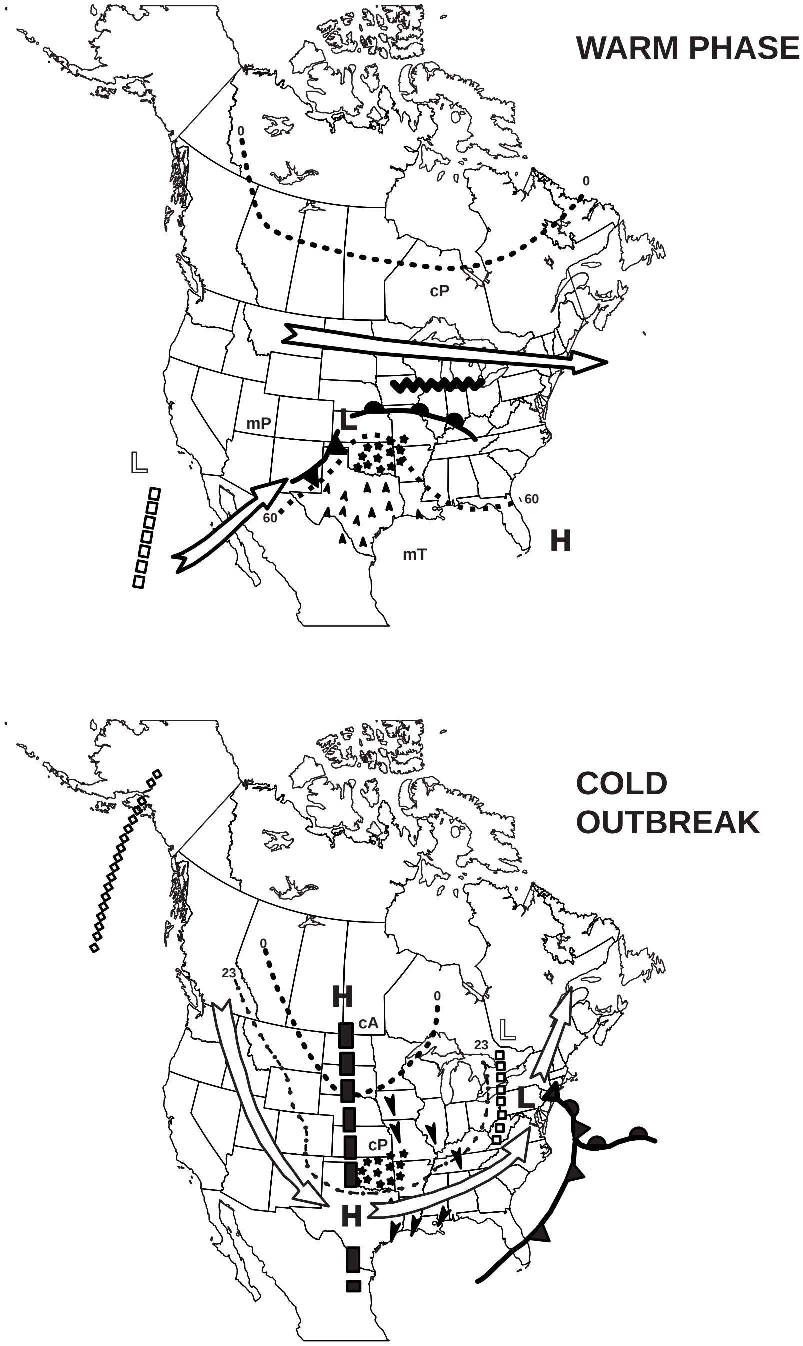


Figure 11. Composite weather maps illustrating the North American meteorological features typically associated with the warm (top) and cold phases (bottom) of false spring over the southcentral USA (Stahle 1990). The legend for this map is presented in Figure 12. Note the strong zonal flow across North America and the warm air advection into the Southern Plains during the warm phase. This zonal pattern breaks down during the cold phase when a deep low pressure disturbance at the surface and upper levels of the atmosphere advect intensely cold polar or arctic air into the Southern Plains and Southeast.

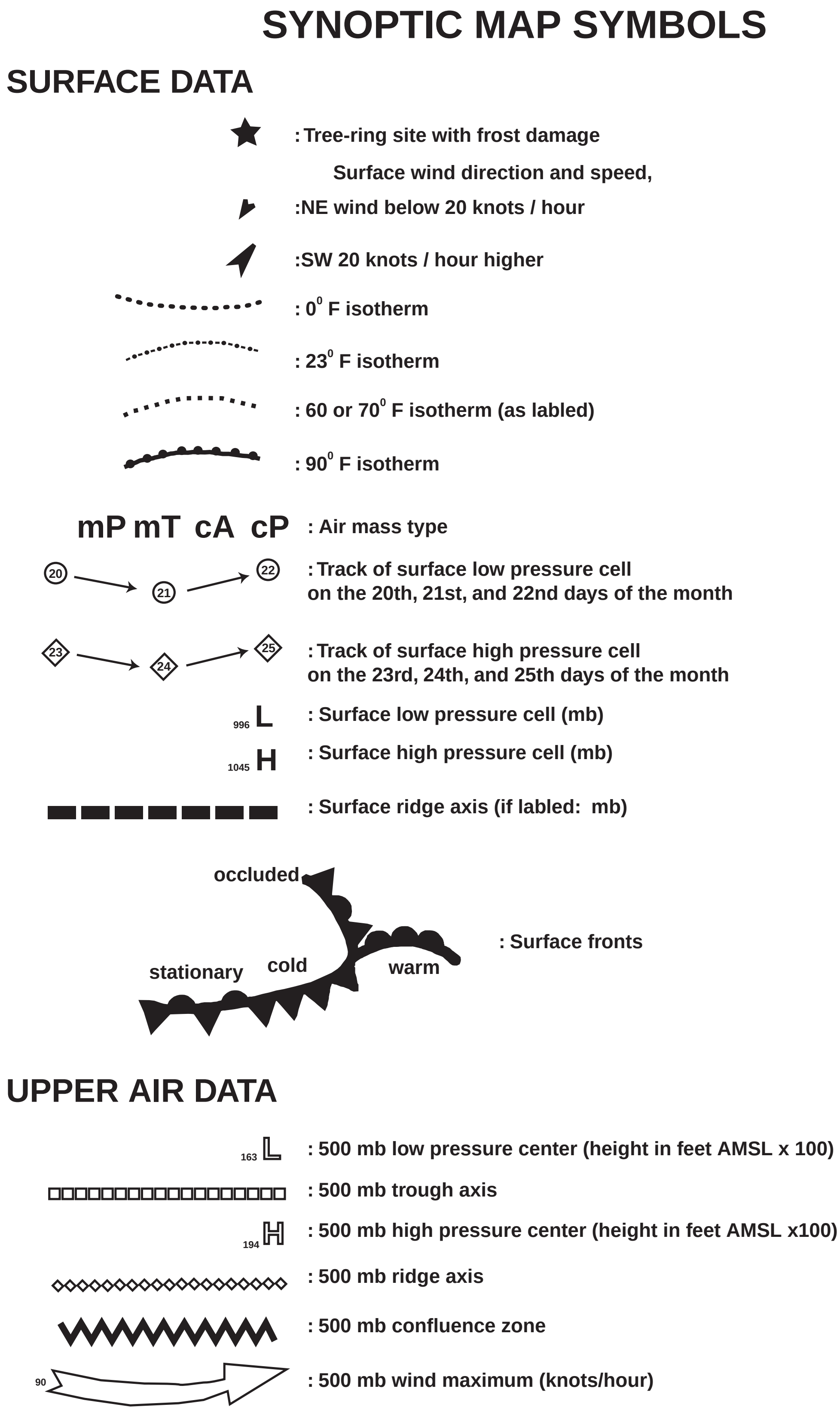


Figure 12. Map legend for Figure 11.

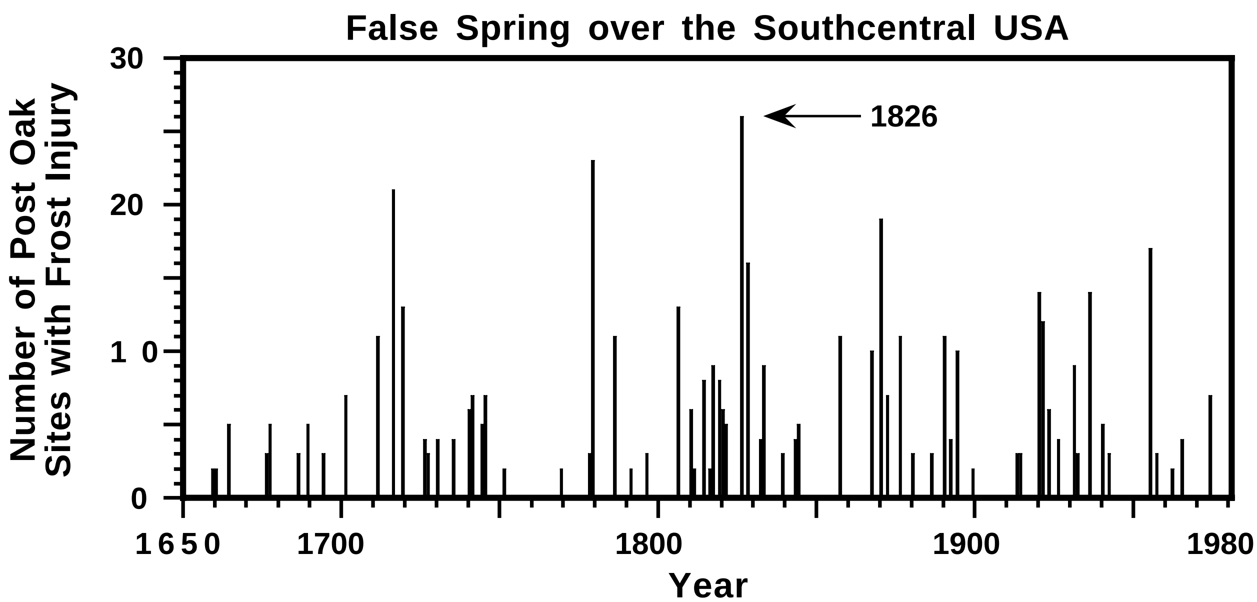


Figure 13. The summary frost ring chronology for all available collection sites from the Southern Plains region (Stahle 1990). The total number of sites with significant evidence for frost damage is a measure of the severity of false spring, and is plotted for all 70 events between 1650 and 1980. The five most extreme events occurred in 1716, 1779, 1826, 1870, and 1955. Note the clusters of recurrent false spring events in the 1730's and 1740's, the first half of the 19th century, and the 1920's and 1930's. The frequent false spring episodes of the early 19th century correspond to the wet episode referred to as the"monsoon" by Merlin Lawson (1974).