DECADAL-SCALE DYNAMICS OF A CROSSTIMBERS FOREST IN OSAGE COUNTY, OKLAHOMA

By

KELLY A MCGRATH

Bachelor of Science in Biology

Truman State University

Kirksville, MO

2005

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
July, 2012

DECADAL-SCALE DYNAMICS OF A CROSSTIMBERS FOREST IN OSAGE COUNTY, OKLAHOMA

Thesis Approved:

Michael W. Palmer

Thesis Adviser

Janette Steets

Rodney Will

Sheryl A. Tucker

Dean of the Graduate College

TABLE OF CONTENTS

Chapter One: The Structural and Compositional Dynamics of Oak Forests, with Special Reference to the Crosstimbers

Chapter Two: A Decade of Change in a Crosstimbers Forest Stand in Osage County, Oklahoma

CHAPTER I

The Structural and Compositional Dynamics of Oak Forests, with Special Reference to the Crosstimbers

The Crosstimbers offer an opportunity for long-term research regarding changes in forest species composition. Within a given forest, structure may vary through time (Oliver and Larson 1996). Stands with a similar structure through time (i.e. steady state) tend to have a large quantity of seedlings and saplings and few old stems (Oliver and Larson 1996). As time passes, the saplings increase in both height and diameter and are replaced by new recruits. In contrast, if a forest stand newly develops in an area (or when a stand recovers following disturbance), mortality due to interstem competition, or thinning, may occur (Peet and Christensen 1980, Oliver 1981). Many trees compete for light and other resources with the trees nearest them, and gradually the stem number in a given area decreases as the trees age. Diameter distributions of a thinning stand are often unimodal, with a high concentration of young, small stems, and few to no large ones. The stems within such a stand are often all of the same age (called single age), originating from a large recruitment event.

Once density-dependent mortality thins the stand to an equilibrium number of trees, diameter distributions are often bimodal or more commonly reverse-*J* (Oliver and

Larson 1996, Clark et al. 2005, Li et al. 2008, Bragg et al. 2012). In reverse *J* distributions, the number of stems declines as a function of size class. Abundant small stems are typically suppressed in the understory. The understory trees either die or are 'released' after the death of a canopy tree and then grow relatively quickly (Peet and Christensen 1987). Because forests with reverse-*J* and bimodal distributions exhibit continuous recruitment, such forests are typically mixed age stands (Clark et al. 2005, Bragg et. al 2012).

Once attaining a bimodal or reverse-*J* diameter distribution, forest structure is usually maintained (Kucbel et al. 2012). In this phase, mortality events within the stand that decrease the stem number and basal area are balanced by recruitment and growth of smaller stems. This is perhaps the most basic definition of a stand maintaining itself. Studies on the mechanisms of this balance often include models such as gap dynamics and catastrophic cycles (Oliver and Larson 1996, Olano and Palmer 2003). However, the connection between a reverse-*J* or bimodal diameter structure and a steady state forest does not hold for every forest type (Lowenstein et al. 2000)

Forest structure is also in part determined by its species composition. The species that are found within the forest affect the dynamics of recruitment, basal area increment, diameter distributions (Li et al. 2008). Many forests undergo changes is species composition over time, which also changes their structure. Based on location and initial species composition, a forests structure and composition may change in predictable ways. This change in species composition through time is known as succession (Connell and Slayter 1977, Oliver and Larson 1996, D'Amato et al. 2008).

Succession may be occurring in *Quercus* forests in North America (and elsewhere) as many oak forests are in a state of flux (Abrams 1996, 2003). Many *Quercus* forests are experiencing a shift in species composition that often leads to replacement by other species (Abrams 2003, Alexander and Arthur 2010). In these forests, recruitment of *Quercus* does not compensate for its loss (Abrams 2003, Rynicker et al. 2006, Holzmueller et al. 2011), and more mesic species such as *Acer* are moving into the canopy and becoming dominant (Abrams 1996, Rodewald and Abrams 2002). This change in composition alters many aspects of the forest, including nutrient availability, ecosystem services such as wildlife habitat, and hydrology (Rodewald and Abrams 2002, Alexander and Arthur 2010). The change to more mesic species may be successional, or a result of fire suppression and climate change (Abrams 1996, DeSantis et al. 2011).

The Crosstimbers is a xeric, *Quercus*-dominated forest, forming a north-south ecoregion extending from Kansas to central Texas (Küchler 1964). Although it is an oak dominated system, it does not appear to be successional, and has not been subject to fire suppression (Stahle 2002, Shirakura at al. 2006, Allen et al. 2009, Allen and Palmer 2011).

The two dominant oak species in the Crosstimbers are blackjack oak (*Quercus marilandica*) and post oak (*Quercus stellata*). The Crosstimbers represents the western edge of the range for both species. *Quercus stellata* is a member of the white oak group (*Quercus* section *Quercus*) and can live up to ~400 years, sometimes achieving heights of 25m (Nixon 1997). *Q. marilandica* is a member of the red oak group (*Quercus* section *Lobatae*), and has a typical lifespan of ~150 years, reaching heights of 15m (Nixon

1997). Neither species is considered particularly valuable commercially due to their slow growth and inaccessible locations, and as a result many areas of Crosstimbers have not been disturbed by harvesting (Therrell and Stahle 1998, Stahle 2002).

Because of this, Crosstimbers forest may be the most undisturbed forest in the eastern United States (Therrell and Stahle 1998, Stahle 2002, Bragg et al. 2012). Its presence is closely tied to edaphic factors: forest is most likely to be found on sandstone-derived soils, while prairies are more often found on limestone-derived soils (Therrell and Stahle 1998, Francaviglia 2000). The Crosstimbers frequently borders tallgrass prairie, where it forms both closed-canopy stands and a mosaic of savanna and glades.

Crosstimbers forest forms an ecotone between the eastern hardwood forest of the eastern United States and the western prairies (Küchler 1964, Dykstehuis 1948, DeSantis et al. 2011). As an ecotone, the Crosstimbers, can be especially vulnerable to stressors like drought (Risser 1995, DeSantis et al 2011). These stresses can cause changes in vegetation composition and structure (Risser 1995). Changes in ecotones can be used as harbingers of coming change (DeSantis et al. 2011).

Through much of Oklahoma, the Crosstimbers are changing species composition (DeSantis 2011, Burton et al. 2010). However, in some areas *Quercus* remains dominant (Therrell and Stahle 1998, Francaviglia 2000, Arévalo 2002, Clark and Hallgren 2005, DeSantis et al. 2010). As such, the Crosstimbers present an opportunity for long term study regarding changes in *Quercus* forest in myriad conditions. However, to study change we must know the past and current state of the Crosstimbers.

Unlike other *Quercus* forests in North America, previous research in the Crosstimbers forests have not generally included certain descriptive statistics for all stems within the stand (i.e. diameter distributions, basal area calculations, tree heights, or ages) and/or they focus on relatively small areas with few stems. This prevents a thorough understanding of the dynamics that create and maintain the structure and composition of the Crosstimbers. Most studies of the Crosstimbers have focused on old growth stands (Therrell and Stahle 1998, Stahle 2002, Clark et al. 2002, Clark and Hallgren 2003, Clark et al. 2005, DeSantis et al 2010, Bragg et al. 2012), or on disturbance within a Crosstimbers stand (Shirakura et al. 2006, Burton et al. 2010, Myster and Malahy 2010). Little long-term work and detailed study of the Crosstimbers composition and structure has been conducted (except see DeSantis et. al 2010). Without a basic understanding of the structure and function of this forest, the opportunity to study changes regarding oak forests and climate change is greatly diminished.

In my work, I use data from a long-term permanent plot of Crosstimbers forest to begin addressing these issues. In 1998, José Ramón Arévalo and Michael W. Palmer at Oklahoma State University set up a 4ha long term research plot, consisting of ~7,600 stems, in a stand of Crosstimbers located at the Tallgrass Prairie Preserve (TGPP) in Osage County, Oklahoma (Figure 1.). I began working in this forest stand in 2008. Owned by the Nature Conservancy, the TGPP consists of ~15,400ha of land in Osage County, Oklahoma. The research plot lies on a western facing slope (3-25%), with Niotaze-Darnell complex soils and a sandstone shoulder running north-south through the center of the plot (Bourlier et al. 1979). The stand has several open areas (Figure 2), and some washes that run down the slope. This land was a former ranching operation in the

1900’s until 1989 when the Nature Conservancy purchased it (Allen et al. 2009), and the stand is fairly close to the original ranch house. The Conservancy uses a patch-burn plan that involves any given area burning approximately once every 3 years (Hamilton 2007), so I can infer that the site has likely burned at least seven times in the last 23 years. This burn frequency is within the range of variation of the fire regime over the past three centuries (Allen and Palmer 2011).

Here, I describe this forest stand in both 1998 and 2008 using diameter distributions, stem density, and basal area. I document the changes that occurred over the 10-year period between sampling and resampling, including mortality rates and growth. I measure heights and took increment cores of a subset of trees within the stand to determine stand age. Using these data, I ask the following questions: Is the stand in a steady state? What is the stand’s age, structure, and species composition? What differences are there, if any, in size-specific growth and mortality of the two dominant species, *Q. stellata* and *Q. marilandica*? How do these results compare to other *Quercus* forests?

Figure 1. Study Site

Photograph taken from the bottom of the southwest-facing slope. Both the northeast and southwest sides of the study plot are bordered by prairie. Photograph by K. McGrath

Figure 2. Gap within the stand

An opening within the stand, taken during leaf off in November 2011. This photograph also shows the typical rocky sandstone found in Crosstimbers forest. Photograph by K. McGrath

References

Abrams, M. D. 1996. Distribution, historical development and ecophysiological attributes of oak species in the eastern United States. Annales Des Sciences Forestieres **53**:487-512

Abrams, M. D. 2003. Where has all the white oak gone? Bioscience **53**:927-939

Alexander, H. D. and M. A. Arthur. 2010. Implications of a predicted shift from upland oaks to red maple on forest hydrology and nutrient availability. Canadian Journal of Forest Research-Revue Canadienne De Recherche Forestiere **40**:716-726

Allen, M. S., R. G. Hamilton, U. Melcher, and M. W. Palmer. 2009. Lessons from the Prairie: Research at The Nature Conservancy's Tallgrass Prairie Preserve. Stillwater, Oklahoma: Oklahoma Academy of Sciences. 44pp

Allen, M. S. and M. W. Palmer. 2011. Fire history of a prairie/forest boundary: more than 250 years of frequent fire in a North American tallgrass prairie. Journal of Vegetation Science **22**:436-444

Arévalo, J. R. 2002. Distribution of trees and saplings at the edge of cross timbers forests, Oklahoma, USA. Natural Areas Journal **22**:99-107

Bourlier, B. G., J. D. Nichols, W. J. Ringwald, P. J. Workman, and S. Clemmons. 1979. Soil Survey of Osage County, Oklahoma. Soil Survey of Osage County, Oklahoma.164 pp.

Bragg, D. C., D. W. Stahle, and K. C. Cerny. 2012. Structural Attributes of Two Old-Growth Cross Timbers Stands in Western Arkansas. American Midland Naturalist **167**:40-55

Burton, J. A., S. W. Hallgren, and M. W. Palmer. 2010. Fire Frequency Affects Structure and Composition of Xeric Forests of Eastern Oklahoma. Natural Areas Journal **30**:370-379

Clark, S. L. and S. W. Hallgren. 2003. Dynamics of oak (*Quercus marilandica* and *Q-stellata*) reproduction in an old-growth cross timbers forest. Southeastern Naturalist **2**:559-574

Clark, S. L. and S. W. Hallgren. 2004. Age estimation of *Quercus marilandica* and *Quercus stellata*: applications for interpreting stand dynamics. Canadian Journal of Forest Research-Revue Canadienne De Recherche Forestiere **34**:1353-1358

Clark, S. L., S. W. Hallgren, D. W. Stahle, and T. B. Lynch. 2005. Characteristics of the Keystone Ancient Forest Preserve, an old-growth forest in the Cross Timbers of Oklahoma, USA. Natural Areas Journal **25**:165-175

Connell, J. H. and R. O. Slayter. 1977. Mechanisms of Succession in Natural Communities and Their Role in Community Stability and Organization. The American Naturalist **111**: 1119-1144

D’Amato, A. W., D. A. Orwig, and D. R. Foster. 2008. The influence of successional processes and disturbance on the structure of *Tsuga canadensis* forests. Ecological Applications **18**:1182-1199

DeSantis, R. D., S. W. Hallgren, T. B. Lynch, J. A. Burton, and M. W. Palmer. 2010. Long-term directional changes in upland *Quercus* forests throughout Oklahoma, USA. Journal of Vegetation Science **21**:606-615

DeSantis, R. D., S. W. Hallgren, and D. W. Stahle. 2011. Drought and fire suppression lead to rapid forest composition change in a forest-prairie ecotone. Forest Ecology and Management **261**:1833-1840

Dyksterhuis, E. J. 1948. The vegetation of the western Crosstimbers. Ecological Monographs **18**:325-376

Francaviglia, R. V. 2000. The cast iron forest : a natural and cultural history of the North American Cross Timbers. Pages 276 . Corrie Herring Hooks series ; no. 43. University of Texas Press, Austin. 276pp

Hamilton, R.G. 2007. Restoring heterogeneity on the tallgrass prairie preserve: applying the fire–grazing interaction model. In: Masters, R.E. & Galley, K.E.M. (eds.) Proceedings of the 23rd Tall Timbers fire ecology conference: fire in grassland and shrubland ecosystems. pp. 163–169. Tall Timbers Research Station, Tallahassee, FL, US

Holzmueller, E. J., J. W. Groninger, C. M. Ruffner, and T. B. Ozier. 2011. Composition of oak stands in the Illinois Ozark Hills 2 decades following light harvesting and no cutting. Northern Journal of Applied Forestry **28**:50-53

Kucbel, S., M. Sangia, P. Jaloviar, and J. Vencurik. 2012. Stand structure and temporal variability in old-growth beech-dominated forests of the northwestern Carpathians: A 40-years perspective. Forest Ecology and Management **264**:125-133

Küchler, A.W. 1964. Manual to accompany to map of potential natural vegetation of the conterminous United States. American Geographic Society. Special Publication **36**

Li, L., S. G. Wei, Z. L. Huang, W. H. Ye, and H. L. Cao. 2008. Spatial patterns and interspecific associations of three canopy species at different life stages in a subtropical forest, China. Journal of Integrative Plant Biology **50**:1140-1150

Lowenstein, E. F., P. S. Johnson, and H. E. Garrett. 2000. Age and diameter structure of a managed uneven-aged oak forest. Canadian Journal of Forest Research. **30**:1060-1070

Myster, R. W. and M. P. Malahy. 2010. Tornado effects on damage, resprouting and spatial heterogeneity in the Cross Timbers ecotone of Oklahoma, USA. Journal of Plant Ecology-Uk **3**:157-163

Nixon, K. C. 1997. *Quercus* In: Flora of North America Editorial Committee, eds. 1993+. Flora of North America North of Mexico. 16+ vols. pp. 356-357. New York and Oxford. Vol. 3

Olano, J. M. and M. W. Palmer. 2003. Stand dynamics of an Appalachian old-growth forest during a severe drought episode. Forest Ecology and Management **174**:139-148

Oliver, C. D. 1981. Forest development in North-America following major disturbances. Forest Ecology and Management **3**:153-168

Oliver, C. D. and B. C. Larson 1996. Forest stand dynamics. Wiley, New York. 520pp

Peet, R. K. and N. L. Christensen. 1980. Succession- A population process. Vegetatio **43**:131-140

Peet, R. K. and N. L. Christensen. 1987. Competition and tree death. Bioscience **37**:586-595

Risser, P. G. 1995. The status of the science examining ecotones-A dynamic aspect of landscapes is the area of steep gradients between more homogeneous vegetation associations. Bioscience **45**:318-325

Rodewald, A.D. and M. D. Abrams. 2002. Floristics and avian community structure: Implications for regional changes in eastern forest composition. Forest Science **48**:267-272

Ryniker, K. A., J. K. Bush, and O. W. Van Auken. 2006. Structure of Quercus gambelii communities in the Lincoln National Forest, New Mexico, USA. Forest Ecology and Management **233**:69-77

Shirakura, F., K. Sasaki, J. R. Arevalo, and M. W. Palmer. 2006. Tornado damage of *Quercus stellata* and *Quercus marilandica* in the cross timbers, Oklahoma, USA. Journal of Vegetation Science **17**:347-352

Stahle, D. W. 2002. The unsung ancients. Natural History **111**:48.

Therrell, M. D. and D. W. Stahle. 1998. A predictive model to locate ancient forests in the Cross Timbers of Osage County, Oklahoma. Journal of Biogeography **25**:847-854

CHAPTER II

A Decade of Change in a Crosstimbers Forest Stand in Osage County, Oklahoma

Introduction

The Crosstimbers are a part of the *Quercus*-dominated forests that spread throughout the eastern United States (Abrams 1992). *Quercus* is the single most abundant tree genus in the northern hemisphere, and has great economic and environmental importance (Arno 1995). Oak forests in the United States have been undergoing structural and species composition changes (Abrams 1992, 1996, 2003, Zaczeck et al. 2002, Alexander and Arthur 2010, Fan et al. 2011, Holzmueller et al 2011). Some of these changes include 'mesophication', a change in the species composition where oaks are failing to recruit and species composition is shifting toward more mesic tree species such as *Acer saccharum* (Abrams 1996, Nowacki and Abrams 2008, Alexander and Arthur 2010). Climate change is also playing a role in changing forest species composition and mortality, due to droughts and heat stress (Alexander and Arthur 2010, Koepke et al. 2010, DeSantis et al. 2011, Heyder et al. 201l).

These changes in structure and species composition are indicated by changes in mortality and recruitment of trees, which species occupy the most basal area, and changes in diameter distributions. Forests that are maintaining themselves will typically be in a steady state, with recruitment balancing mortality and fairly constant basal area and diameter distributions (Oliver and Larson 1996). In contrast, forests that are past establishment but not yet in steady state or have experienced a catastrophic disturbance might be undergoing thinning (i.e.- density dependent mortality of stems). These stands will typically be gaining basal area while losing stem density, and diameter distributions will change over time (Oliver and Larson 1996, Peet and Christensen 1987).

Unlike many of the oak forests in North America, some areas of the Crosstimbers show little change in species composition (Stahle and Therrell 1998, Stahle 2002, Arévelo 2002, Shirakura et al. 2006, Clark and Hallgren 2003, Clark et al 2005., Bragg et al 2012). Very little is known about the dynamics of Crosstimbers forest, which may be the largest system of relatively undisturbed forest in the eastern United States and has many areas of old growth (Therrell and Stahle 1998, Stahle 2002, Clark et al. 2005, Bragg et al. 2012). Adapted to fire, the Crosstimbers are composed almost exclusively of post oak (*Quercus stellata*) and blackjack oak (*Quercus marilandica*). It is a xeric forest composed of a mosaic of savannas, glades, and forest stands forming a north-south ecoregion that extends from Kansas to central Texas (Dyksterhuis 1948, Arévalo 2002).

While many eastern forests have experienced fire suppression over the last few centuries, most Crosstimbers forests have experienced an uninterrupted and frequent fire regime (Shirakura et. al. 2006, Allen and Palmer 2011). Crosstimbers forest is believed to have existed in its current form in the southern Great Plains since the beginning of the most recent interglacial period (Francaviglia 2000, Stahle 2002, Clark et al. 2005). Crosstimbers species do not readily or frequently colonize disturbed or unburned areas, nor is there a known successional phase leading to it or from it (Burton et al. 2010, DeSantis et al. 2010). Some studies indicate shifts in species composition and forest structure, including size distribution of the trees, basal area of species present, and age distribution (Burton et al 2010, DeSantis et al 2010), often tied to areas where fire suppression has occurred, or to severe drought.

The Crosstimbers are an ecotone, the last forest at the edge of the western prairies (Dyksterhuis 1948, Arévalo 2002). Both of the co-dominant oak species, *Q. stellata* and *Q. marilandica*, are at the western edge of their range. As an ecotone, the Crosstimbers can be especially sensitive to environmental changes, with stress leading to changes in species composition and more mortality events (Risser 1995, Koepke et al. 2010). Because of this, studies of structural or species composition changes in the Crosstimbers can give us an early idea of what environmental changes, such as climate change might have on other oak forests around the world (Koepke et al. 2010, DeSantis et al. 2011). To date, few studies have looked for long-term changes in the Crosstimbers (but see Stahle 2002, DeSantis et al. 2010) or detailed Crosstimbers stand dynamics.

The purpose of this study was to document the dynamics of a mapped Crosstimbers forest stand from 1998 through 2008. Based on previous research in the Crosstimbers (Dyksterhuis 1948, Therrell and Stahle 1998, Clark et al. 2005), I hypothesize the forest stand will display steady state dynamics in which mortality is balanced by recruitment, and thus the species composition (type of species present and ratio of species) and structure (age and size distribution of stems, basal area of the species) of the stand is maintained (Oliver and Larson 1996, D'Amato et al 2008, Olano and Palmer 2003, Bragg et al. 2012). The Crosstimbers historical presence and non-successional nature make finding steady state dynamics a reasonable expectation. If indeed the forest is in a steady state, this would indicate the stand is maintaining itself, something most *Quercus* forests throughout North America are not (Elliot and Swank 1994, Abrams 1996, 2003, Ryniker et al 2006, Alexander and Arthur 2010, Fan et al. 2011, Holzmueller et al 2011).

Another possible state might be thinning, the loss of stems based on density-dependent mortality (Oliver and Larson 1996, Peet and Christensen 1987). I expect to see thinning in stands where almost all stems are much younger than the maximum lifespan. Low recruitment and high mortality of small stems, changing diameter distributions over time, and an even age structure provide evidence of thinning. Understanding the mechanisms of how Crosstimbers forests are maintaining themselves (or not) could help us understand the changes taking place in *Quercus* forests worldwide.

My study addressed the following research questions. (1) What are the dynamics of the stand in terms of mortality and recruitment?, (2) How do size-specific growth and mortality vary between the two dominant oak species, *Q. stellata* and *Q. marilandica*?, (3) Are the dynamics consistent with a forest in steady state or thinning?, (4) What is the age structure of the stand?

Methods

Study Site

The study site consists of a 200m x 200m (4ha) plot in the Tallgrass Prairie Preserve (TGPP) in Osage County, northern Oklahoma. The TGPP is owned and managed by The Nature Conservancy, and consists of ~15,400ha of land, located between 36.73˚ and 36.90˚N latitude and 96.32˚ and 96.49˚ W longitude (Allen and Palmer 2011). Average annual rainfall for Osage County is 101cm, with average maximum temperature of 22.2˚ C (Allen et al. 2009). The study plot was placed within a stand of Crosstimbers (centered on 36.83˚ N latitude and 96.41° W longitude) on a western facing slope (3-25%), with Niotaze-Darnell complex soils (classified as fine, smectitic, thermic aquic paleustalfs, with sandstone within a depth of 50.8cm) (Bourlier et al. 1979) and a sandstone shoulder running north-south through the center of the plot. The Nature Conservancy uses a patch-burn plan that involves any given area burning approximately once every 3 years and has controlled the site since 1989, so I can infer that the site has burned at least 7 times in the last 23 years (Hamilton 2007). Burn frequencies have been found to be constant over the past three centuries (Allen and Palmer 2011).

Data Collection

José Ramón Arévalo established the study plot in 1998. All stems ≥2.5cm in diameter at breast height (DBH, 1.3m above the base) were tagged with an individual identification number on an aluminum tag, and their geographic coordinates were recorded. Each tree's species, DBH (using a DBH tape), and status (alive or dead) were also recorded. In December 2008, I resurveyed the site for growth, mortality, and recruitment. Any new stems ≥2.5cm were mapped, tagged, and DBH and species recorded.

In 2012, I collected 48 tree cores and 96 tree heights of *Q. stellata* stems using a stratified random sampling design. I divided the trees into12 size classes of 3cm each based on their 1998 DBH, starting at 2.5- 5.4cm and ending with a size class of 35.5-all others (due to having few trees above that class). I randomly selected one tree from each size class for each 1ha area of the plot and then collected a core from that tree using an increment borer (using standard dendrochronology techniques, Fritts 1976) at breast height, for a total of 48 tree cores. I used a similar sampling design to choose stems to quantify for heights. I measured 2 randomly chosen stems (including the tree I cored) per size class in each hectare using a Haglöf Vertex Hypsometer.

I visually examined aerial photographs from four separate time points (1954, 1966, 1991 from the USGS Soil Conservation Service survey, and a 2012 image from Google Earth) to determine gross changes in structure and extent of tree cover.

Analysis

I analyzed diameter distributions for *Q. marilandica* and *Q. stellata* in both 1998 and 2008. I calculated mortality and changes in basal area (basal area in $m^2 = 0.00007854 \times DBH^2$). I also examined growth rate as a function of 1998 DBH and mortality by 1998 DBH size classes. Tree cores were aged using standard dendrochronological techniques (Fritts 1976) with the aid of a dissecting scope. Only present rings were used in the age estimation. I subtracted years from trees cored in 2011 and 2012 to calculate 2008 age. Because the cores were derived from a size-class *stratified* random sample, they represent a biased age distribution. For example, very large and very small stems are overly represented in the sample. Therefore, I corrected the age distribution by weighting age classes according to the diameter distribution of *Quercus stellata*. *Quercus stellata* composed 89% of the stems in the stand in 1998, and 92% of stems in 2008.

Results

Overall Stand Structure

In 1998 there were a total of 7,620 stems in the 4ha plot (1905 stems ha^{-1}). The majority (6,772) of stems were *Q. stellata*. There were 842 stems of *Q. marilandica*, and only 6 stems of other species (*Fraxinus, Prunus,* and *Celtis*). No *Juniperus virginiana*, which commonly increases in unburned Crosstimbers (van Els et al. 2010), were found within the stand. When resampled in 2008, the stand had experienced a drastic loss of stems, but an overall increase in basal area (Table 1) and an increase in average stem diameter (Figures 1 and 2); this pattern is consistent with a stand undergoing thinning. We were unable to locate only 301 stems out of the original 7,620.

Aerial photos (not shown) indicate no clear signs of disturbance nor changes in the extent of forest cover. However, the images varied in resolution, time of year sampled (and hence the status of the foliage), and lighting; thus I cannot offer any conclusive interpretation from these images other than a lack of great change.

Basal Area and Recruitment

Q. marilandica lost basal area over the decade, while *Q. stellata* gained basal area (Table 1). *Q. marilandica* recruited two stems into the 2.5cm diameter class, while *Q. stellata* recruited 3 stems.

Diameter Growth

Confidence intervals for both species growth rates overlapped, showing no significant difference in the size-specific growth rate between species (Figure 3). For *Q. marilandica*, stem diameter distribution shifted toward larger stems over the decade. The majority of *Q. marilandica* stems in 1998 were between 3.76 and 6.25cm DBH, while in 2008 the majority of stems were between 6.26 and 8.75cm DBH (Figure 2). Average growth rate was highest for stems with diameters up to 20cm, at which point it began to decrease (Figure 3, dashed line). For *Q. stellata*, stem diameter distribution also shifted toward larger stems over the decade. Most stems in 1998 were between 6.26 and 8.75cm DBH; in 2008 the majority of stems fell between 8.76 and 11.25cm DBH (Figure 1). Average growth of *Q. stellata* stems tended to increase with increasing diameter (Figure 3, solid line).

Mortality

Both species exhibited high mortality at the smallest classes, exceeding 70% for the smallest stems (Figure 4), consistent with thinning. *Q. marilandica* exhibited significantly higher mortality than *Q. stellata* at all size classes except the very smallest, when it was comparable to *Q. stellata,* and at 24cm DBH, potentially due sample size (only 9 stems of *Q. marilandica* in that size class exist in the stand). *Q. marilandica* exhibited a *U*-shaped mortality function, with maximum survivorship at 11cm DBH, and mortality approaching 60% at large diameters (Figure 4). This may reflect *Q. marilandica's* shorter lifespan. In contrast, *Q. stellata*'s decadal mortality remained close to zero at larger diameters. Over the decade and across size classes, *Q. stellata* experienced 20% mortality, while *Q. marilandica* experienced 40.9%.

Stand Age and Height of Quercus stellata

In 1998, the vast majority of *Q. stellata* stems in the stand (4641) were estimated to be between 40-49 years old. In 2008, the majority of stems in the stand (3097) were estimated to be between 50-59 years old. There were an estimated ~18 stems over 100 in 2008 (Figure 5). Based on subtracting current ages to 1998 age estimations and the stand diameter distribution in 1998, it appears the stand became more mixed age over the decade-long period. The relationship between age and diameter was plotted (Figure 6), as was the relationship between diameter and heights (Figure 7).

Discussion

This Crosstimbers forest stand is decidedly not in steady state, neither with respect to species composition nor forest structure. Species composition, if trends continue, is moving toward monodominance of *Q. stellata*. The structure of the stand is losing stem density but gaining basal area and average stem size. The stand is moving toward a more mixed-aged structure, but is still unimodal in its age distribution; most of the stems were recruited in the 1960's, with smaller periods of recruitment both before and after. Recruitment appears to have lessened greatly around the 1980's.

The observations presented here suggest that the stand is successional in nature, and/or is recovering from a significant stand-wide disturbance. Successional stands are seen as transitory in time, with specific species compositions that change as the stand ages (Connell and Slayter 1977). However, with the near absence of stems of other species (as might be found in forests undergoing mesophication (Nowacki and Abrams 2008), it is unclear what the forest could be succeeding to, except a stand dominated completely by *Q. stellata.* My results also suggest a stand undergoing 'thinning', that is, undergoing interstem competition (Peet and Christensen 1987, Oliver and Larson 1996). In this phase, stems are competing for resources, and many stems die while the survivors become larger. Few to no new stems are recruited, so there is no balance for the high mortality rates.

Age Distribution of Quercus stellata

In 2008 both species have unimodal diameter distributions often associated with even-aged stands, rather than reverse-*J* or bimodal distributions, that might be indicative of uneven-aged or mature stands (Figures 1 and 2) (Bragg et al. 2012, but see Lowestein et al. 2000). The age distribution of *Q. stellata* is also unimodal (Figure 5). *Q. stellata* stems that are predominantly 50-59 years old make up the majority of stems, meaning most of the trees in stand were established in the late 1950's and early 1960s. This is consistent with some literature that indicated *Quercus* forests recruit after drought events (Clark and Hallgren 2003, Galiano et al 2010). The area suffered drought in the early 1950's (NOAA NESDIS 2012). Aerial photos from the 1950s and 1960s do not show an observable difference in tree cover, but were taken at different altitudes and time points.

Stems recruited during this period would have been below the canopy and thus not visible.

Mortality and Recruitment

The U-shaped mortality curve I found in *Q. marilandica* is consistent with much of the literature (Olano and Palmer 2003, Vieilledent et al. 2009, Hurst et al. 2011) for both young and old hardwood forests. The smallest stems in our study had only about a 10% survival rate in the studied decade. This is most likely due to competition for resources, especially light, as neither species is shade tolerant (Dyksterhuis 1948, Nixon 1997). The lower mortality for intermediate diameters presumably corresponds to trees with healthy canopies undergoing active photosynthesis. Other studies in the region (Shirakura et al. 2006, Burton et al. 2010, DeSantis et al. 2010) also indicate a widespread decline in *Q. marilandica* relative to *Q. stellata.* In upland forests in the Ozark highlands, Fan et al. (2011) found similar high rates of mortality for black and red oaks compared to white. Thus, the change in this stand may be reflecting a regional decrease in members of the red oak group.

The increase in mortality for larger stems of *Q. marilandica* is likely attributed to two non-exclusive sources: (1) aging/ senescence and (2) being more susceptible to disturbances such as windthrow and ice damage (Yang et al. 2003). Larger stems of both species are likely to be older and reaching the end of their lifespans. However, the majority of stems *Q. stellata* stems in this stand are less than 100 years old (Figure 5). While *Q. marilandica*'s lifespan is ~150, *Q. stellata*'s is much longer, ~400yrs (Nixon 1997). This could explain the lack of as drastic an uptick in mortality at larger sizes for

Q. stellata. In addition, larger trees with more surface area and a larger canopy are often more vulnerable to mechanical damage via disturbances like wind and ice (Hurst et al. 2011). *Q. marilandica* is known for retaining its lower and dead limbs, and as a member of the red oak group has been found to be more susceptible to wind disturbances (Shirakura et al. 2006). This could also explain, in part, the far higher mortality of large *Q. marilandica* compared to large *Q. stellata*.

Whereas I was unable to find traces for a few of the trees tagged in 1998 (301 stems were missing out of the 1695 that died), the vast majority of dead trees were standing dead or had fallen onto the forest floor. Only rarely were there obvious signs of charring due to fire, and thus (especially since charred wood tends to persist) it is unlikely that fire represented an important direct cause of mortality for either species. The Crosstimbers forest is unique among other *Quercus* forests in that its fire history has been found to be fairly consistent through time (Shirakura et al 2006, Allen and Palmer 2011). In fact, recurring fire plays a key role in maintaining the Crosstimbers (Hamilton 2007, Burton et al 2010, DeSantis et al 2010, DeSantis et al 2011). This likely means that the lack of recruitment in this stand is again indicative of thinning, rather that the presence of fire.

Stem Density and Basal Area

Stem density decreased for both species, but there was an overall increase in basal area over the decade due to growth of *Q. stellata*, a white oak. Similar changes in stem density and basal area were documented in the Ozark Hills oak forests of Illinois by Holzmueller et al. (2011). In their study of oak forest composition under no cutting and light harvesting, they found in both treatments an increase in the basal area of white oak (*Q. alba*, a member of the *Quercus* section *Quercus*), and a loss of stem density and basal area in black (*Q. velutina*) and northern red oak (*Q. rubra*), members of *Quercus* section *Lobatae*. Unimodal diameter distributions, low recruitment, and similar basal area values have also been found in *Quercus gambelii* communities in Lincoln National Forest Park in New Mexico, another xeric forest dominated by oaks (Ryniker et al. 2006).

Growth

Our observed pattern of lower growth rates for small trees is also consistent with a stand undergoing thinning. Younger/smaller trees are suppressed until they reach a certain size, and are then released due to the mortality of a neighbor (Oliver and Larson 1996). Growth then slows (or appears to slow with cm/decade) due to age and eventual mortality (Oliver and Larson 1996, Kucbel et al. 2012). However, it is worth noting that a given diameter increment gain in a large tree corresponds with a much larger increase in basal area than it does for a small tree, so a decline in diameter growth at larger diameters is largely expected even for healthy trees.

Conclusions

Like many *Quercus* forests, I found a lack of recruitment of *Quercus* stems. I also found a shift in species composition in the loss of members of the red oak group, a trend seen by others working in the Crosstimbers (DeSantis et al 2010, Shirakura et. al 2006, Myster and Malahy 2002) and other North American *Quercus* forests (Nowacki and Abrams 2008, Alexander and Arthur 2010). I did not, however, find evidence of mesophication in this area (an influx of more mesic species such as *Acer saccharum*) of the Crosstimbers (unlike DeSantis et al 2010). This is potentially due to the continuous presence of fire at the Tallgrass Prairie Preserve. In contrast, areas of the DeSantis et al. (2011) study were subject to fire suppression. These study areas had encroachment of *Juniperus virginiana*. which may have prevented oak recruitment. Also, their sites in the far west may have experienced more severe drought and altered the stand dynamics (DeSantis et. al 2011).

I saw evidence of a large recruitment event (several thousand stems that are between 50-59 years old currently) that would have taken place after a widespread drought in the 1950's (NOAA NESDIS 2012)- this increases the connection between *Quercus* recruitment and drought events (Clark and Hallgren 2003, Galiano et al 2010, although see Perez-Ramos et al 2010). Interestingly, aerial photos from the 1950's and 1960's do not indicate a smaller canopy, and photos from the 1990's do not clearly show the larger canopy I might have expected as stems recruited in the '50's and 60's reached crown height.

In conclusion, the dynamics of this stand appear to be somewhat of a paradox with no clear resolution. A dramatic transition in forest structure, consistent with thinning, does not seem to be accompanied by successional change (except for a relative increase in Quercus stellata dominance). The lack of recruits further argues against a steady state. Age distributions imply a stand that is around half a century old, yet older aerial photographs imply a closed canopy forest from the period. This study underscores the need for long-term, permanent plot data – as most of my findings could not have been inferred from static data. Resampling the stand in the future will help us better understand the nature of structural change in the Crosstimbers.

Table 1. Stand Statistics

Mortality, recruitment, and changes in stem density and basal area for *Q. stellata* and *Q. marilandica* in a 4ha Crosstimbers stand in Osage County, Oklahoma. There were only six stems of other species found within the stand (two of *Celtis occidentalis*, and one each of *Fraxinus americana*, *Fraxinus pennsylvanica*, *Prunus americana*, and *Prunus mexicana*).

	Q. stellata		*Q. marilandica*	
	1998	2008	1998	2008
Stem Density (stemsha^{-1})	1693	1355	210	125
Basal Area (m^{2}ha^{-1})	17.93	20.48	2.28	1.72
Mortality		20.0%		40.0%
Recruitment (stems ≥2.5cm ha^{-1})		0 .75		0.50

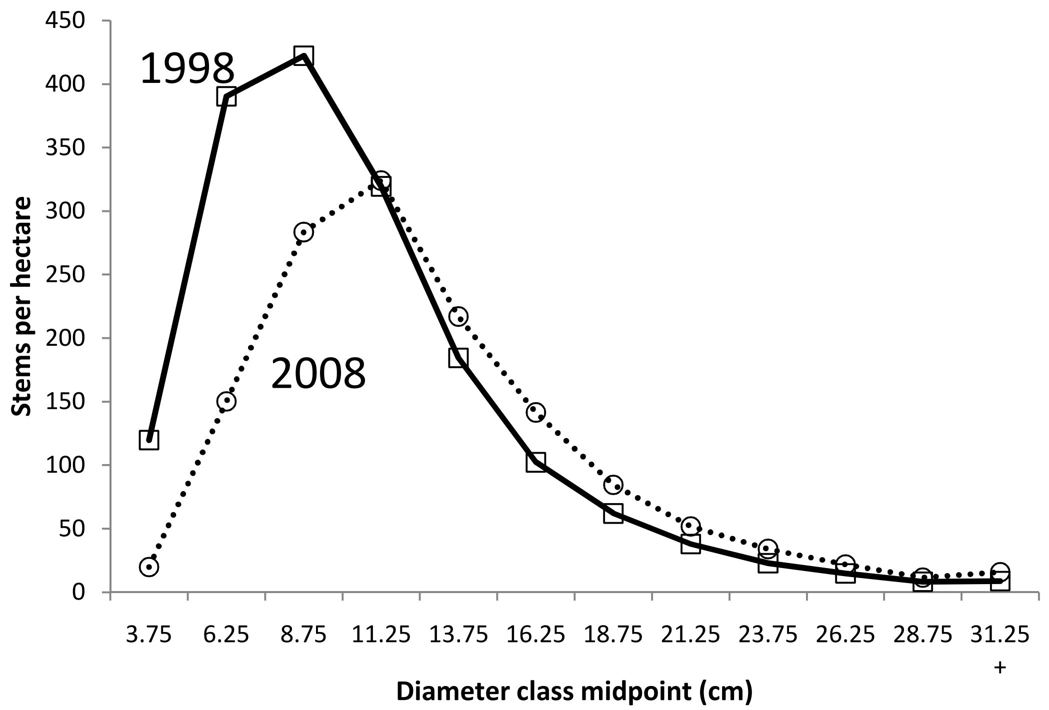

Figure 1. **Diameter distribution of *Q. stellata***

Diameter distribution of *Q. stellata* in 1998 and 2008.

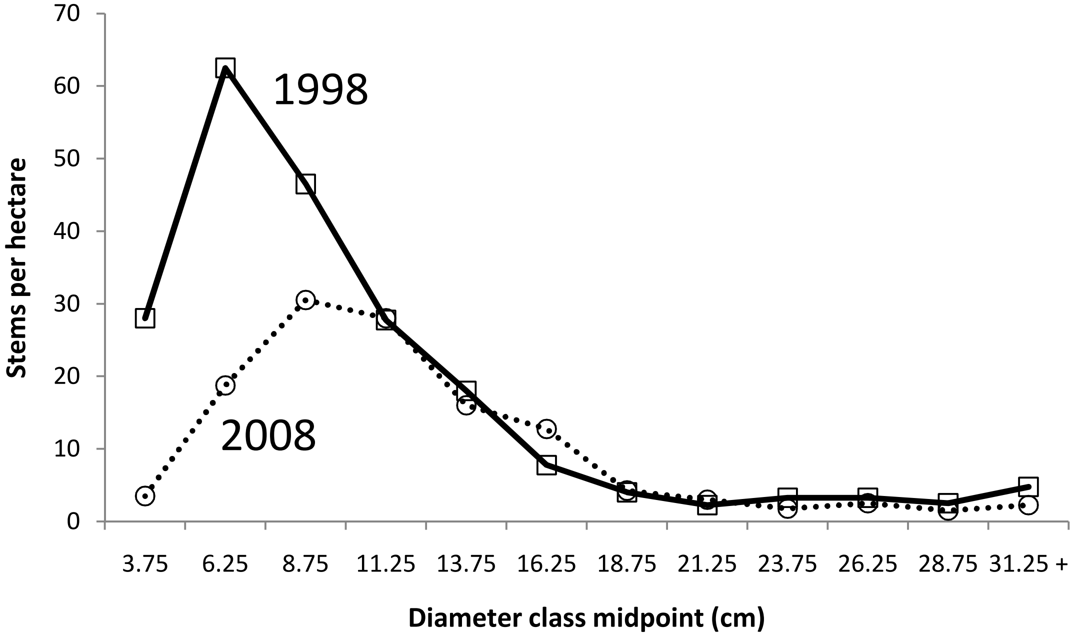

Figure 2. Diameter distribution of *Q. marilandica*

Diameter distribution of *Q. marilandica* in 1998 and 2008

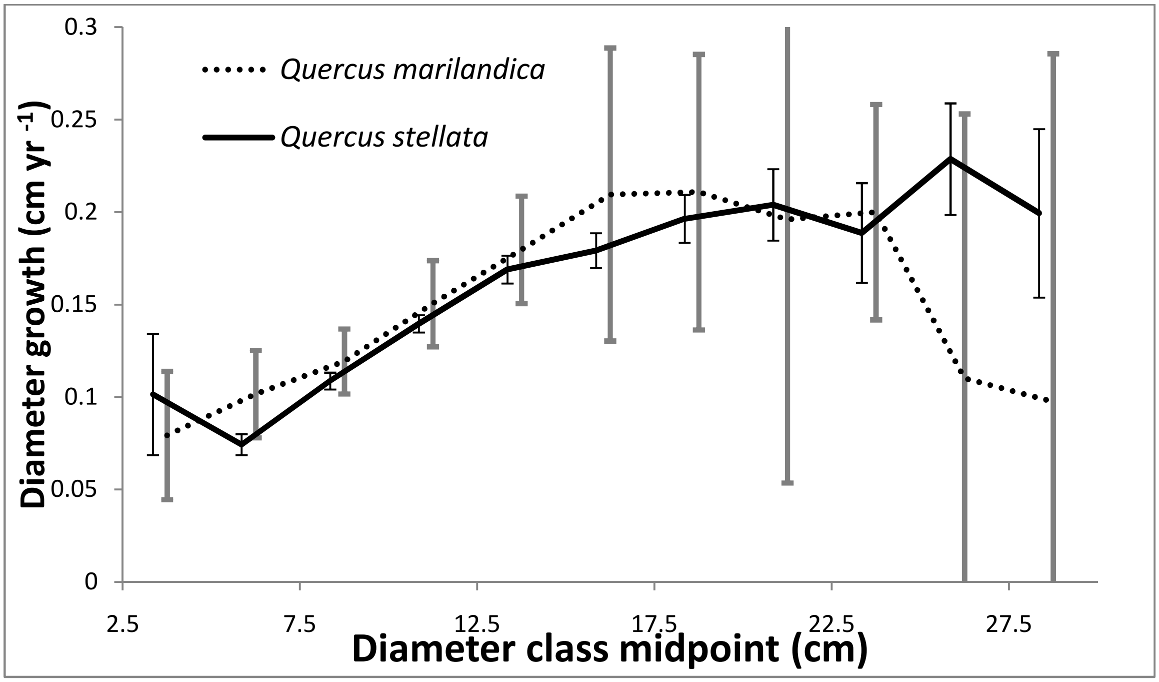

Figure 3. Growth rate as a function of diameter for *Q. marilandica* and *Q. stellata*

Growth rate as a function of 1998 diameter class midpoint for *Q. stellata* and *Q. marilandica*. Error bars indicate 95% confidence intervals around the means.

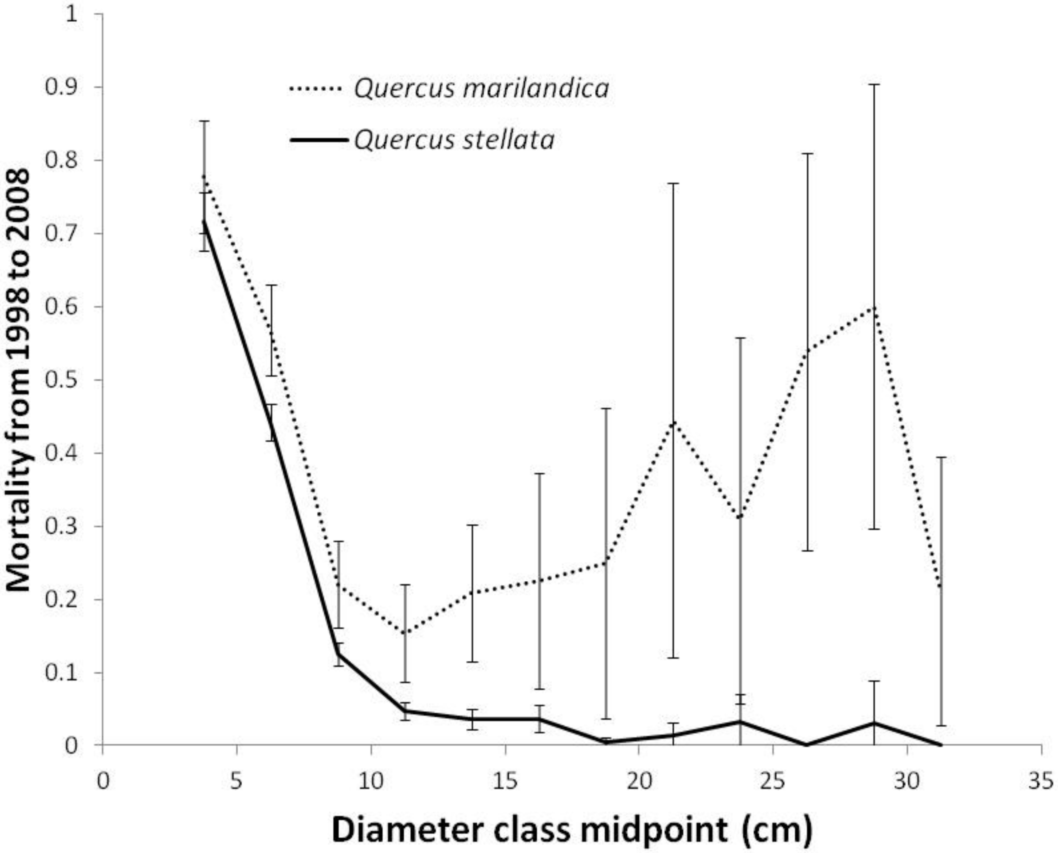

Figure 4. Mortality as a function of diameter for *Q. stellata* and *Q. marilandica*

Mortality by 1998 diameter class midpoint for *Q. stellata* (solid line) and *Q. marilandica* (dashed line). Error bars indicate 95% confidence intervals.

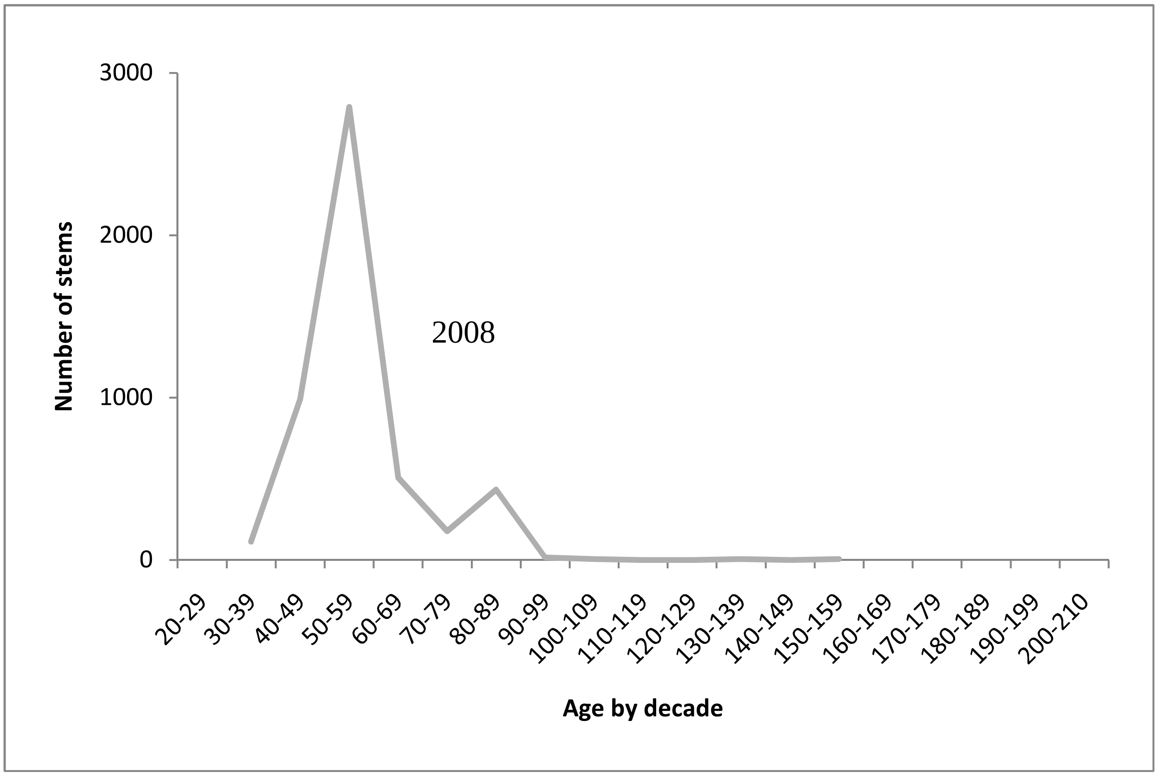

Figure 5. Estimated age structure of Q. stellata and 2008.

Estimated age structure of *Q. stellata* stems for 2008 (light grey bars). Estimations are based on increment cores collected in a stratified random sample and are corrected for diameter distribution.

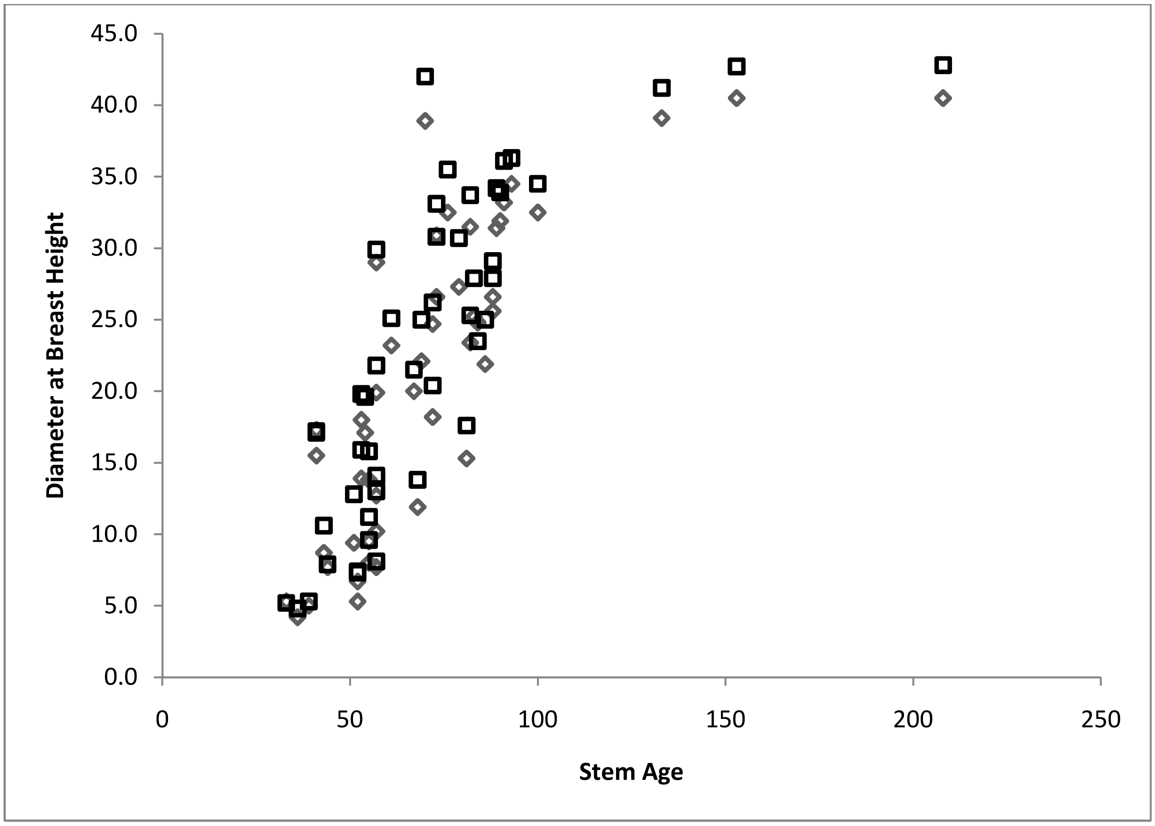

Figure 6. Stem age and diameter at breast height.

The relationship between stem age and diameter for 1998 (black squares) and 2008 (grey triangles).

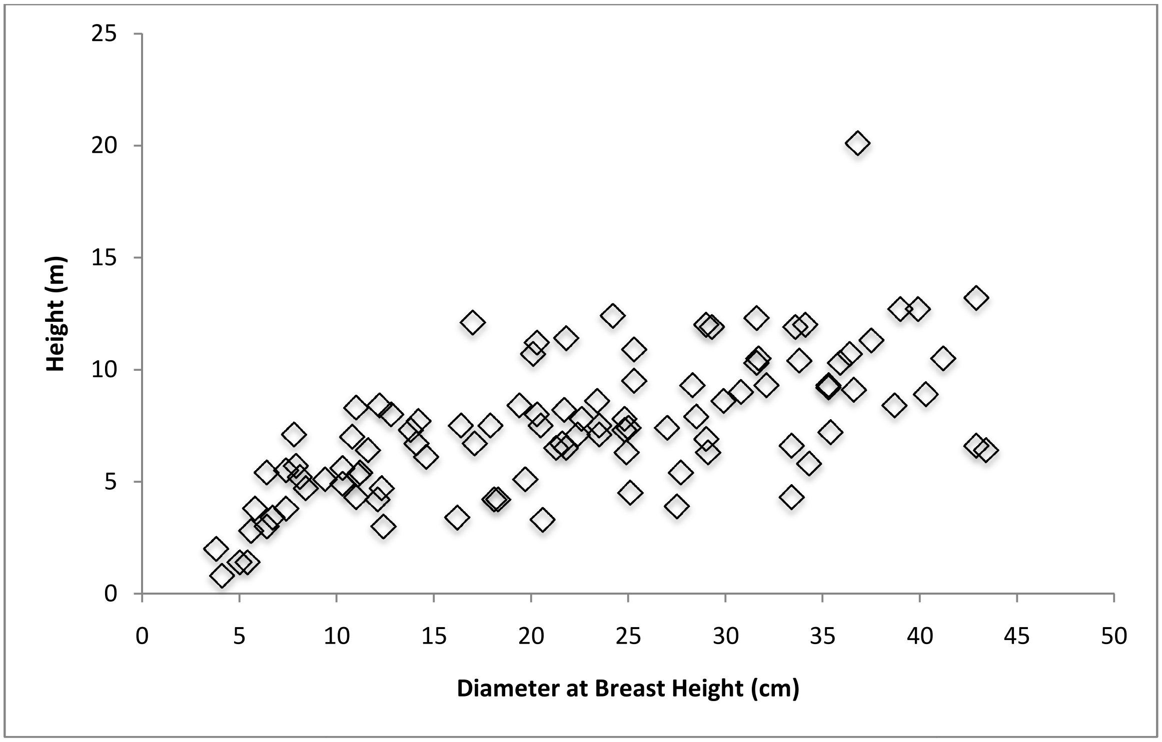

Figure 7. Height(m) as a function of diameter at breast height (DBH).

Diameter and height relationship of stems selected from stratified random sampling.

References

Abrams, M. D. 1992. Fire and the development of oak forests. Bioscience **42**:346–353.

Abrams, M. D. 1996. Distribution, historical development and ecophysiological attributes of oak species in the eastern United States. Annales Des Sciences Forestieres **53**:487-512

Abrams, M. D. 2003. Where has all the white oak gone? Bioscience **53**: 927-939

Alexander, H. D. and M. A. Arthur. 2010. Implications of a predicted shift from upland oaks to red maple on forest hydrology and nutrient availability. Canadian Journal of Forest Research--Revue Canadienne De Recherche Forestiere **40**:716-726

Allen, M. S., R. G. Hamilton, U. Melcher, and M. W. Palmer. 2009. Lessons from the Prairie: Research at The Nature Conservancy's Tallgrass Prairie Preserve. Stillwater, Oklahoma: Oklahoma Academy of Sciences. 44pp

Allen, M. S. and M. W. Palmer. 2011. Fire history of a prairie/forest boundary: more than 250 years of frequent fire in a North American tallgrass prairie. Journal of Vegetation Science **22**:436-444.

Arévalo, J. R. 2002. Distribution of trees and saplings at the edge of cross timbers forests, Oklahoma, USA. Natural Areas Journal **22**:99-107.

Arno, J. 1995. The mighty oaks. In: Fine Woodworking Editors (eds.) Wood: the very best of fine woodworking.pp. 8–11. Taunton Press, Newtown, CT, US.

Bourlier, B. G., J. D. Nichols, W. J. Ringwald, P. J. Workman, and S. Clemmons. 1979. Soil Survey of Osage County, Oklahoma. Soil Survey of Osage County, Oklahoma.:164 pp.

Bragg, D. C., D. W. Stahle, and K. C. Cerny. 2012. Structural attributes of two old-growth cross timbers stands in western Arkansas. American Midland Naturalist **167**:40-55.

Burton, J. A., S. W. Hallgren, and M. W. Palmer. 2010. Fire frequency affects structure and composition of xeric forests of Eastern Oklahoma. Natural Areas Journal **30**:370-379.

Clark, S. L. and S. W. Hallgren. 2003. Dynamics of oak (*Quercus marilandica* and *Q. stellata*) reproduction in an old-growth cross timbers forest. Southeastern Naturalist **2**:559-574.

Clark, S. L. and S. W. Hallgren. 2004. Age estimation of Quercus marilandica and Quercus stellata: applications for interpreting stand dynamics. Canadian Journal of Forest Research-Revue Canadienne De Recherche Forestiere **34**:1353-1358

Clark, S. L., S. W. Hallgren, D. W. Stahle, and T. B. Lynch. 2005. Characteristics of the Keystone Ancient Forest Preserve, an old-growth forest in the Cross Timbers of Oklahoma, USA. Natural Areas Journal **25**:165-175.

Connell, J. H. and R. O. Slayter. 1977. Mechanisms of Succession in Natural Communities and Their Role in Community Stability and Organization. The American Naturalist **111**: 1119-1144.

DeSantis, R. D., S. W. Hallgren, T. B. Lynch, J. A. Burton, and M. W. Palmer. 2010. Long-term directional changes in upland *Quercus* forests throughout Oklahoma, USA. Journal of Vegetation Science **21**:606-615.

DeSantis, R. D., S. W. Hallgren, and D. W. Stahle. 2011. Drought and fire suppression lead to rapid forest composition change in a forest-prairie ecotone. Forest Ecology and Management **261**:1833-1840.

Dyksterhuis, E. J. 1948. The vegetation of the western Crosstimbers. Ecological Monographs **18**:325-376.

Elliot, K. J. and W. T. Swank. 1994. Impacts of drought on tree mortality and grwoth in mixed hardwood forest. Journal of Vegetation Science **5**:229-236

Fan, Z. F., X. L. Fan, M. A. Spetich, S. R. Shifley, W. K. Moser, R. G. Jensen, and J. M. Kabrick. 2011. Developing a stand hazard index for oak decline in upland oak forests of the Ozark Highlands, Missouri. Northern Journal of Applied Forestry **28**:19-26.

Francaviglia, R. V. 2000. The cast iron forest : a natural and cultural history of the North American Cross Timbers. Pages 276. Corrie Herring Hooks series ; no. 43. University of Texas Press, Austin.

Fritts, H. 1976. Tree Rings and climate. Academic Press. 567 pgs.

Galiano, L. J. Martinez-Vilalta, and F. Lloret. 2010. Drought-induced multifactor Decline of scots pine in the Pyrenees and potential vegetation change by the expansion of co-occurring oak species. Ecosystems **13**:978-991

Hamilton, R.G. 2007. Restoring heterogeneity on the tallgrass prairie preserve: applying the fire–grazing interaction model. In: Masters, R.E. & Galley, K.E.M. (eds.) Proceedings of the 23rd Tall Timbers fire ecology conference: fire in grassland and shrubland ecosystems. pp. 163–169. Tall Timbers Research Station, Tallahassee, FL, US.

Heyder, U., S. Schaphoff, D. Gerten, and W. Lucht. 2011. Risk of severe climate change impact on the terrestrial biosphere. Environmental Research Letters **6**:1-8

Holzmueller, E. J., J. W. Groninger, C. M. Ruffner, and T. B. Ozier. 2011. Composition of oak stands in the Illinois Ozark Hills 2 decades following light harvesting and no cutting. Northern Journal of Applied Forestry **28**:50-53.

Hurst, J. M., R. B. Allen, D. A. Coomes, and R. P. Duncan. 2011. Size-specific tree mortality varies with neighbourhood crowding and disturbance in a montane *Nothofagus* Forest. Plos One **6**.

Koepke, D. F., T. E. Kolb, and H. D. Adams. 2010. Variation in woody plant mortality and dieback from severe drought among soils, plant groups, and species within a northern Arizona ecotone. Oecologia **163**:1079-1090

Kucbel, S., M. Saniga, P. Jaloviar, and J. Vencurik. 2012. Stand structure and temporal variability in old-growth beech-dominated forests of the northwestern Carpathians: A 40-years perspective. Forest Ecology and Management **264**:125-133.

Lowenstein, E. F., P. S. Johnson, and H. E. Garrett. 2000. Age and diameter structure of a managed uneven-aged oak forest. Canadian Journal of Forest Research. **30**: 1060-1070

Nixon, K. C. 1997. *Quercus* In: Flora of North America Editorial Committee, eds. 1993+. Flora of North America North of Mexico. 16+ vols. New York and Oxford. Vol. 3, pp. 356-357.

NOAA, National Oceanic and Atmospheric Administration, 2010. Satellite and Information Service, U.S. Department of Commerce, NOAA, NESDIS and NCDC. http://www7.ncdc.noaa.gov/CDO/CDODivisionalSelect.jsp# Accessed July 2010.

Nowacki, G. J. and M. D. Abrams. 2008. The demise of fire and "Mesophication" of forests in the eastern United States. Bioscience **58**:123-138

McEwan RW and BC McCarthy. 2008. Anthropogenic disturbance and the formation of oak savanna in central Kentucky, USA. Journal of Biogeography **35**: 965-975.

Olano, J. M. and M. W. Palmer. 2003. Stand dynamics of an Appalachian old-growth forest during a severe drought episode. Forest Ecology and Management **174**:139-148.

Oliver, C. D. and B. C. Larson. 1996. Forest stand dynamics. 520 p. Wiley, New York.

Peet, R. K. and N. L. Christensen. 1987. Competition and tree death. Bioscience **37**:586-595.

Perez-Ramos, I. M., J. M. Ourcival, J. M. Limosin, and S. Rambal. 2010. Mast seeding under increasing drought: results from a long-term data set and from a rainfall exclusion experiment. Ecology **91**:3057-3068

Risser, P. G. 1995. The status of the science examining ecotones-A dynamic aspect of landscapes is the area of steep gradients between more homogeneous vegetation associations. Bioscience **45**:318:325.

Rodewald, A.D. and M. D. Abrams. 2002. Floristics and avian community structure: Implications for regional changes in eastern forest composition. Forest Science **48**:267:272.

Ryniker, K. A., J. K. Bush, and O. W. Van Auken. 2006. Structure of Quercus gambelii communities in the Lincoln National Forest, New Mexico, USA. Forest Ecology and Management **233**:69-77

Shirakura, F., K. Sasaki, J. R. Arévalo, and M. W. Palmer. 2006. Tornado damage of Quercus stellata and Quercus marilandica in the cross timbers, Oklahoma, USA. Journal of Vegetation Science **17**:347-352.

Stahle, D. W. 2002. The unsung ancients. Natural History **111**:48.

Therrell, M. D. and D. W. Stahle. 1998. A predictive model to locate ancient forests in the Cross Timbers of Osage County, Oklahoma. Journal of Biogeography **25**:847-854.

van Els, P, R.E. Will, M.W. Palmer, and K.R. Hickman. 2010. Changes in forest understory associated with *Juniperus* encroachment in Oklahoma, USA. Applied Vegetation Science **13**: 356-368.

Vieilledent, G., B. Courbaud, G. Kunstler, J. F. Dhote, and J. S. Clark. 2009. Biases in the estimation of size-dependent mortality models: advantages of a semiparametric approach. Canadian Journal of Forest Research-Revue Canadienne De Recherche Forestiere **39**:1430-1443.

Yang, Y. Q., S. J. Titus, and S. M. Huang. 2003. Modeling individual tree mortality for white spruce in Alberta. Ecological Modelling **163**:209-222

Zaczek, J. J., J. W. Groniger, and J. W. Van Sambeek. 2002. Stand dynamics in an old-growth hardwood forest, in southern Illinois, USA, Natural Areas Journal **22**:211-219

VITA

Kelly Arleen McGrath

Candidate for the Degree of

Master of Science

Thesis: DECADAL-SCALE DYNAMICS OF A CROSSTIMBERS FOREST IN OSAGE COUNTY, OKLAHOMA

Major Field: Botany

Biographical:

Education:

Completed the requirements for the Master of Science in Botany at Oklahoma State University, Stillwater, Oklahoma in July, 2012.

Completed the requirements for the Bachelor of Science in Biology at Truman State University, Kirksville, Missouri in 2005.

Experience:

Teaching assistant for:
<u>Oklahoma State University</u>
Botany 1404 Fall 2009, Spring 2010, Fall 2010, Spring 2012

- Teach labs
- Create and grade lab practicals and homework

Biology 3034 Fall 2008, Spring 2009, Spring 2011, Fall 2011

- Prepare and teach labs
- Create and grade quizzes and papers

Professional Memberships:

Ecological Society of America
Botanical Society of America

Name: Kelly McGrath **Date of Degree: July 2012**

Oklahoma State University **Stillwater, Oklahoma**

Title of Study: DECADAL-SCALE DYNAMICS OF A CROSSTIMBERS STAND IN OSAGE COUNTY, OKLAHOMA

Pages in Study: 37 **Candidate for the Degree of Master of Science**

Major Field: Botany

Scope and Method of Study:

The objective of this research was to answer several questions regarding Crosstimbers stand dynamics: 1) What are the dynamics of the stand in terms of mortality and recruitment? (2)How do size-specific growth and mortality vary between the two dominant oak species, *Q. stellata* and *Q. marilandica*? (3)Are the dynamics consistent with a forest in steady state? (4)What is the age structure of the stand? In 1998, José Ramón Arévalo placed a rectangular (200m x 200m) plot within an area of forest at the Tallgrass Prairie Preserve in Osage County, Oklahoma. All stems ≥2.5cm in diameter at breast height (DBH, 1.3m) were tagged with an individual identification number on an aluminum tag, and their geographic coordinates were recorded. Each tree's species, diameter, and status (alive or dead) were also recorded. I resampled the stand in 2008, again recording status, changes in DBH, and recruitment of new stems. Using these data, I calculated basal area and developed diameter distributions for both time points, and measured growth rates and mortality for both species. Using a stratified random sampling design I measured the heights of 96 stems across 12 size classes (3cm increments starting at 2.5cm DBH). I also used increment bores taken from 48 stems across the same 12 size classes to assess the age structure of the stand and examine the relationship between age and diameter.

Findings and Conclusions:

Over a 10 year period, basal area increased and the number of stems decreased by 33%, with the majority of those deaths in *Quercus marilandica* stems. Only five stems have been recruited into the stand. The diameter distribution for both species in both years was unimodal, with the majority of stems in the smaller size classes. The peak of the diameter distributions shifted toward slightly larger stems (from 7.5cm DBH to 10cm DBH) during the 10 year study period. Growth rate is greatest for stems of medium size (between 15-25cm DBH). Age analysis of the stand revealed a relatively even-aged stand. There is a positive relationship between height and diameter much scatter. Diameter generally increases with age, although age can vary drastically within size classes. Dynamics indicate that this forest stand is undergoing thinning of stems.

ADVISOR'S APPROVAL: Michael W. Palmer________