# LITERATURE REVIEW OF DENDROCHRONOLOGY RESEARCH IN OKLAHOMA, U.S.A.

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## ABSTRACT

Dendrochronology, the study of tree-rings to help understand events of the past, is a growing body of research that has become well-established in scientific literature within the last century. Oklahoma is a distinct resource to dendrochronology as it exists at the eastern deciduous forests and western prairies/grasslands transition. The extent of dendrochronological research conducted in Oklahoma has not yet been determined. A literature review was performed to catalogue and quantify dendrochronological research for Oklahoma. Thirty-seven written works were identified ranging through years 1923 to 2018. Nine research topics were developed to aid publication synthesis, with climate reconstruction, fire history, and stand dynamics being the most frequently encountered topics. Reviewed publications indicated that humans and climate, specifically drought, largely impacted Oklahoma forests historically, and remain a current threat. Results provide a detailed resource of dendrochronological applications within Oklahoma that spans the past century. Presented literature can be referenced for future Oklahoma dendrochronology studies, with presented knowledge also benefiting studies of similar forest types elsewhere.

## INTRODUCTION

North American forests have undergone species compositional changes and remain susceptible to further change (Bürgi et al. 2000; Hall et al. 2002; Dyer 2006, Pederson et al. 2014). Factors contributing to forest changes include climate change, anthropogenic effects, biotic interactions, and natural disturbances (Wallin et al. 1996; Radeloff et al. 1999; Gerhardt and Foster 2002; Guyette et al. 2003). Oklahoma contains an estimated 12.2 million acres (4.9 million ha) of forestland which amounts to 27% of total land area (Dooley 2018). The Great Plains and eastern deciduous forest complex converge within Oklahoma, resulting in a central forest-grasslands ecotone (Robinson et al. 2019). Oklahoma's earliest U.S. Geological Survey was conducted on eastern Indian Territory from 1895 to 1898 and documented an estimated 12 million forested acres in eastern Oklahoma (Johnson et al. 2015). Land-use practices by Native Americans and Euro-American settlers largely affected Oklahoma's forests (Johnson et al. 2015; Oklahoma Forestry Services 2019a). Native Americans cleared forests for agriculture/ rangeland and performed intentional burning (Oklahoma Forestry Services 2019a). Euro-American settlement in Oklahoma which began in the early 1800s also impacted forests through agriculture, intentional burning, lumber harvesting, commercial logging, incentivized planting, and fire suppression/exclusion (Smola 1985; Johnson et al. 2015; Oklahoma Forestry Services 2019a). Consequences of


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historic land-use practices are still observable within Oklahoma's forests.

Historic and current abiotic factors such as topography, soil nutrient availability, wildfire, and climate also affect Oklahoma forestland (DeSantis et al. 2010a; DeSantis et al. 2010b; Johnson et al. 2015). Precipitation and temperature gradients contribute to an observed pattern of decreasing forest cover from east to west as well as tree species distribution (Kloesel et al. 2018). Oklahoma's largest forest-type group is oak-hickory (*Quercus* L.-*Carya* Nutt.), comprising more than half (55.5%) of all Oklahoma forestland as defined by the United States Department of Agriculture Forest Service (Dooley 2018). Other notable forest-type groups are much smaller in proportion: elm-ash-cottonwood (*Ulmus* L.-*Fraxinus* L.-*Populus* L.; 11.5%), loblolly-shortleaf pine (*Pinus taeda* L.-*Pinus echinata* Mill.; 10.0%), oak-pine (*Quercus*-*Pinus* L.; 7.8%), and other eastern softwoods (4.5%) (Dooley 2018). The oak-hickory forest-type group includes one of Oklahoma's major forest types, the post oak-blackjack oak forest type, or "Cross Timbers", which is centrally located from north to south within Oklahoma (Oklahoma Forestry Services 2019b). Post oak (*Quercus stellata* Wangenh.), blackjack oak (*Quercus marilandica* Münchh), and black hickory (*Carya texana* Buckley) dominate the overstory of the Cross Timbers, which exists as a matrix of prairie, deciduous forest, and savanna (Johnson et al. 2015; Oklahoma Forestry Services 2019b). The Cross Timbers, which also extends into Kansas and Texas, is one of the least disturbed forest types in the eastern United States (Johnson et al. 2015). Tree-ring research within Oklahoma's Cross Timbers has revealed the presence of undisturbed ancient forest tracts (Therrell and Stahle 1998). Encroachment of native *Juniperus virginiana* L. has become a threat to the Cross Timbers, woodlands, grasslands, and bottomland hardwoods of Oklahoma, impacting hardwood recruitment and wildlife habitat (Johnson et al. 2015).

Additional threats to Oklahoma forests include invasive plant species, invasive insects/fungi and associated diseases, natural disturbances, urbanization, severe weather, and climate change (Johnson et al. 2015; Kloesel et al. 2018; Oklahoma Invasive Plant Council 2019; Oklahoma Forestry Services 2020). Climate change will likely impact all the beforementioned threats to Oklahoma forests (Kloesel et al. 2018). Natural ranges of floral and faunal species are already limited within Oklahoma's forest-grassland transitional landscape, and small changes to the environment may have consequential effects (Kloesel et al. 2018). A clearer understanding of what factors have previously affected and shaped Oklahoma forests is essential for future conservation efforts involving forest management.

Identifying variables that have previously affected forests can be explained using dendrochronology: the study of tree-ring structure to examine past events in time (Fritts 1976). Trees grow in response to the surrounding environment, and when site history is known, influencing factors can be defined by examining patterns of tree-ring width (Speer 2010). Climate impact on annual tree-ring width has been well documented (Fritts 1976; Swetnam 1993; Guyette et al. 2004; Stambaugh et al. 2009; Brose et al. 2013). Narrow tree-rings represent limited growth and wide tree-rings represent ample growth under favorable environmental conditions (Stokes and Smiley 1996). When accurately dated using accepted methods and statistical techniques, tree-ring widths can provide long records of environmental conditions going back thousands of years (Schulman 1954; Stahle et al. 2019), vital knowledge that would have otherwise remained unknown.

Dendrochronology data remains limited in many regions across the United States. Although dendrochronology research has increased significantly in the past century, with over 11,000 publications as of 2010, assessing new geographic regions can help expand this scientific field (Speer 2010). Dendrochronology research has been conducted in Oklahoma, but a comprehensive review of Oklahoma dendrochronology literature has not yet been performed. This literature review aims to discover tree-ring research studies performed in Oklahoma. Cataloguing and discussing Oklahoma dendrochronology publications (ODP) discloses what subdisciplines of dendrochronology have been previously investigated and reveals topics where research is lacking. Species and locations utilized in studies were also catalogued to help identify areas with future research potential.

## METHODS

Peer-reviewed, full-text articles published in scientific journals relating to dendrochronology in Oklahoma were collected using academic databases available online through the Max Chambers Library (MCL) at the University of Central Oklahoma (UCO), Edmond, Oklahoma. Digital libraries (Ebscohost, JSTOR, and ProQuest) and scientific literature databases (Biological Abstracts, BioOne, Environment Complete, ScienceDirect, and Sci-Tech Premium Collection) were searched for article retrieval using the keywords "dendrochronology," "tree-ring," "climate reconstruction," and "fire history" in conjunction with "Oklahoma". The inter-library loan program through MCL was used to retrieve articles that were unavailable via academic databases. Referencing citations within recovered articles helped locate additional literature. During the review process, theses, reports, bulletins, and conference proceedings were also encountered, and when found relevant, were included within the literature review. The written works collected, although not all are published literature, will be hereafter referred to as the Oklahoma Dendrochronology Publications (ODP), for clarification.

The focus of the literature review was to highlight how dendrochronology research has been conducted exclusively within Oklahoma over time and which tree species were utilized. For this reason, dendrochronology research articles that combined Oklahoma with other states/regions were not included. Unpublished individual tree-ring records were also not quantified. Tree-ring records and regional studies are still highly pertinent to dendrochronology overall, in and out of Oklahoma, and a few notable publications are mentioned within the Discussion.

Retrieved ODP were assigned to "research topics" to clarify literature review results. Research topics were also catalogued with supplementary information into Appendix A to serve as an efficient resource for future dendrochronology investigations in Oklahoma and surrounding regions. Reviewed literature will have presented more information/data than discussed here as methods utilizing tree-ring analysis were explored primarily. The succeeding literature review was performed during the years 2019 and 2020, and it should be disclosed that there was likely additional literature published and produced since its development and publication.

## RESULTS

Thirty-seven publications were found that performed dendrochronological analyses within Oklahoma (Table 1, Appendix A). Twenty-four publications were journal articles which were published among 19 scientific journals (Table 1; Literature Cited). Publication years ranged from 1923 to 2018, although Sellards (1923), the earliest written work discovered, was not represented graphically (Figure 1). Following the two earliest publications (Sellards et al. 1923; Harper 1960), at least one publication per decade was observed (Figure 1).

Table 1 A total of 37 written works involving dendrochronological analysis within Oklahoma were found among seven types of literature.

| **Oklahoma Dendrochronology Publication Types** | |
|---|---|
| journal articles | 24 |
| master's theses | 4 |
| conference publications | 3 |
| doctoral theses | 3 |
| bulletin | 1 |
| honors thesis | 1 |
| report | 1 |
| **Total** | **37** |

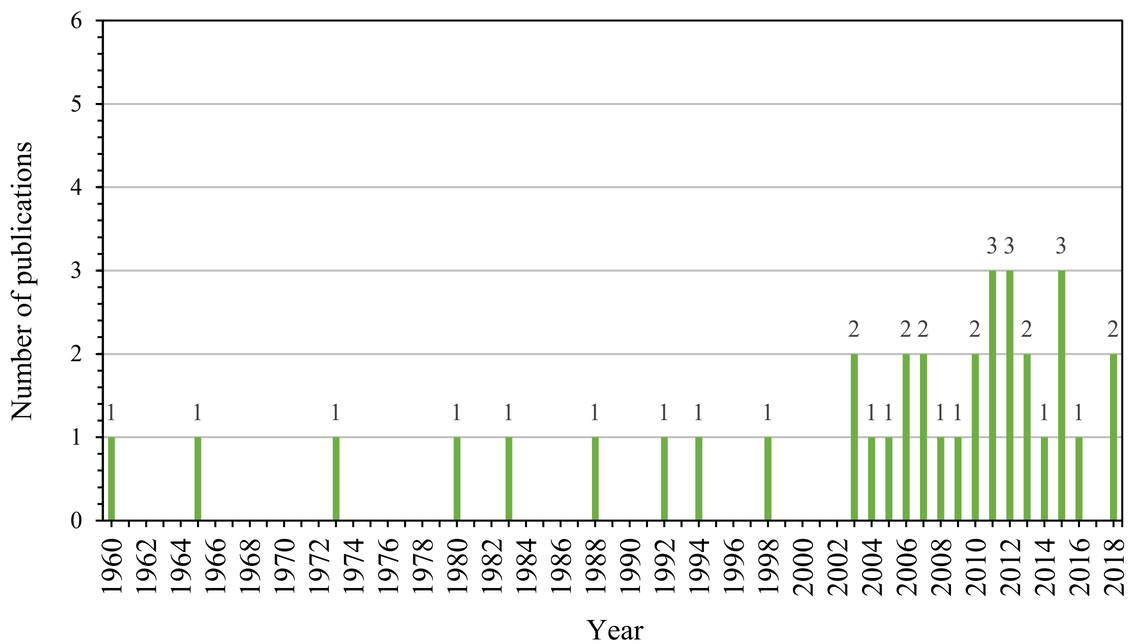


Figure 1 Thirty-six publications published between 1960 and 2018 each presented dendrochronological research conducted in Oklahoma (Sellards et al. [1923] not shown).

Sellards et al. (1923) was part of a Supreme Court ruling for which the boundary line between Oklahoma and Texas, originally defined by the Red River's natural course, needed to be reestablished. Physiographical, geological, and ecological evidence was used to help date the land area surrounding the Red River valley/riverbanks, which included determining age structure for trees of the area (Sellards et al. 1923). The most recent publication retrieved was Hoff et al. (2018). Earliest ODP were shorter, had smaller sample sizes, and typically focused on one variable affecting tree-ring width (Harper 1960; Johnson and Risser 1973). Variability in study site locations was observed, but some areas were subject to repeated study over time.

*Study sites*

Thirty-one ODP focused on research within the Cross Timber and 18 studies investigated forest reserves and management areas: Wichita Mountains Wildlife Refuge/Wichita Mountains, Keystone Ancient Forest Preserve, Tallgrass Prairie Preserve, Okmulgee Game/Wildlife Management Area, and Nickel Family Nature and Wildlife Preserve. Six ODP evaluated counties, ecoregions, and other areas throughout Oklahoma: Oklahoma/Texas boundary, Bryan County, Oklahoma County, Payne County, Harper County, Ellis County, and Ozark Highlands. Areas of repeat investigation resulted in some tree genera/species explored more often than others among the ODP (Figures 2 and 3).

*Genera and species*

Species from 12 families and 13 genera were investigated among the 37 publications with *Quercus* being the most frequently examined genus and *Juniperus* being second (Figure 2; Appendix B). Twenty-one tree/shrub species of 12 genera were analyzed dendrochronologically for various purposes specific to each publication (Figure 3). Sellards et al. (1923) did not specify trees at the species level and Hoff et al. (2018) grouped some species by genus for analyses. Only trees where species were known were included in Figure 3.

Although an array of genera and species were investigated, *Quercus* showed the highest presence within the ODP (Figure 2), particularly *Q. stellata* and *Q. marilandica* (Figure 3; Appendix B). Some tree species were investigated less frequently as main species within the ODP: *Fraxinus pennsylvanica* Marshall (King and Buck 2018), *Pinus echinata* Mill. (Taylor 1965, Stambaugh et al. 2013a, Cerny et al. 2016) and *Prunus angustifolia* Marshall (Dunkin et al. 2008). *Juniperus virginiana* L. was the third most examined species and the main study species for six ODP (Butler and Walsh 1988; Engle and Kulbeth 1992; Edmondson 2006; Dunford et al. 2007; Hammer 2012; Bode 2015; Figures 2 and 3). In seven ODP, *Q. marilandica*, *Q. stellata*, and *J. virginiana*, were main study species collectively (Clark 2003; DeSantis 2010; DeSantis et al. 2011; Hallgren et al. 2012; Stambaugh et al. 2013b; Stambaugh et al. 2014; King and Cheek 2015).

*Research topics*

Oklahoma dendrochronology publications (ODP) were assigned to nine research topics based on each study's objectives, methods, and results (Figure 4). The task of assigning publications to one topic was at times problematic due to occasional overlap in studies' hypotheses, results, and discussions. Complexity of research goals for some studies required the assignment of a combination of research topics. Research topics were developed during the literature review based on types of dendrochronological investigations encountered among the ODP. The nine research topics are Age-diameter/Growth rate, Age-diameter/Growth rate & Stand dynamics, Climate, Climate and Stand dynamics, Fire history, Fire history and Stand dynamics, Geomorphology, Oil extraction, and Stand dynamics (Figure 4, Appendix A).

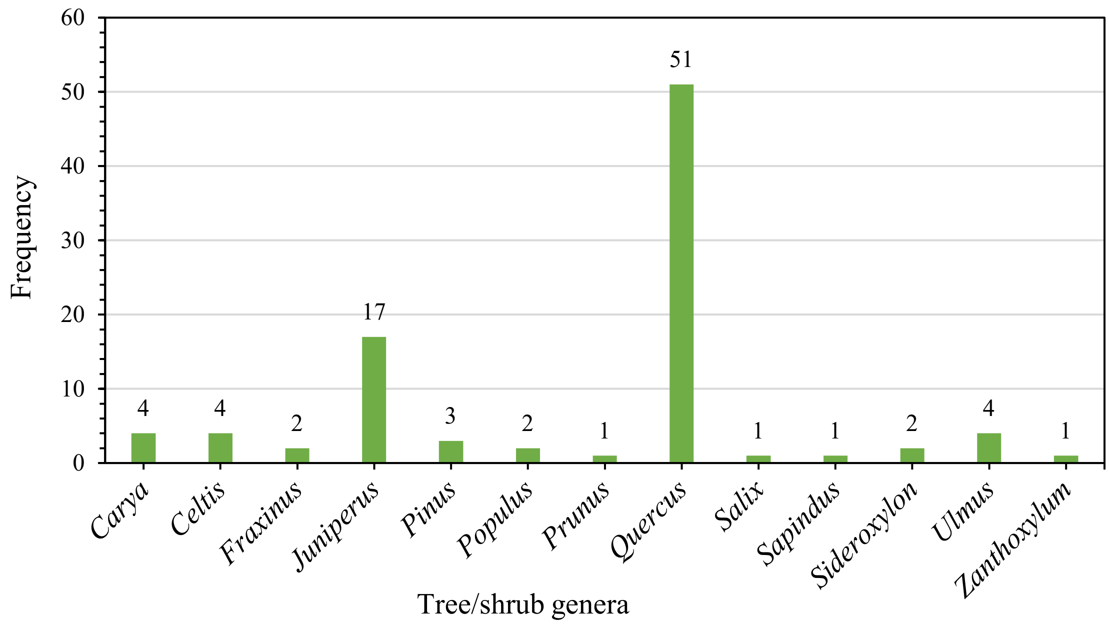


Figure 2 Thirteen genera were researched among the 37 Oklahoma dendrochronology publications.

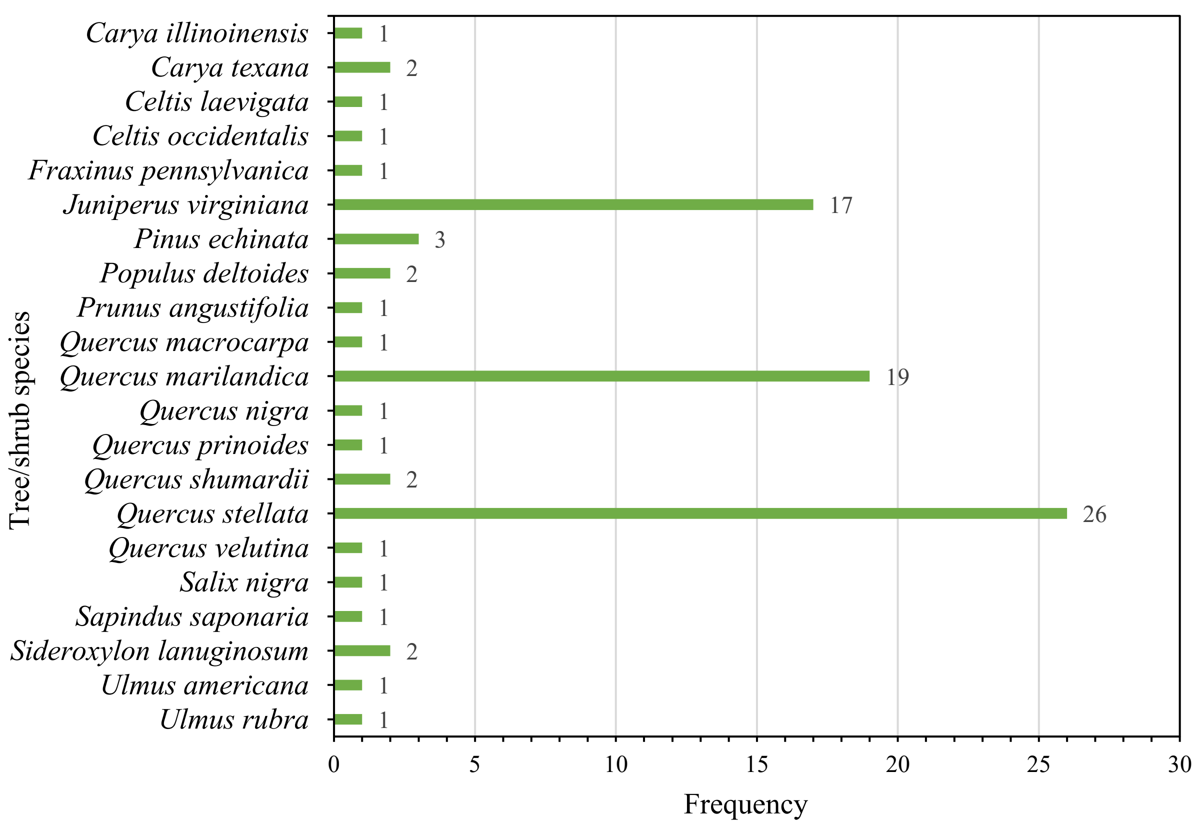


Figure 3 Twenty-one species were researched among the 37 Oklahoma dendrochronology publications.

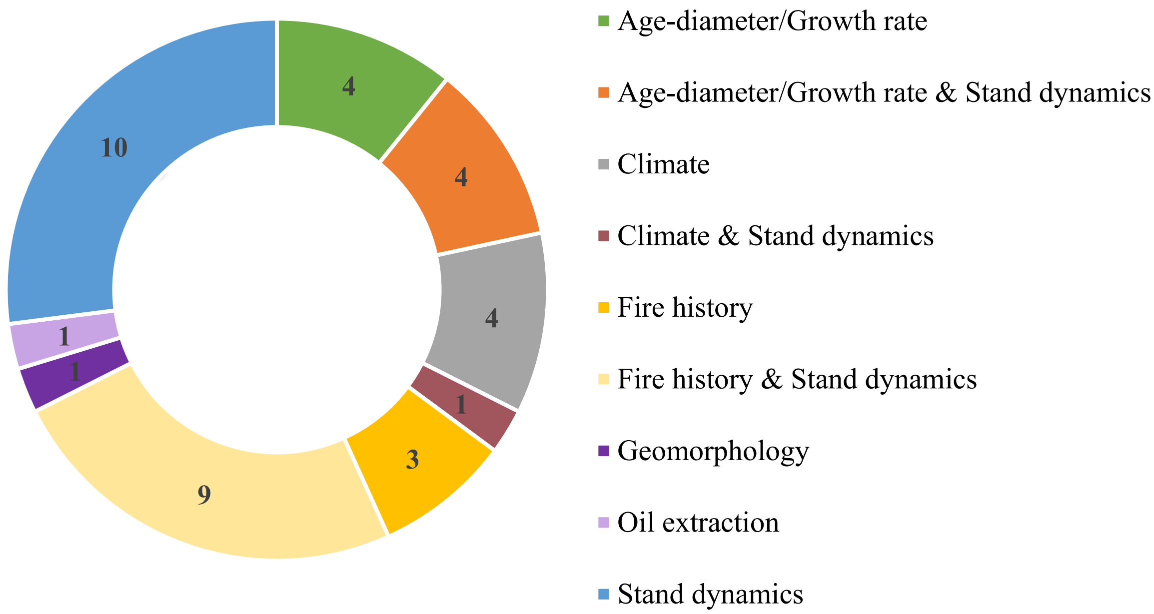


Figure 4 The 37 Oklahoma dendrochronology publications were designated into nine research topics based on the primary study objectives of each publication.

Appendix A chronologically discloses assigned research topics for the 37 ODP and the species used for dendrochronological analysis. Research topics were assigned to the ODP based on how tree-rings were specifically analyzed to answer questions posed by investigators. Specific results and analysis of publications within some research topics was suitably reserved for the Discussion. The least investigated topics were Geomorphology, Oil Extraction, and Climate & Stand Dynamics (Figure 4). Stand Dynamics was the most investigated subject as it was the broadest category by collectively including ODP that performed tree-ring analyses to assess temporal patterns/changes in forest composition: competition, conversion, distribution, disturbance, encroachment, recruitment, regeneration, and succession (Figure 4). Climate and Fire History were the next most investigated subjects. Of the 37 ODP, 31 involved Climate, Fire History, and Stand Dynamics at varying degrees (Figure 4). These heavily investigated research topics are historically and ecologically connected.

## DISCUSSION

This literature review granted an overview of the progression and use of dendrochronology research in Oklahoma over time (Figure 1). Sellards et al. (1923) was a distinct and historically significant application of tree-ring analysis in Oklahoma. As the amount of dendrochronology literature increased in Oklahoma, methods were refined, information became more accessible, and dendrochronological studies occurred more frequently and were conducted at a larger scale (Clark et al. 2007; Stambaugh et al. 2009; Stambaugh et al. 2014; Figure 1).

Publications generally increased in complexity over time regarding objectives, methods, and results. Tree-rings, false-rings, and fire scars were analyzed using a variety of living and dead sample types: cores, stem/root cross-sections, and fallen trees/snags. As seen in Figures 2 and 3, two genera and three tree species dominated the Oklahoma dendrochronology literature during the observed temporal period. These species were encountered the most among the ODP for numerous reasons.

*Quercus stellata* and *Q. marilandica* are dominant species in the Cross Timbers, the largest forest type in Oklahoma (Dooley 2018; Oklahoma Forestry Services 2019b). Encroachment of *J. virginiana* is also occurring within the Cross Timbers (Dooley 2018; Johnson et al. 2015; Oklahoma Forestry Services 2019b). Results show that *Q. stellata* has had greater population stability than *Q. marilandica* for the past half-century considering increased drought and *J. virginiana* encroachment (Johnson and Risser 1973; Powell and Lowry 1980; Dooley 1983; Shirakura et al. 2006; Hammer 2012; Stambaugh et al. 2013b). However, McGrath (2012) observed stable *Quercus* recruitment was lacking despite absence of mesophication and *J. virginiana* invasion. Hammer (2012) researched within the Wichita Mountains National Wildlife Refuge and found that all dominant tree species (*Quercus* and *Juniper*) were experiencing ample reproduction despite temporal anthropogenic/environmental changes. *Quercus stellata* and *J. virginiana* are long-lived species, making them ideal for climate reconstructions, and *Q. stellata* has been shown to produce the best climate signal of trees of this region (Stahle and Cleaveland 1988; Therrell 2000).

Assigning publications to research topics helped illustrate what scientific areas were explored most often. Some research topics were assessed only once, such as Geomorphology which included Sellards et al. (1923), and Oil Extraction, which included Dunford et al. (2007) who quantified oil distribution in heart/sapwood based on age for urban *J. virginiana* trees (Figure 4). Age-diameter/Growth Rate literature is still currently relevant, with Powell and Lowry (1980), Engle and Kulbeth (1992), and Dunkin et al. (2008) providing rangeland management recommendations and Rosson (1994) assessing *Q. stellata* growth characteristics/stand structure as a commercial resource. Age-diameter/Growth Rate & Stand Dynamics consisted of Dooley (1983), McGrath (2012), Hammer (2012), and Hoff et al. (2018) who all investigated species compositional changes in the Cross Timbers. Dooley (1983) observed stable *Quercus* establishment while McGrath (2012) observed a lack of stable *Quercus* recruitment coupled with a lack of mesophication, likely due to an enacted prescribed burning regime. Hammer (2012) examined anthropogenic, topography, and fire exclusion effects on *J. virginiana* expansion, distribution, and age. Results from Hoff et al. (2018) offered evidence that *Quercus*-dominated forests may be experiencing a compositional transition due to fire exclusion (early 1900s) and mesophication (post 1950s), a change also occurring in other parts of the U.S. (Abrams 1992).

Further research is needed to help determine why some but not all Cross Timbers forests are experiencing a dominant species transition. Some areas experience prescribed burnings while others do not, and other disturbances/environmental factors have been removed/added within the last century, which can also influence forest stand dynamics. Investigating publications from the literature review revealed the greatest factors influencing Oklahoma forest stand dynamics involved climate and fire.

Determining the most limiting environmental factor affecting tree-ring width at the stand-level is a recurrent goal for dendrochronologists (Fritts 1976; Speer 2010). Many ODP offered evidence that drought was a significant variable affecting Oklahoma tree growth. Climate ODP of different decades focused on drought reconstruction (Harper

1960; Johnson and Risser 1973; Butler and Walsh 1988; and Bode 2015). Harper (1960) determined drought frequency and Johnson and Risser (1973) assessed drought effects by evaluating annual tree-ring variation in *Quercus*. Butler and Walsh (1988) and Bode (2015) both demonstrated innovative applicability of *J. virginiana* in dendroclimatology despite the species being difficult to cross-date due to false-ring formation. Bode (2015) discovered false-ring events were more likely to occur in areas with the most variable precipitation. In the sole publication of Climate and Stand Dynamics, DeSantis et al. (2011) showed that species compositional changes such as reduced *Quercus* recruitment in central Oklahoma forests was due to factors associated with fire exclusion and drought.

Fire occurrence in Oklahoma was historically common (Oklahoma Forestry Services 2019a). Fire History ODP helped establish the impact of humans and drought on historic fire regimes (16th to 21st centuries) by dating fire scars to develop fire chronologies (DeSantis et al. 2010b; Allen and Palmer 2011; Stambaugh et al. 2013a). Removal of Native Americans, influx of Euro-Americans, and fire exclusion were all found to correlate with historic fire regime changes; humans had a more significant effect on fire regimes compared to drought.

Fire, drought, and human habitation/land-use were further explored in the Fire History and Stand Dynamics ODP, which developed fire histories to better understand current forest conditions (Shirakura 2006; Clark et al. 2007; Stambaugh et al. 2009; DeSantis 2010; DeSantis and Hallgren 2011; Hallgren et al. 2012; Stambaugh et al. 2013b; Stambaugh et al. 2014; and King 2015). Factors in addition to fire history were explored, such as topography (Clark et al. 2007), sprout regeneration (DeSantis and Hallgren 2011), and sapling age structure (King 2015). While scale of studies varied, *Q. stellata, Q. marilandica,* and *J. virginiana* were the main species for all publications of this topic. Altered temporal fire regimes within central Oklahoma forests were more often linked to anthropogenic activity rather than drought (Clark et al. 2007; DeSantis et al. 2010b; Allen and Palmer 2011; Stambaugh et al. 2013b; Stambaugh et al. 2014; King 2015). These ODP revealed that historic/current fire regimes have affected successional processes of Oklahoma forest ecosystems, particularly by removal of fire from the landscape and mesophication.

The Stand Dynamics research topic contained the highest number of ODP with the most diverse main study species: *P. echinata* (Taylor 1965; Cerny et al. 2016), *J. virginiana* (Edmondson 2006), *Quercus* (Therrell and Stahle 1998; Clark 2003; Clark and Hallgren 2003; Clark and Hallgren 2004; Clark et al. 2005; King and Cheek 2015), and *F. pennsylvanica* (King and Buck 2018). Numerous forest types/locations were assessed: upland *Quercus-Pinus* stand (Taylor 1965), Shortleaf Canyon (Cerny et al. 2016), upland Cross Timbers (Therrell and Stahle 1998; Clark 2003; Clark and Hallgren 2003; Clark and Hallgren 2004; Clark et al. 2005; Edmondson 2006), an urban forest (King and Cheek 2015), and a lakeside bottomland hardwood forest (King and Buck 2018). Many factors leading to forest composition changes were evaluated in the Stand Dynamics research topic.

Stand Dynamics ODP's methodologies and results were distinct from all other ODP. Taylor (1965) was the first analysis of *P. echinata* in Oklahoma at its western range and Cerny et al. (2016) documented its range expansion. Therrell and Stahle (1998) developed a GIS model that identified soil type to help predict ancient Cross Timbers forest tract locations: a new utilization of dendrochronology. The thesis by Clark (2003) was published successively as journal articles and provided a high amount of information on *Quercus* forest dynamics and Oklahoma Cross Timbers ecology. *Quercus* primarily reproduced by stump sprouting based on root age structure (Clark and Hallgren 2003), methods to correct age estimates were introduced (Clark and Hallgren 2004), and old-growth *Quercus* forests (~200 years) successfully regenerating among mesophytic species was documented (Clark et al. 2005). Edmondson (2006) developed the first *J. virginiana* tree-ring chronology (~360 years) and a false-ring chronology. Investigating directly in an urban area, King and Cheek (2015) demonstrated that disturbed urban forests are an important dendrochronological resource. Due to urbanization, drought, fire exclusion, and lack of management, *Quercus* recruitment decreased as non-*Quercus* recruitment increased, with *J. virginiana*, mesic species, and invasive *Ligustrum sinense* Lour. (Chinese privet) dominating the midstory and understory. King and Buck (2018) described characteristics of bottomland hardwood forest and obtained baseline data for *F. pennsylvanica* in case of an invasive insect outbreak by *Agrilus planipennis* Fairmaire (emerald ash borer). The diverse dendrochronology applications observed in the Stand Dynamics ODP showed analyzing tree-rings can go far beyond studying tree age.

Major ecological questions were addressed by the Stand Dynamics ODP. What is the state of Oklahoma's old-growth forests? How is *Quercus* reproducing? What impact does fire exclusion have? How can laboratory methods be refined to provide more accurate results, and can we analyze false-rings instead of dismissing them? How are forests changing considering urbanization and climate change? Comparing late Stand Dynamics publications to the earliest Oklahoma dendrochronological studies demonstrates how this body of knowledge has advanced over time.

A recurring topic for many ODP were two leading factors affecting forest stand dynamics: historical land-use and drought. Land-use changes over time due to population movements of Native Americans and settlement by Euro-Americans showed a gradual effect on forest ecosystems and disturbance patterns as both groups cleared forests for agriculture, grazing, and logging, and changed fire regimes (Taylor 1965; Clark 2003; Allen and Palmer 2011; and Stambaugh et al. 2013b). More recent effects due to urbanization include fire exclusion, *J. virginiana* encroachment, and introduction of non-native plant species (King and Cheek 2015; Hoff et al. 2018; King and Buck 2018). Several ODP established new techniques and foundspecies applicable to the field of dendrochronology beyond Oklahoma (Therrell and Stahle 1998; Clark and Hallgren 2004; Edmondson 2006; Bode 2015; King and Cheek 2015). Studies that comprised the ODP are significant to forests within Oklahoma, but also to the international field of dendrochronology.

## CONCLUSION

From early studies estimating age structure to fire history reconstructions that spanned centuries, there are still more inquiries for Oklahoma forests that can be addressed using dendrochronology. Future dendrochronology studies could examine understudied research topics as revealed by this review, such as Geomorphology and Age-diameter/Growth rates. Field sites from some of the earliest ODP could also be revisited to assess compositional changes. There was also a lack of diversity in tree species utilized in the ODP. Sensitive tree species, such as *Q. stellata*, *Q. marilandica*, and *J. virginiana*, were researched more frequently than others, even though Oklahoma has many other species suitable for dendrochronology studies.

Three ODP included *Pinus* as a main study species (Taylor 1965, Stambaugh et al. 2013a; Cerny et al. 2016). *Taxodium distichum* (L.) Rich. (bald cypress) is also native to Oklahoma but was not a main species in any ODP despite its longevity (>2000 years) and reconstruction capability (Stahle et al. 2019; United States Department of Agriculture 2021). Both *P. echinata* and *T. distichum* are known to produce long tree-ring chronologies which makes them highly applicable for future denchrochronological studies in Oklahoma (Grissino-Mayer and Butler 1993; LaForest et al. 2005-6; Stahle et al. 2019). Long tree-ring chronologies are essential for reconstructions, but analyses of young trees and invasive trees can also provide valuable information. Fast-growing, invasive *Pyrus calleryana* Decne. (Callery pear) is invading Oklahoma open prairies, woodlands, and urban/rural forests (Oklahoma Invasive Plant Council 2019). *Pyrus calleryana* can outcompete native tree species and its eradication is difficult. Dendrochronology could be used to help validate the impact planting this species as an ornamental has on Oklahoma forests.

Oklahoma dendrochronology studies can positively impact dendrochronology research elsewhere. Tree-ring records for species studied in Oklahoma could potentially be submitted to the International Tree-Ring Databank (ITRDB), which is the world's largest tree-ring data repository that is readily available for research (National Oceanic and Atmospheric Administration 2021). The ITRDB is a global resource of tree-ring chronologies containing over 2000 chronologies that spans six continents with the aims to preserve tree-ring data and encourage international research collaborations (Speer 2010). Increasing the diversity of Oklahoma tree-ring records will help expand species representation within this reputable international database. Various historical and potential impacts to Oklahoma forests were recognized within the ODP, many of which likely impact forests outside of Oklahoma.

Multi-state/regional dendrochronology publications that included Oklahoma were not reported in the literature review but are still relevant to dendrochronology research in Oklahoma and elsewhere. Notable research that involved Oklahoma within more comprehensive studies offers substantial findings regarding climate relationships/reconstructions (Stahle and Hehr 1984; Stahle 1990; Cook et al. 1999; Edmondson 2010; LeBlanc and Stahle 2015; Guyette et al. 2015), dendrohydrology (Cleaveland and Stahle 1989), and fire frequency (Guyette et al. 2015; Rooney and Stambaugh 2019). These studies used larger field sites and sample sizes, that increased the significance of results from there research. Oklahoma's inclusion within these multi-state studies demonstrates the role it serves within the larger field of dendrochronology. Future research could include developing a second literature review that catalogues regional/multi-state dendrochronology studies that include Oklahoma. Larger, regional studies, along with the reviewed Oklahoma dendrochronology publications, will likely help uncover the continuous impacts of increased urbanization and climate change on North American forests.

Dendrochronology is one of few environmental proxies that allows researchers to reconstruct environmental conditions of the past with great confidence, offering an outlook into how forests may develop in the future under similar conditions. Compared to other regions in the U.S., there are still a limited number of dendrochronological studies for Oklahoma forests. Discovering new locations, species, and applications within Oklahoma that hold potential for dendrochronological studies is needed to help expand this body of literature within and outside of Oklahoma.

Dendrochronology has helped researchers understand what dominating factors have affected forest stand dynamics in Oklahoma: people and climate. Drought is predicted to increase in length and frequency due to climate change. Urban areas are growing as human populations continue to increase, a contributing variable to climate change. The need for further dendrochronological research remains exceedingly important as climate and humans, the factors that have the greatest impact on Oklahoma forests, are also likely to affect forests worldwide.

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## APPENDIX A
## Chronological Inventory of Oklahoma Dendrochronology Publications (ODP)

| Publication Type Abbreviations | Research Topic Abbreviations |
|---|---|
| B = bulletin | AD/GR = age-diameter/growth rate |
| CP = conference proceedings | AD/GR & SD = age-diameter/growth rate & stand dynamics |
| DT = doctoral thesis | C = climate |
| HT = honors thesis | C & SD = climate and stand dynamics |
| JA = journal article | FH = fire history |
| MT = master's thesis | FH & SD = fire history and stand dynamics |
| R = report | GM = geomorphology |
| | OE = oil extraction |
| | SD = stand dynamics |

| In-text citation*; Publication type | Research topic | Main study genera/species |
|---|---|---|
| Sellards et al. (1923); B | GM | *Carya illinoinensis, Celtis* spp., *Fraxinus* spp., *Populus deltoides*, *Ulmus* spp., *Sideroxylon lanuginosum* ssp. *oblongifolium, Zanthoxylum* spp. |
| Harper (1960); JA | C | *Quercus macrocarpa, Quercus nigra, Quercus stellata* |
| Taylor (1965); JA | SD | *Pinus echinata* |
| Johnson and Risser (1973); JA | C | *Quercus marilandica, Quercus stellata* |
| Powell and Lowry (1980); JA | AD/GR | *Quercus marilandica, Quercus prinoides, Quercus stellata* |
| Dooley (1983); DT | AD/GR & SD | *Quercus stellata* |
| Butler and Walsh (1988); JA | C | *Juniperus virginiana* |
| Engle and Kulbeth (1992); JA | AD/GR | *Juniperus virginiana* |
| Rosson (1994); CP | AD/GR | *Quercus marilandica, Quercus stellata* |
| Therrell and Stahle (1998); JA | SD | *Quercus stellata* |
| Clark (2003); DT | SD | *Juniperus virginiana, Quercus marilandica, Quercus stellata* |
| Clark and Hallgren (2003); JA (originally in Clark 2003) | SD | *Quercus marilandica, Quercus stellata* |
| Clark and Hallgren (2004); JA (originally in Clark 2003) | SD | *Quercus marilandica, Quercus stellata* |
| Clark et al. (2005); JA (originally in Clark 2003) | SD | *Carya texana, Juniperus virginiana, Quercus marilandica, Quercus shumardii, Quercus stellata, Quercus velutina* |

| **In-text citation*; Publication type** | **Research topic** | **Main study genera/species** |
|---|---|---|
| Shirakura (2006); MT | FH & SD | *Quercus marilandica, Quercus stellata* |
| Edmondson (2006); HT | SD | *Juniperus virginiana* |
| Clark et al. (2007); CP (originally in Clark 2003) | FH & SD | *Carya texana, Juniperus virginiana, Quercus marilandica, Quercus shumardii, Quercus stellata* |
| Dunford et al. (2007); JA | OE | *Juniperus virginiana* |
| Dunkin et al. (2008); JA | AD/GR | *Prunus angustifolia* |
| Stambaugh et al. (2009); JA | FH & SD | *Quercus stellata* |
| DeSantis (2010); DT | FH & SD | *Juniperus virginiana, Quercus marilandica, Quercus stellata* |
| DeSantis et al. (2010b); JA (originally in DeSantis 2010) | FH | *Quercus stellata* |
| DeSantis et al. (2011); JA (originally in DeSantis 2010) | C & SD | *Juniperus virginiana, Quercus marilandica, Quercus stellata* |
| Allen and Palmer (2011); JA | FH | *Quercus stellata* |
| DeSantis and Hallgren (2011); JA (originally in DeSantis 2010) | FH &SD | *Quercus marilandica, Quercus stellata* |
| Hallgren et al. (2012); CP | FH & SD | *Juniperus virginiana, Quercus marilandica, Quercus stellata* |
| Hammer (2012); MT | AD/GR & SD | *Juniperus virginiana* |
| McGrath (2012); MT | AD/GR & SD | *Quercus marilandica, Quercus stellata* |
| Stambaugh et al. (2013b); R | FH &SD | *Quercus stellata, Juniperus virginiana* |
| Stambaugh et al. (2013a); JA | FH | *Pinus echinata* |
| Stambaugh et al. (2014); JA | FH & SD | *Juniperus virginiana, Quercus marilandica, Quercus stellata* |
| King and Cheek (2015); JA | SD | *Juniperus virginiana, Quercus marilandica, Quercus stellata* |
| King (2015); JA | FH& SD | *Celtis laevigata, Celtis occidentalis, Juniperus virginiana, Quercus marilandica, Quercus stellata, Sapindus saponaria* var. *drummondii*, *Sideroxylon lanuginosum* ssp. *oblongifolium, Ulmus americana, Ulmus rubra* |
| Bode (2015); MT | C | *Juniperus virginiana* |
| Cerny et al. (2016); JA | SD | *Pinus echinata, Quercus stellata* |
| King and Buck (2018); JA | SD | *Fraxinus pennsylvanica, Populus deltoides, Salix nigra* |
| Hoff et al. (2018); JA | AD/GR & SD | *Carya* spp., *Celtis* spp., *Juniperus virginiana, Quercus marilandica, Quercus stellata*, *Ulmus* spp. |

## APPENDIX B
## Index of Tree/Shrub Species Reviewed in Oklahoma Dendrochronology Publications

Main tree/shrub genera and species assessed in the ODP are listed below alphabetically by family/scientific name along with common names and status (N=native, I=introduced) (http://plants.usda.gov; United States Department of Agriculture 2020).

| Family name | Scientific name | Common name | Status |
|---|---|---|---|
| **CELTIDACEAE** | *Celtis* L. | hackberry | N |
| | *Celtis laevigata* Willd. | sugarberry | N |
| | *Celtis occidentalis* L. | common hackberry | N |
| **CUPRESSACEAE** | *Juniperus virginiana* L. | eastern redcedar | N |
| **FAGACEAE** | *Quercus macrocarpa* Michx. | bur oak | N |
| | *Quercus marilandica* Münchh. | blackjack oak | N |
| | *Quercus nigra* L. | water oak or black oak | N |
| | *Quercus prinoides* Willd. | dwarf chinkapin oak | N |
| | *Quercus stellata* Wangenh. | post oak | N |
| | *Quercus shumardii* Buckley | Shumard's oak | N |
| | *Quercus velutina* Lam. | black oak | N |
| **JUGLANDACEAE** | *Carya* Nutt. | hickory | N |
| | *Carya illinoinensis* (Wangenh.) K. Koch | pecan | N |
| | *Carya texana* Buckley | black hickory | N |
| **OLEACEAE** | *Fraxinus* L. | ash | N, I |
| | *Fraxinus pennsylvanica* Marshall | green ash | N |
| **PINACEAE** | *Pinus echinata* Mill. | shortleaf pine | N |
| **ROSACEAE** | *Prunus angustifolia* Marshall | Chickasaw plum | N |
| **RUTACEAE** | *Zanthoxylum* L. | pricklyash | N, I |
| **SALICACEAE** | *Populus deltoides* W. Bartram ex Marshall | eastern cottonwood | N |
| | *Salix nigra* Marshall | black willow | N |
| **SAPINDACEAE** | *Sapindus saponaria* L. var. *drummondii* (Hook. & Arn.) L.D. Benson | western soapberry | N |
| **SAPOTACEAE** | *Sideroxylon lanuginosum* Michx. ssp. *oblongifolium* (Nutt.) T.D. Penn | gum belly or chittamwood | N |
| **ULMACEAE** | *Ulmus* L. | elm | N, I |
| | *Ulmus americana* L. | American elm | N |
| | *Ulmus rubra* Muhl. | slippery elm | N |