ANALYSIS OF LAND USE, LAND COVER CHANGE

IN THE UPLAND FORESTS OF OKLAHOMA:

A COMPARISON BETWEEN THE 1950s AND 2000s

By

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CHAPTER I

INTRODUCTION

Oklahoma abounds in natural diversity and variety of ecosystem types. Situated at both a geographic and climatic crossroads, flora and fauna of eastern, western, northern and southern eco-regions converge to create unique interactions (Hoagland, 2000; Tyrl *et al*., 2007). Often described as one continuous ecotone (Rice & Penfound, 1959; Johnson & Risser, 1972), Oklahoma forests can be divided into twenty-five distinct community types that combine into five associations. All five associations are classified as variations on the eastern deciduous oak-hickory forest that reaches its western most extent in the state (Dyksterhuis, 1957; Rice, 1960). The most wide spread is the post oak-black jack oak association found in 65 of the state's 77 counties covering more area than all other upland forest types combined (Rice & Penfound, 1959; Hoagland, 2000). Known locally and regionally as the Cross Timbers (Hoagland *et al.,* 1999; Francaviglia, 2000), it ranges from an oak-hickory dominance with nearly a closed canopy in the eastern portion of the state to a more open oak woodland and finally to oak savannah as one moves westward (Johnson & Risser, 1972; Hoagland, 2000). In all five associations, both tree species diversity and percent canopy cover decline moving west from the eastern state border (Rice & Penfound, 1959). For the purposes of this study, the term "forested" applies to an area dominated by trees. Grass openings may occur and the canopy may not be closed as is common in Oklahoma upland forest types (Dyksterhuis, 1957; Tyrl *et al*., 2007). Some descriptions of Oklahoma's tree canopy cover make the distinction between forests, with greater than 60% canopy cover, and woodland or woodland savannah, with 25%-60% canopy cover (Hoagland, 2000). Both classifications are included in this study of upland forests.

Original 1950s Study

In the 1950s, Elroy Rice and William Penfound, two scientists working with the University of Oklahoma and the Oklahoma Biological Survey, established 209 field research sites of varying size to investigate and sample Oklahoma's existing upland forests that were estimated to cover 24% (4,200,000 ha) of the state (Rice & Penfound, 1959; Johnson & Risser, 1972). The original objectives comprised the "identification and distribution of all relatively undisturbed forest types and quantitative description of each stand based on the woody species" (Rice & Penfound, 1959). Dividing the state into six regions that cut across forest types, they were able to look at combinations of significant north-south temperature and east-west precipitation gradients. Most of the field sites, also called stands, were located in the post oak-black jack oak forest association due to its extensive dominance in the state. Sites were also located within the oak-hickory forest type as well as the oak-pine forest type. One stand is located in the loblolly pine forest type and the shinnery oak type was not sampled due to its shrubby nature and limited extent (Rice & Penfound, 1959). Using county road maps, they located at least three areas in each selected county with few or no roads as a measure of low human disturbance. From that list, 208 field sites in 60 of the state's 77 counties were selected for sampling as part of the 1950s study. There was a data sheet for stand 209 added at the end of the study in late summer 1957 but for an unknown reason it was not included in the 1959 published study. Each stand data sheet actually comprised two pages. The first page showed detailed geographic descriptions of the stand including a legal description based on Oklahoma's legal land description of township, range and section number, officially titled the Public Land Survey System (PLSS) (Griffin *et al.*, 2005). It also included region of the state, species present, acreage sampled, land use history and other information of direct importance to this present study. The second page contained data regarding tree density, sapling density, basal area, importance percentage and other items not of direct relevance to this study. The hand drawn field maps on each sheet were of particular importance and illustrated the actual stand location within a given section. These maps combined with other information on each data sheet, including distance from towns and notations of physical or topographic features facilitated revisiting and measuring of the same stands originally studied fifty years ago.

Although the original Rice and Penfound study selected field sites based on a relatively low level of human disturbance, it should be noted that some level of disturbance was accepted. On the first page of each data sheet, notes were made regarding the land use history of that stand including such items as trees cut, grazing and fire occurrence. A quick count of the information for the 194 stands revisited for this current research revealed that in the ten to fifteen years just prior to the 1953 study onset, approximately 80 (41%) stands had significant numbers of trees removed, 60 (31%) stands indicated current levels of heavy to moderate grazing and 65 (33%) had not burned in recent memory. Rice and Penfound noted in their study (1959) that the absence of fire combined with increased grazing pressure had altered the forest landscape they had sampled, in particular by allowing woody encroachment into grassland areas and increasing tree stem density.

Focus of Current Study

The focus of my research was the examination and analysis of the remaining stands with their accompanying data sheets to determine which stands remained relatively intact and which stands had been disturbed by human action. Utilizing current aerial photography within a Geographic Information System (GIS), a measure of both disturbance level and disturbance type was recorded for each stand in the study. For my project "disturbance" was defined as an observed removal of tree cover due to human activity on previously documented forestland with conversion to another land use type. Stands given a 'None' designation had no readily visible human activity as a cause of the disturbance but may have contained more subtle changes including species shifts, effects of grazing pressure on under story layers, drought impacts or (non) occurrence of fire. Although these changes were not the focus of this study, they were addressed to a certain degree in both the Review of Literature and Discussion sections.

The data collected by Rice and Penfound from 1953 to 1957 represented a snapshot in time and documented the location, composition and extent of representative field sites in Oklahoma's upland forests. My hypothesis stated that when the historical stands were reexamined, fifty years after the original research study, any human disturbance and overall loss of forest cover in previously forested areas, was due to either urbanization or agricultural conversion. Some important questions that I hoped to answer were as follows: 1.Which of these historic upland forest stands remained relatively intact with a minimal to moderate level of disturbance and which had a significant to complete level of disturbance? 2. If disturbance had occurred, what land use had replaced the forest cover? 3. Geographically, where were the changes located and were there certain regions of the state that were affected to a greater degree? 4. How was disturbance related to forest type, stand acreage or urban proximity? This study examined human driven land use change from forest cover to another land use category with the conversion done for human benefit. Other studies have been conducted over the years using the Rice and Penfound stands, but were limited in area and scope (Johnson & Risser, 1972; Johnson & Risser, 1975; Hoagland *et al.*, 1999). Baseline quantification for this set of historical field sites provided valuable data documenting the status and condition of each stand aiding scientists who desire to use them in further research studies.

As various aspects of population pressure combine with alterations in land use, changes in the integrity and functioning of ecosystems are being studied, documented and analyzed (Turner *et al*., 2007; Leu *et al.*, 2008). A GIS, can provide a comprehensive and powerful analysis environment for both managing and interpreting data, and it can also generate detailed documents, reports or other deliverables. (Ningal *et al.*, 2008). This study was well suited for use within GIS particularly due to its examination of land use change over time and human influence on the landscape (Wallace *et al*., 2003; Galicia & Romero, 2007). A study such as this one may provide an opportunity to educate the general public, policy or decision makers, landowners, educators and natural resource managers about the land use changes affecting management of our state's forests.

CHAPTER II

REVIEW OF LITERATURE

Land Change Science

At the forefront of both global and national conversations on environmental issues is the topic of global climate change and the influence on it by human activity. Within the scientific community, a new area of research has emerged, Land Change Science (LCS). In 2007, a paper was presented to the National Academy of Science promoting the cause for LCS as an over arching interdisciplinary approach to studying the many facets and impacts of land cover land use changes being documented on a global scale (Turner *et al.,* 2007). Since the mid 1990s, NASA has funded and conducted extensive research through its Land Cover and Land Use Change Program housed at the University of Maryland. A decade of integrated work pulling from both natural and social disciplines and utilizing the latest remote sensing, GIS and modeling technology, paved the way for the emergence of Land Change Science in the past year (NASA, 2008). The Land Cover and Land Use Change Program, paralleling Land Change Science, examines direct human causes of land use change and the resulting effects on climate change and ecosystem functions with regard to a sustainable provision of human needs. So, what is Land Change Science? In a broad general sense, it is the study of human caused changes on the natural landscape and the consequences or significance of those changes to both the environment and mankind's well being. Additionally, LCS examines the dynamic interface between human and natural systems within a GIS framework resulting in a powerful interdisciplinary research arena. Allowing for both social and environmental problem solving the power and potential of this scientific endeavor is to model projected changes based on current information and trends at the global level (Turner *et al*., 2007). Driven by a need for seamless, current, global land cover data, LCS is pushing the GIS and remote sensing communities to continually upgrade and improve information databases. (Turner *et al.*, 2007). This definition takes in historical studies, archeology, climate change and other related disciplines. However, with the advance of analytical and observational technologies, the ability of science not only to investigate but also to model and project these changes has increased significantly (Schneider & Pontius, 2001; Wallace *et al*., 2003; Ningal *et al*., 2008). Additional research from the fields of sociology, economics and public health adds a human dimension and begins to give depth to a LCS definition. This new field has four main components or research categories. First is the continued observation and monitoring of land use changes already taking place. This is also the primary focus of this paper and research project. The second component is an evaluation and understanding of these changes in the human context, which is also addressed in this paper to some degree. Third is a modeling of specific changes and projections for future changes and finally, an analysis and assessment of these changes with regard to ecosystem sustainability (Turner *et al.*, 2007).

Studies in Land Use Change

A study of past human impacts on the landscape is an important area of research within the field of environmental science. Knowledge of the cultural history of a place is essential when evaluating land use changes and the subsequent alterations in ecosystem functioning (Foster *et al.*, 2003; Lunt & Spooner, 2005). Humans have been altering the natural environment for centuries and even processes considered ‘natural’ the effect on ecosystems is modified by past anthropogenic activity (Christensen, 1989). Many studies, both in the US and around the globe, are looking at why and how people affect the land and the speculation that patterns of land use change frequently have the same drivers (Galicia & Romero, 2007; Ningal *et al*., 2007; McEwan & McCarthy, 2008). One study examining anthropogenic disturbance within the 11 western most states with an area bordering Oklahoma identified a series of disturbance types and assigned importance values based on their perceived level of impact. The three primary human disturbances, in order of importance to ecosystem integrity are agriculture, urban or rural development and infrastructure. Each of the many identified disturbance categories is weighted and used within a GIS to create a “human footprint” model allowing analysis of various human effects on the landscape including sensitive impact areas, potential disturbance areas and wildland fire risk areas (Leu *et al.*,2008). Another recent study looking specifically for undisturbed areas within the Cross Timbers, documented several of the same human disturbance categories with parallel shifts in land use and land cover types (Griffin *et al*., 2005). This idea that the legacy of historical land use continues long into the future, for decades or even longer, is an integral piece when making management or policy decisions (Iverson, 1988; Christensen, 1989; Foster *et al*., 2003). Often driven by shifts in population and human needs, land use change in the United States has left us with a constantly moving mosaic or patchwork of current and abandoned agriculture land, lands taken out of or returned to tree cover and ever expanding urban or suburban boundaries (Christensen, 1989; Boren *et al*., 1997; Pearson *et al*., 1998; Farley *et al*., 2002).

Defining Disturbance

The composition and extent of ecotone forests, such as exist in Oklahoma, have been shaped over time by disturbance, primarily fire and weather events (Dyksterhuis, 1957; Nuzzo, 1985; Hoagland *et al*., 1999). Since European settlement however, disturbance in these forest types has increasingly been a human driven combination of agricultural practices and altered fire regimes (Hoagland, 2000; Pogue & Schnell, 2001). Several studies suggest that forest cover and agricultural land use are reciprocally related with a cycle of conversion, use, abandonment, regeneration and then conversion again back to agriculture or another land use type such as urbanization (Pearson *et al.*, 1998). The introduction of domestic livestock and crop cultivation to the country's grasslands and forests set into motion this very cycle of land conversion that continues today (Christensen, 1989; Boren *et al*., 1997). Chronic and concentrated grazing by domestic livestock, is a type of disturbance that often results in a drop in both the abundance and diversity of native grass and herb species in the forest under story (Pearson *et al*., 1998; Wallace *et al*., 2003) and can favor expansion of woody species into prairie areas (Dyksterhuis, 1957; Griffin *et al*., 2005). Ironically, it is the clearing and opening of the land often with subsequent over grazing that eventually diminishes the availability and quality of forage (Pearson *et al*., 1998). Oak woodlands and oak savannas, common in Oklahoma, are particularly vulnerable to this type of conversion cycle and a far reaching result of agricultural land abandonment is that the resulting vegetation will rarely, in the timeframe of humans, return to pre disturbance conditions (Farley *et al*., 2002; Leu *et al*., 2008).

Fire in an ecosystem is frequently defined as a type of disturbance but, some studies suggest that the absence or removal of fire in certain habitats may also be considered disturbance (Nuzzo, 1985; Boren *et al.*, 1997). Because fire regimes and fire management strategies have differed around Oklahoma over time (Penfound, 1962; Pogue & Schnell, 2001), it raises the question whether the presence or exclusion of fire in specific areas has favored the long term presence of either trees or rangeland (Griffin *et al*., 2005; McEwan & McCarthy, 2008). In their research, Rice & Penfound (1959) suggested that the state had undergone periods of deforestation, reforestation and afforestation over time due to a combination of natural causes and human activity. Removal of fire and conversion of native ecosystems to intensive grazing land favors encroachment of trees into prairies and an increase in tree stems per acre resulting in a canopy closing effect within forests and woodlands (Abrams, 1992; Pogue & Schnell, 2001; Wallace *et al.*, 2003). The converse however demonstrates that frequent and fairly intense fires will favor grasses and have detrimental effects on woody species (Johnson & Risser, 1975). It seems a likely conclusion that the current structure, composition and extent of Oklahoma's forests and woodlands are primarily the result of past human actions, specifically agricultural activity and suppression of fire (Abrams, 1992; Foster *et al*., 2003).

Implications of Fragmentation

While not the focus of this study, one issue that arose is the concept of fragmentation. Published research in this area is extensive and is often concerned with the implications and long term effects of forest fragmentation on biodiversity, habitat quality, ecosystem function including watersheds around large metropolitan areas, forest regeneration and the low probability that small forest fragments will remain forested (Boren *et al*., 1997; Schneider & Pontius, 2001; Galicia & Romero, 2007; Turner *et al*., 2007). One common thread concerns human driven land use, land cover change as a principal cause of landscape fragmentation (Pearson *et al.*, 1998; McEwan & McCarthy, 2008). In the 1950s, low tree density of less than 110 trees per hectare was not uncommon particularly in the western two thirds of Oklahoma counties but the level of connectivity was high (Farley *et al*., 2002). Since the 1970s, forest fragmentation in Oklahoma due to human activity has resulted in an overall loss of forest cover area accompanied by a decrease in biodiversity within those regions (Boren *et al*., 1997; Farley *et al*., 2002).

Worldwide, an increased conversion of land to agriculture from other land use types in addition to the expansion of human population areas are the two leading causes of landscape fragmentation (Pearson *et al.*, 1998; Lunt & Spooner, 2005; Turner *et al*., 2007). When lands are converted to agriculture uses, routinely what occurs is the creation of a patchwork layout containing straight edge boundaries between the converted land, abandoned areas and native habitats (Iverson *et al*., 1988). This decrease in edge complexity can be devastating to the abundance and diversity of native flora and fauna which must adapt to small, often isolated habitat fragments of poor quality (Turner *et al*., 1995; Pogue & Schnell, 2001). Land use, land cover change and resulting fragmentation can also provide the opportunity for establishment of exotic species and may favor native generalist or opportunistic species (Pearson *et al*., 1998; Foster *et al*., 2003). These species shifts could be linked in part to the continued effects of agriculture land use practices such as use of fertilizers or pesticides whose residual times may not be clearly understood (Christensen, 1989).

Ecotones have been observed to be highly sensitive to fragmentation particularly in the case of agricultural conversion. Fields converted from native tree cover but later abandoned, usually regenerate but with an altered floristic composition. (Pogue & Schnell, 2001; McEwin & McCarthy, 2008). The overall effects of fragmentation on previously forested land appear to be a combination of the spatial arrangement of remaining patches, the level of connectivity with areas of similar composition and surrounding land use within a temporal context (Christensen, 1989; Turner *et al.,* 1995; Pearson *et al*., 1998).

GIS Analysis

Human driven land use land cover change is arguably one of the dominant forces impacting native landscapes during the 20th century (Iverson, 1988; Schneider & Pontius, 2001). New technology such as the recent creation of a vast GIS database combined with other historical data allows researchers to examine these changes in new ways (Turner *et al.,* 1995; Turner *et al*., 2007). Many current studies focusing primarily on human driven change are gathering field data and other relevant information for analysis and modeling utilizing GIS (Wallace *et al.*, 2003; Galicia & Romero, 2007; Ningal *et al*., 2008). GIS is being readily incorporated into specific temporal studies of land use, land cover change in other countries. In central Mexico, researchers are examining decadal aerial photos and satellite images for the 1970s, 1980s and 1990s to evaluate human driven losses of historic forest cover over time. They also were interested in correlations between loss of canopy with social issues such as urbanization and governmental policy changes (Galicia & Romero, 2007). Information from both the image evaluations and fieldwork are analyzed and georeferenced within a GIS. This type of application improves both analysis quality and time efficiency while illustrating trends. The image quality differences between the decades of study reinforce the importance of fieldwork and viewing other historical land cover sources for validation of results and analysis (Galicia &Romero, 2007). A similar study is ongoing in Papua New Guinea where land use change trends related to human activities, primarily urbanization and large scale agriculture, are evaluated in light of losses in biodiversity and environmental quality (Ningal *et al*., 2008). The comparisons between time periods start with a preliminary analysis of historical, static maps and records pertaining to areas previously documented as forested followed by utilization in a GIS environment with current Landsat images (Ningal *et al*., 2008).

In the United States, regional studies of land use, land cover change, utilize GIS to improve analysis and modeling. Researchers examining suburban Boston in northeastern Massachusetts had a particular interest in watershed integrity, leading planners to develop a model that identifies areas with a potential for deforestation (Schneider & Pontius, 2001). Utilizing a statewide GIS system called MassGIS containing aerial photos, satellite images, land use data and other relevant spatially detailed data, researchers developed a GIS model that bases a specific area's probability of deforestation on three factors. The first factor is the suitability of that area for another use based on such things as soil type, elevation, and proximity to a waterbody or slope. Second, the areas proximity to a land use type other than forestland is evaluated. How far is it to other residential or agricultural or commercial property? Third, how large is the area? The model takes into account that smaller parcels are impacted more readily and more completely than larger intact forestland tracts. GIS easily and dramatically incorporates all three of these inputs or factors into a comprehensive analysis that allows highly usable reports to be issued to decision makers in the affected watershed (Schneider & Pontius, 2001).

Studies in Oklahoma are also using GIS to streamline analysis and vividly illustrate land use land cover trends, changes and impacts. A 1997 study (Boren *et al.*), acquired aerial photos for Tulsa, Washington and Osage counties, from the USDA Field Office taken in the 1960s, 70s, 80s and 1990. These photos were digitized, validated using topographic quadrangle maps from the Oklahoma Geological Survey covering the same time period, and finally converted to raster maps with a 5m resolution. After maps were imported to a GIS, analysis focused on temporal changes in vegetation cover and land use types by county and by classification as rural or urban areas. Fragmentation, as measured by patch size, and landscape structure was also examined. This type of study is very time intensive and is limited to 3 counties so more detailed examination of changes is possible. Many of the state level aerial photos are now available in the public domain providing base data for more widespread study areas.

Historical Perspectives on Oklahoma Forests

Since the time Thomas Nuttall and Washington Irving traveled through the area in the early 1800s, several significant contemporary works have been done in the analysis of Oklahoma's forests and woodlands (Tyrl *et al.*, 2007) including scientists such as E.B. Little who wrote the first *Forest Trees of Oklahoma* book in 1926, the monographs of Bruner in the 1930s and the 1940s Duck and Fletcher study of fur bearing animals that yielded the definitive statewide vegetative cover map which remains a research standard (Rice & Penfound, 1959; Rice, 1960; Penfound, 1962; Griffin *et al.,* 2005). This map forms the basis for forest type identification in both this current study and the 1950s Rice and Penfound study (1959). Both studies were able to draw from this reservoir of research to determine the criteria for analysis of their stand locations.

Although this study is not looking at why or how trees were removed, only that sometime between the mid-1950s and 2000s they were removed, the questions of why and how remain interesting. Rice and Penfound described in many of their narratives on the site data sheets and again in the published journal article, the beginning effects of the 1950s drought. They commented on the stress level of the trees, where trees appeared to be dying and the poor regeneration primarily in the western part of the state (Rice & Penfound, 1959). Research estimates and other historical data suggest that the drought of the 1950s, due to its seasonal timing during critical growing cycles, may have been worse, in terms of tree survivability, than the 1930s Dust Bowl years (Hoagland *et al.*, 1999; Stahle *et al.*, 2007). Did these two decades of prolonged drought, combined with lesser droughts in the 1980s and late 1990s, favor a shift to grassland dominated ecosystems, particularly on the perimeter or ecotone between grass and forest (Hoagland, 2000)?

Continued investigation of historical trends and events reveals that land management choices of the time period are often influenced by governmental policies (Lunt & Spooner, 2005). Land management practices and program implementation in the years between Rice and Penfound's analysis of Oklahoma's upland forests and 2006 may have had a significant impact on the results of this study. Government programs promoting herbicide use and brush removal to increase grazing lands and agricultural production were widespread across the central US from the 1950s into the early 1980s, peaking in the 1970s (Iverson, 1988; Boren *et al*., 1997; Engle *et al*., 2006). Forest cover in Oklahoma and the central United States is estimated to have decreased by 28% between the end of WWII and 1990 driven primarily by agriculture and resulting in an increased level of fragmentation (Boren *et al*., 1997; Pogue & Schnell, 2001). Trends worldwide illustrate that land cleared for agriculture is often converted to range first, followed by conversion to cropland. With advances in mechanized agriculture, crop yield per acre increases and marginal lands are often abandoned or put back in grasses or tree cover, usually introduced species. Rarely are preexisting native conditions replicated (Engle *et al.,* 2006; Galicia & Romero, 2007; Ningal *et al.,* 2008). Beginning in the late 1980s, government policy started to shift and encouraged landowners to identify marginal agricultural land to put back into more permanent vegetation as part of the Conservation Reserve Program (CRP). This often resulted in planting introduced grasses or establishing forest plantations (Iverson, 1988; Lewis, 2001; Farley *et al.,* 2002).

One final historical impact on Oklahoma's forests was the extensive creation of water bodies in the years following WW II. Lakes and reservoirs were constructed state wide, often at the expense of low lying post oak and black jack oak areas (Griffin *et al*., 2005). Farm ponds, generally less than 3 acres, were constructed by the thousands and paid for primarily with government funds (Farley *et al*., 2002). The images of the Dust Bowl were still fresh on everyone's mind and water reserves were a top priority.

CHAPTER III

METHODS

Among the original 209 forest stands selected by Rice & Penfound (1959), 12 sites were abandoned or combined with other stands sometime during the original study leaving 197 stands and their corresponding data sheets. Data sheet copies were obtained from the Oklahoma Biological Survey with a corresponding GIS generated map that showed the geographic distribution of all 197 remaining field sites. Data sheets for 101, 138 and 186 were missing and could not be included in this study. After each data sheet was read and examined for completeness and general information (Figure 1), a list was created including stand number, county, original acreage sampled and region within the state. Although not included in the original published study, stand 209 was included based on its consistent data sheet format. The data sheet for stand 161 consisted only of the first page but was also included because the information relevant to this study was present. The total number of site data sheets analyzed was 194.

Method Development from Sub-Sample Data

From the of 194 stands, five sites were selected at random within each of the six regions, northwest (NW), north central (NC), northeast (NE), southeast (SE), south central (SC) and southwest (SW), as defined by Rice & Penfound (Figure 2). A preliminary study

UPLAND FORESTS OF OKLAHOMA

Date June 14, 1956 Stand No. 125 NW

Owner or Lessee Lynn Womack

Location of O. or L. 3/4 Mi. E. and 2 Mi. N of stand

Location		
County	Sect. No. and Specific Location	Township
Dewey	Sec. 36 - SW 1/4	T17N, R14W
Nearest town	Distance and Direction from Town	
Oakwood	3 E - 1 1/2 S.	

Acreage of Stand 100A Topography Level

Past History			
Cut-Over	Burned	Grazed	Other
Few trees cut out for firewood prior to 20 years ago. Few trees removed for posts.	Not in last 20 years or so.	Apparently fairly heavily.	

Present Status		
Apparent Dominants	Less frequent trees	Shrubs and Woody Vines
Post Oak Q. stellata Blackjack Q. marilandica	Juniperus virg. Celtis reticulata Bumelia lanuginosa Q. havardii (specimen) Q. muehlenbergii	Rhus trilobata Symphoricarpos ~~Q. Mohriana? (specimen)~~ R. glabra Prunus gracilis Parthenocissus

Reproduction: Post Oak ____ Black Hickory ____

Black Jack ____ Black Oak ____

Other ____

Substratum Sand

O.K. also

Condition of Stand Many blackjacks dead from drouth.

Present Use Fairly heavy grazing.

Photographs

Miscellaneous notes

(Some post oak looks like cross with something else - perhaps Q. havardii. Very deeply cut leaves - often more than 5 lobes) Some post oak quite typical.

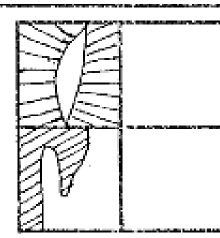

Figure 1 Sample first page of a Rice and Penfound data sheet

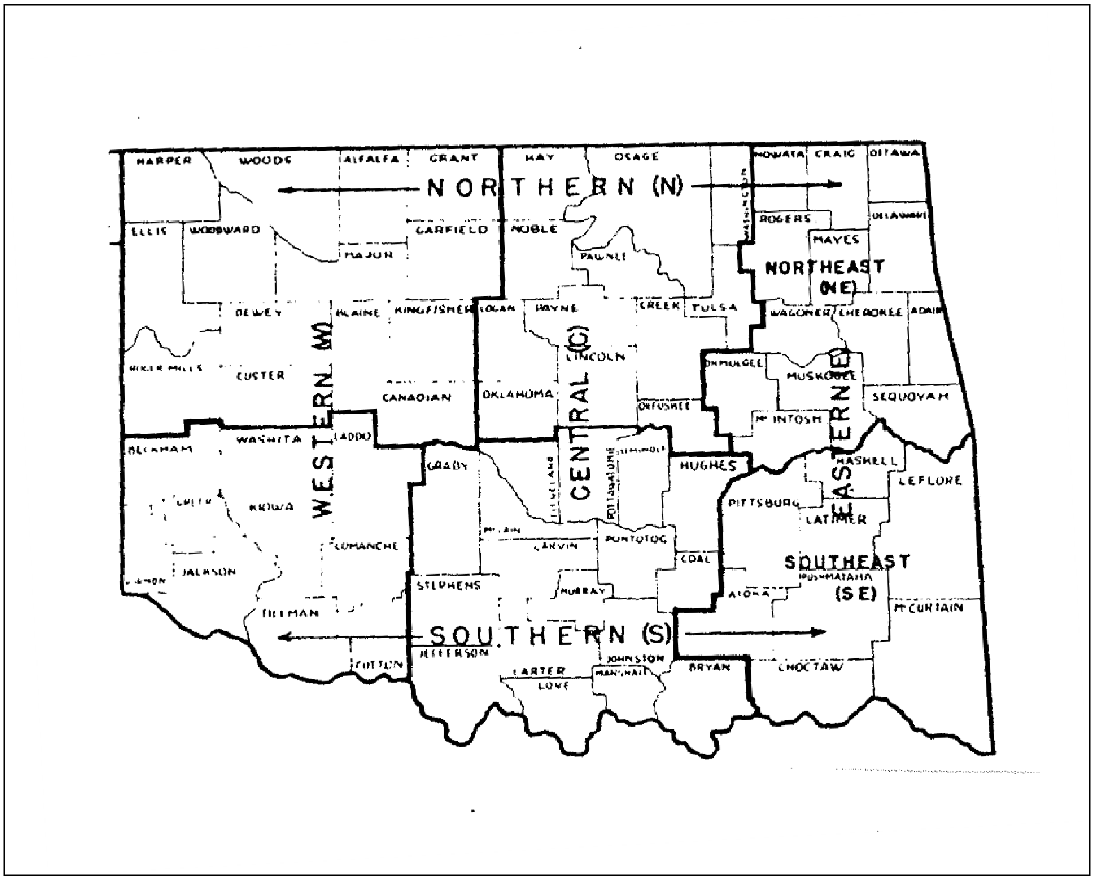

Figure 2 Six state regions as defined in the Rice and Penfound research (1959)

onn this stand subset to determine the best techniques and define disturbance types. It should be noted that both the Oklahoma City and Tulsa metropolitan areas fell within the NC region.

Several articles within the current literature related to human caused disturbance were reviewed, specifically those that focused on the various methods of scoring and evaluating that disturbance (Boren *et al.,* 1997; Farley *et al.,* 2002; Wallace *et al.,* 2003; Leu *et al.,* 2008). Using a 2006 edition of *The Roads of Oklahoma* atlas, the legal descriptions and drawn field map on each data sheet and 2006 aerial photographs provided by the Oklahoma Department of Agriculture, Food and Forestry (ODAFF), these thirty sample sites were located and analyzed in the field for the purpose of evaluating land cover changes and developing a disturbance level and disturbance type scoring rubric (Table 1 & Table 2). On some of the Rice and Penfound data sheets, the number of acres sampled was given as an estimate. In addition, some field maps were very difficult to read and determine the precise location of the original field-sampling site; therefore, I chose to make each disturbance level a range of percent tree cover loss rather than assigning exact area figures. Each range was represented by both a letter designation of A, B, C or D and a description of minimal, moderate, significant or complete, in increasing order of disturbance level. In the field, some stands were observed to have high levels of fragmentation. Individual trees or clumps of a few dozen in pastures and tree rows such as windbreaks or fencerows were noted. These also made precise measurement difficult.

DISTURBANCE LEVEL CLASSES	
A	Minimal = less than or equal to 10% loss of tree cover
B	Moderate = greater than 10% but less than or equal to 50% loss of tree cover
C	Significant = greater than 50% but less than 90% loss of tree cover
D	Complete = greater than or equal to 90% loss of historical tree cover

Table 1 Disturbance level classes based on % tree cover loss from historic level

Based on field observations of land use, land cover conversions from upland forest, a set of major categories was developed to encompass all new land use types. These categories fell into five general classes of human based disturbance. Note that small water bodies, or ponds, of less than three acres fell into either urbanization or agriculture depending on the surrounding primary land use. Following both the 1930s and 1950s droughts, there was a proliferation of farm pond construction, mostly small in size, and built primarily for agriculture uses such as maintenance of livestock (Farley *et al.*, 2002; Stahle, 2007). The area and impacts of these small ponds were included in this study within the agriculture category. They were also a good indicator of past or present land use. Another trend noted in the analysis of the aerial photos and ground truthing, was the construction of neighborhood ponds and water features within a surrounding housing addition. These small water bodies were included in the urbanization category. Large lakes, ponds and reservoirs greater than 3 acres were placed in a separate water category. Roads as a disturbance type also became quite complicated. For the purposes of this study, any minor roads, such as property access, neighborhood or pasture roads were included in the overall urbanization or agriculture category. Major roads such as county roads or state and federal highways, were included in the infrastructure category. This category also included roads associated with oil and gas or mining activity (Farley *et al.*, 2002). Rural development included primarily buildings or structures with at least 5 acres surrounding them.

DISTURBANCE TYPE CLASSES	
Urbanization (Urban)	Multiple housing developments, commercial development with associated driveways and access or neighborhood roads. Also includes ponds within housing areas.
Rural Development (Rural Dev't)	Single housing including mobile homes and 'ranchettes' with 5 acres or more around each dwelling, farm buildings, associated access roads and driveways, clearings around buildings
Agriculture (Ag)	Land cleared for crops, grazing or logging with associated minor roads. Small ponds < 3acres, old fields cleared but abandoned. Does not include buildings.
Infrastructure (Infra)	Utility transmission lines, oil & gas sites with associated access roads and clearings, railroad lines, mining activity, large raised/graded through 'signed' roads including county roads, state/national highways, recreational areas such as boat docks, camp grounds and associated access roads
Water	Large, > 3 acres, ponds, lakes, reservoirs
None (N/A)	Areas designated as 'undisturbed' with minimal evidence of new human disturbance. No disturbance type observable

Table 2 Disturbance type classes for human impacts and changes to land use

Stands were assigned to the ‘None’ category when there was no observable disturbance from the defined types and no apparent loss of forest cover from the 1950s levels. Other subtle changes may have occurred and a minimal disturbance level could be assumed due to past land use history (Griffin *et al*., 2005). The disturbance level for these stands always fell into the **A** or minimal disturbance category.

After reviewing observations and information gathered from the field site visits, each of the thirty sample stands was evaluated and given a preliminary disturbance level designation of **A, B, C** or **D**. Any assigned disturbance level may have been due to one or a combination of disturbance types. All of the field data for each of the thirty sample sites were compiled in a table (Table 3) and evaluated again in the lab using the current aerial photographs to gain accuracy and precision in equating photographic images with corresponding physical items on the ground. Initial forest type designation was based on a hard copy of the Duck & Fletcher vegetation map (1947) and any notations on the data sheet such as the description of tree species present. Using this method, of the thirty sample sites, 23 were in the post oak-black jack oak forest type (PO/BJ), 5 stands were in the oak-hickory type (OA/HI) and 2 were in the oak-pine type (OA/PI). Sites were located evenly between east and west parts of the state and were also located in both rural and urban settings.

ANALYSIS OF 30 SAMPLE STANDS						
STAND # **(Region)**	COUNTY	ORIGINAL ACRES	FOREST TYPE	DISTURB. LEVEL	DISTURBANCE TYPE	DESCRIPTIONS
(NW) 128	Woodward	140	PO/BJ	A	Infrastructure	Oil & Gas pads and roads
123	Dewey	70	PO/BJ	C	Agriculture	Crops
136	Garfield	50	PO/BJ	A	N/A	Small pond and minor dirt roads
132	Kingfisher	20	PO/BJ	D	Agriculture	Mostly open grazing, small ponds
119	Canadian	90	PO/BJ	D	Infrastructure and Agriculture	Oil & gas with roads, old field, trees mostly cedars restricted to ravines
(NC) 106	Osage	90	PO/BJ	A	N/A	Small pond and minor dirt roads
95	Payne	40	PO/BJ	B	Water, Urban	Large pond comes into stand boundaries, commercial development from Perkins
87	Oklahoma	80	PO/BJ	A	Rural Dev't	Fairly heavy grazing but canopy intact small home site
102	Creek	80	PO/BJ	A	Infrastructure	Route 66 course altered. Utility lines
118	Tulsa	225	PO/BJ	C	Urban, Infra, Water, Rural Dev't, Agriculture	Has everything-housing developments, power lines, rural type ranchettes, ag with large pond. Still 100 ac left intact
(NE) 146	Rogers	80	PO/BJ	B	Infra, Rural Dev't, Agriculture	Road changed location, ranchettes, old ag clearings
149	Craig	70	PO/BJ	B	Agriculture, Infra	Grazing clearings, abandoned mining pits
172	Delaware	90	OA/HI	A	N/A	
115	Muskogee	50	PO/BJ	A	Rural Dev't	Recent small ranchette
54	Sequoyah	100	OA/HI	A	Rural Dev't, Infra, Agriculture	Railroad moved, small rural housing, old ag field regenerating with trees

(SW) 60	Caddo	120	PO/BJ	D	Agriculture	Primarily grazing
59	Caddo	30	PO/BJ	D	Agriculture	Primarily grazing
163	Kiowa	50	PO/BJ	A	N/A	Quartz Mountain area
156	Comanche	150	PO/BJ	A	N/A	Wichita Wildlife Refuge some natural clearings
159	Comanche	90	PO/BJ	A	N/A	Near WWR
(SC) 63	McClain	150	PO/BJ	C	Agriculture	Highly terraced, remaining trees restricted to ravines. Mostly grazing
17	Stephens	150	PO/BJ	D	Agriculture, Infra, Rural Dev't	One housing site, oil & gas sites with roads, 5 ponds, grazing, utility lines
16	Carter	15	PO/BJ	C	Agriculture	Grazing
34	Pontotoc	35	PO/BJ	D	Agriculture	Old clearing, tree regeneration evident, still some grazing
75	Seminole	100	PO/BJ	B	Agriculture, Infra, Rural Dev't	Mostly old clearings, substantial oil & gas presence, new home site
(SE) 41	Pittsburg	40	PO/BJ	D	Agriculture	Crops
49	LeFlore	100	OA/PI	A	N/A	Ouachita National Forest - minor service roads
28	Atoka	15	OA/HI	A	N/A	
203	Pushmataha	300	OA/PI	A	N/A	Old Dierks timberlands, minor logging roads present
194	McCurtain	30	OA/HI	C	Rural Dev't, Agriculture	Almost all 5 acre ranchettes now with limited grazing

Table 3 Sample data results gathered from the set of 30 sample stands. The first stand listed for each region is designated in bold with NW, NC, NE, SW, SC, SE

GIS Analysis

Land use, land cover changes were evaluated through comparison of historical and static geographic data to current digital based data sets, combined with ground truthing (Boren *et al*., 1997; Farley *et al.*, 2002; Turner *et al.*, 2007). With the assistance of the ODAFF Information Technology Division and using 2003 1m resolution and 2006 2m resolution state wide aerial photographs obtained from the USDA National Agriculture Imagery Program (NAIP), a GIS viewer using Arc Reader was constructed. Layers were added including the digitized Duck & Fletcher vegetation map, county boundaries, PLSS and the Rice and Penfound (R&P) forest stand map (Table 4). In an initial analysis which included a re-evaluation of the 30 sites from the sample data set, each of the 194 stands was located within the GIS viewer and evaluated for possible disturbance. The locater symbol for each stand on the R&P map layer represented the center of the section in which the stand occurred. The GIS database was created by using the R&P forest stand layer attribute table as a foundation and performing a one to one relationship join to add fields for the disturbance level and disturbance type classes (Appendix). Forest type was assigned based on the digital Duck and Fletcher map. A few sites fell just outside an upland forest type on this map, in tall grass prairie or bottomland forest for example, and these were assigned a forest type based on proximity analysis. Within the GIS viewer and utilizing the field map, acreage and other information listed on each stand's data sheet, an effort was made to locate the historic stand on the aerial photo layer. The 2006 photos were more recent but the 2003 photos had a higher resolution and were used for comparisons. Using the GIS measure tool a determination was made on the location of the original stand acres and an assessment was made on disturbance level or percent of forest cover remaining. Individual trees and small isolated clumps of trees or fencerows measuring less than an acre were not counted due to the low level of connectivity (Pearson *et al.*, 1998). Precursory notes were taken on disturbance type(s) and notes were recorded on any problems with stand analysis including a stand being marked for possible ground truthing. If tree cover had been reduced on any given stand and other indicators of agriculture were present, grazing was assumed and an agriculture disturbance type was assigned. It must be noted however that even if no disturbance type could be identified or recorded, grazing in the under story could not be precluded (Rice & Penfound, 1959; Tyrl *et al.*, 2007).

Data Layer	Source	Availability
Aerial Photos	USDA NAIP 2006/2003	www.datagateway.nrcs.usda.gov
R&P Forest Stands	OK Biological Survey (2007)	Must contact OBS directly
D&F Vegetation Cover	OK Natural Heritage Inventory (digitized 2004 version)	www.biosurvey.ou.edu/pub
County Boundaries	US Census Bureau 2000 TIGER	www.csa.ou.edu
PLSS	USGS 1994	www.csa.ou.edu
OK City Point Layer	US Census Bureau, 2000 census	www.ocgi.osu.edu

Table 4 Source and availability of GIS data sets

Some of the layers required pre-processing before being used for attribute queries and the creation of maps to illustrate the geographic distribution of disturbance levels and types. The dissolve tool applied to the county boundaries layer was used to create the regions map and a buffer zone application allowed for identification of stands within each of the radii around the urban areas.

Data Sheet Analysis

Each of the 194 stands was initially evaluated using the GIS viewer and data sheet information to locate and measure on the aerial photos, as accurately as possible, the area of both the 1950s stand and the current stand. In addition to assigning a disturbance level based on measurements, and a preliminary disturbance type or combination of types to each stand within the database, specific stands were flagged for further analysis if any discrepancies arose. Next, the first page of each data sheet was carefully studied and comparisons were made between the legal description, acreage, field map, landmarks or other topographic features, directions from a town and any other typed notes. All of the typed information on each data sheet was compared and a list was made of stand sheets containing discrepancies. This list was added to the similar list from the GIS analysis and these problem sites were re-evaluated using a combination of all methods previously described. In addition, several more stands were ground truthed for visual clarification of issues that could not be determined in the lab. A total of 70, or 36%, of the 194 field sites were ground truthed for this study. A table was created of discrepancy categories (Table 5) and a final table of data sheets with unresolved discrepancies was also created including a description of how the discrepancy was handled in the final project analysis (Table 6). It should be noted that Rice and Penfound divided some stands at a single location into two stands if the stand was of significant size and the xeric and mesic areas were sampled separately. These particular stands appeared as one location on the maps in the Results section of this study. Finally, using the *Roads of Oklahoma* atlas, which contained multiple land use symbols and descriptions such as transmission lines, both historic and current railroads, significant buildings, mining activity and other relevant information, the assigned disturbance type or types for every stand was re-evaluated. An oil and gas history for every stand was researched using the www.oil-law.com website to verify any assigned land use designation given for that activity.

DATA SHEET DISCREPANCY CATEGORIES	
Legal Description	Township & Range, or section number(s) listed, are not consistent with other data
Field Map	Given location of sampled stand as drawn on data sheet field map is not consistent with other data
Acres Sampled	The acreage listed is not consistent with other data

Table 5 Data sheet discrepancy categories encountered during data sheet analysis

County	Stand #	Discrepancy Type	Suggested Change Made in Analysis
Adair	175	Field Map	Go with field map drawing that shows primarily in SE/4 of NW/4 not SW/4 of NW/4 as typed on data sheet
Adair	178	Field Map	Actual location of road in section 14 is a ¼ section west of map drawing. should be in NW/4 of section not NE/4 as drawn
Adair	179	Legal Description	Based on location from town, may be 15N 26E, not 14N 26E as typed. Section #s likely sections 1 and 2 not 1 and 14 but no clear info on field map. Road shape matches sect 2 of 14N 26E so evaluated 30 acres west of road in section 2.
Alfalfa	209	Legal Description	No legal given at all. Based on all other data, likely in 23N 11W section 1. 24N 11W sec 36 is possible.
Carter	14	Field Map	Typed data sheet says W/2 of NE/4 but this analysis uses the field map that shows W/2 of SE/4
Cherokee	182/183	Legal Description Acreage	s together in same sections- 15 and 14 not 15 and 19. No acres given for #182 so 80 total acres divided between 2 s
Comanche	154	Field Map	Wichita Wildlife Refuge (WWR) Field map shows SW/4 of section 5 but typed sheet NE/4 of section 5 is likely correct
Comanche	155	Legal Description	WWR- Based on mountain location and typed sheet, sections are 28 & 27 not 25 & 27 as listed on field map
Comanche	156	Field Map Legal Description	WWR Deer Creek Flats- slightly north west of field map. This puts some in section 1 as well as the section 12 & 7 listed.
Comanche	157	Field Map	WWR Due to location of mountain, field map likely off part of a section
Comanche	158	Legal Description	WWR Sulphur Flats located in SE/4 of section 24, 3N 14W not section 19 3N 13W. Just over one section to the west.
Comanche	159	Legal Description	Section listed on typed data sheet as 115 obviously wrong. Should be section 15
Delaware	172	Field Map	shape fits field map drawing perfectly if shifted about 40 acres west
Garfield	137	Field Map	Typed data sheet notes say SW/4 in section 4 but went with field map drawing which shows NW/4 of section 4

Grady	55	Acreage	Typed notes indicate 540 acres sampled but field map shows the NW/4 or 160 acres as the sample size
Hughes	77	Legal Description	Location and shape of road places in section 6 NOT in section 5 as on the data sheet
Hughes	79	Acreage	No exact acres given but based on field map drawing, estimations are about 300 acres sampled
Latimer	190	Field Map	On the field map drawing, the placement of sections 4 and 33 should be reversed
Latimer	191	Acreage	Typed data sheet shows 100 acres sampled but based on field map drawing, sample size is about 300 acres
Latimer	192	Acreage	Typed data sheet indicates 640 acres sampled but field map actually shows 140 acres
Mayes	143	Legal Description Acreage	Directions from town and other typed information all disagree on location so default to field map. No map for NW 40 so not analyzed. SW/4 of section 25 equals 160 acres not 170.
Okmulgee	104	Field Map	Based on actual road location, shift road and s as drawn on field map half a section to the east
Osage	106	Field Map	Evaluate SE/4 of section 1 as on field map not NW/4 as typed on data sheet
Osage	109	Legal Description	No mention of railroad, highway 10 or town of Herd, all in section 35, suggests this is actually in section 36
Ottawa	168	Acreage	Data sheet indicates 500 acres sampled but field map looks more like 50.
Pontotoc	36	Field Map	Field map shows several hatch mark areas but typed data sheet description indicates only 40 acres sampled in NE/4 of section 6
Pushmataha	202	Legal Description	Section 24 also listed as sampled but no field map, no other information given as to location so not included in analysis
Tulsa	117	Legal Description	Location is 21N 12E not 12N 12E as typed on data sheet which is not even in the correct county.

Table 6 Specific data sheet discrepancies and method of evaluation in the analysis

CHAPTER IV

RESULTS

Disturbance Levels

Overall, 44% of the stands fell into the minimal disturbance class and nearly 20% were completely disturbed (Table 6). When the minimal and moderate disturbance classes were combined they equaled 69%, over two thirds of the stands surveyed. A high percentage of minimally disturbed sites were found in each of the regions, stand acreage ranges and forest types. Statistical analysis supported differences among regions in the distribution of stands by disturbance level ($\chi^2_{(15, N=194)} = 27.93$, $p = 0.022$). Compared to an accepted standard of p>.05, the distribution of stands by disturbance class within the regions could be attributed to factors other than random occurrence. Significant findings included a high number of minimally disturbed stands (80%) in the SW region. Further, the NE and SE regions also had a significant number of stands, 80% and 74%, with minimal to moderate disturbance. The NW and SC regions had the highest levels of disturbance with approximately 50% of their stands subjected to significant or complete disturbance. A geographic display of all 194 stands illustrates the occurrence of each disturbance level class by county and region (Fig 3).

Disturbance Level Percentages by Class				
	A [Minimal] x ≤ 10%	B [Moderate] 10%>x ≤ 50 %	C [Significant] 50%>x<90%	D [Complete] x ≥90%
(# Stands)	Percent of Total or Region			
Total (194)	44	25	15	16
NW (20)	30	20	25	25
NC (28)	39	32	18	11
NE (45)	49	31	11	9
SW (15)	80	0	7	13
SC (51)	25	33	18	24
SE (35)	60	14	11	14

Table 7 Disturbance level percentages by class for each region and statewide where x represents the % tree cover removed from 1950s levels

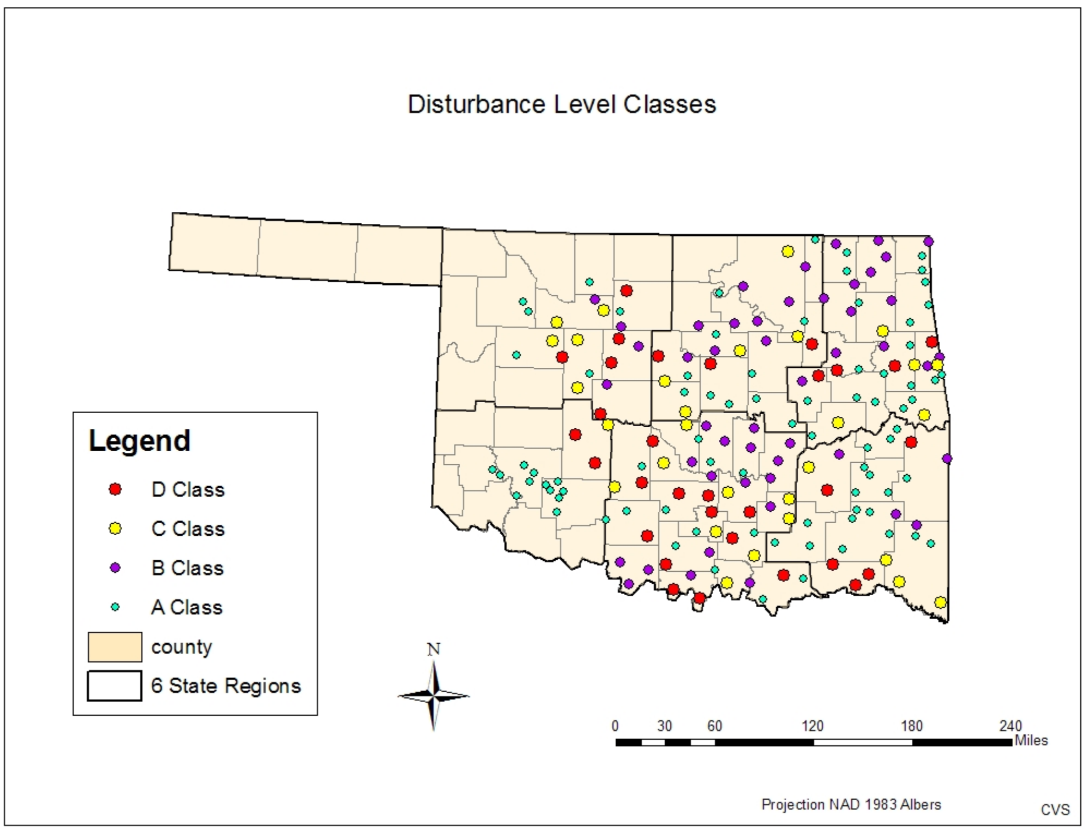

Figure 3 Map of disturbance level classes showing geographic distribution

Disturbance Types

Agriculture was the single largest disturbance type overall affecting 125 (64%) of the total stands and 42% of those had significant to complete disturbance levels (Table 7). Approximately half of the stands with agriculture disturbance had it as the sole disturbance type and the other half had agriculture combined with another disturbance type or types, most often rural development or infrastructure. Regionally, the NE, SC and NW had the highest agriculture disturbance with 71%, 73% and 80% of their stands, respectively, that showed agriculture as a contributing factor to overall levels. One important difference however was that most stands located in the NE region had only minimal to moderate disturbance levels (Figure 4).

Disturbance Type Percentages by Class						
	None	**Urban-ization**	**Rural Dev't**	**Agri-culture**	**Infra-structure**	**Water**
(# Stands)	Percent of Total or Region					
Total (194)	11	6	30	64	36	4
NW (20)	5	0	35	80	40	0
NC (28)	4	25	39	57	54	7
NE (45)	4	4	47	71	31	2
SW (15)	67	0	7	27	7	0
SC (51)	2	4	31	73	41	2
SE (35)	17	0	9	57	31	9

Table 8 Disturbance type percentages by class for each region and statewide. Row totals may exceed 100% due to combinations of disturbance types

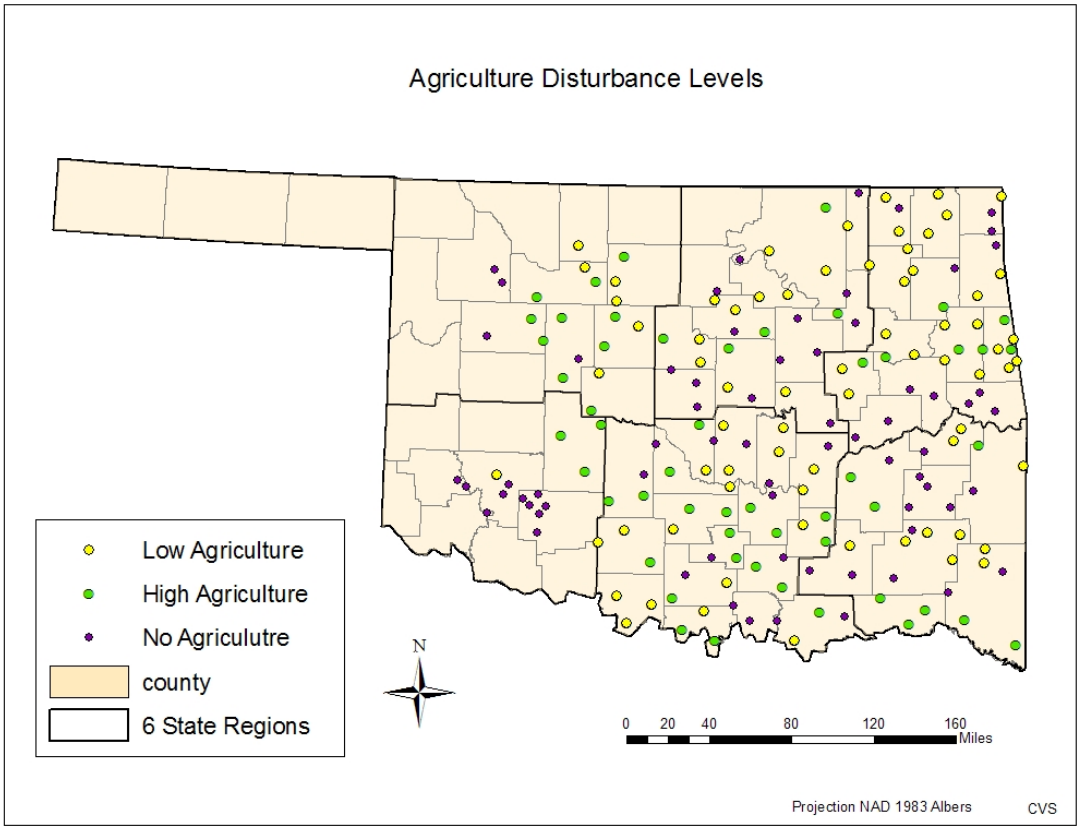

Figure 4 Map of agriculture disturbance showing geographic distribution and level where high equals significant plus complete disturbance, low equals minimal plus moderate disturbance and no means no agriculture disturbance.

Statewide, 70 stands, 36%, had infrastructure as a disturbance type. Of those identified sites, 37% had infrastructure as the sole disturbance type. Only about one fourth of stands with infrastructure disturbance suffered significant to complete disturbance levels. Regionally, NC had higher overall infrastructure influence with 54% of stands affected but the stands fell primarily in the low disturbance levels (Figure 5). Only in the NE was infrastructure not the second highest disturbance type. The infrastructure category contained several different land use types however the dominant activity encountered in this study was related to the oil and gas industry and included pumping sites, transmission lines, associated roads or pipelines and storage facilities. Of the identified 70 sites, 53% had oil and gas activity.

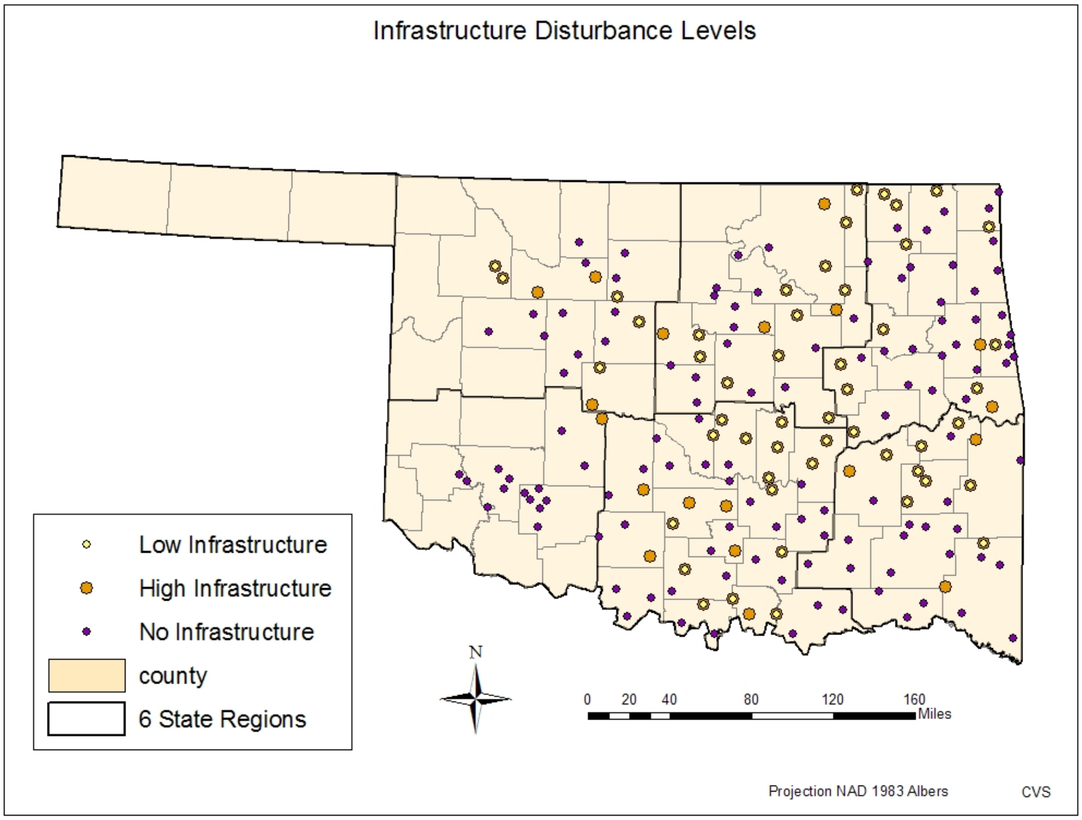

Figure 5 Map of infrastructure disturbance showing geographic distribution and level where high equals significant plus complete disturbance, low equals minimal plus moderate disturbance and no means no infrastructure disturbance.

Rural development also was an important disturbance type with 59 sites, 30%, statewide and approximately one third of those stands fell into the high disturbance levels. The disturbance type for only 19% of the identified stands was attributed solely to rural development which frequently paired with agriculture. The NE region had the highest overall rural disturbance, 47%, followed by the NC region at 39% (Figure 6). Sites in the

NE region however, tended to be primarily in the lower disturbance levels. The SE and SW regions had the lowest rural development disturbance levels.

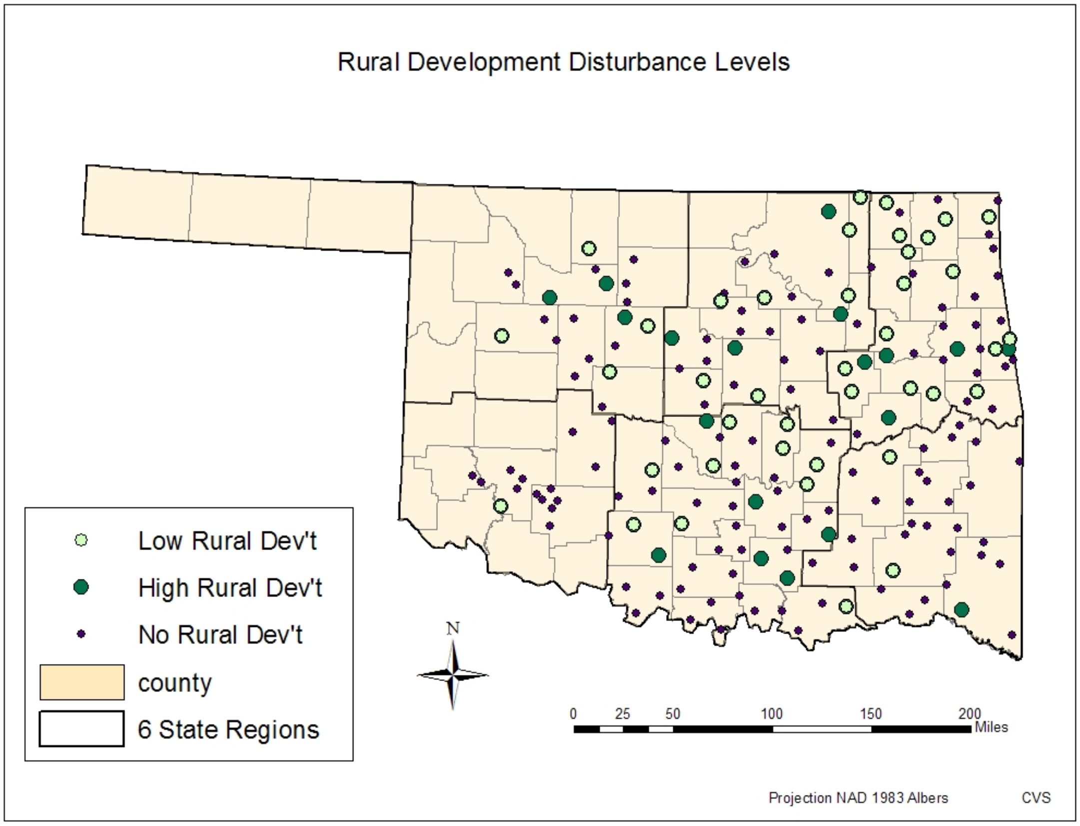

Figure 6 Map of rural development disturbance showing geographic distribution and level where high equals significant plus complete disturbance, low equals minimal plus moderate disturbance and no means no rural development disturbance.

Urbanization and water had the lowest impact on forest stands overall. Only 11 sites statewide, 6%, had urbanization as a disturbance type with 75% in high disturbance levels. Most of the urban stands occurred in the NC region including the two sites where urban and water were found together. (Figure 7) Water as a disturbance type was found in 7 sites with nearly three fourths of those either in or bordering the SE region and 71% were in the high disturbance levels. Water was the sole disturbance type in only one stand while urbanization was the sole disturbance type in four stands. Regionally, 25% of the NC region's sites showed urbanization as a disturbance type. One site in SC had urbanization as a disturbance type and did not occur near an identified urban area. This site contained a highway bordered by high commercial development.

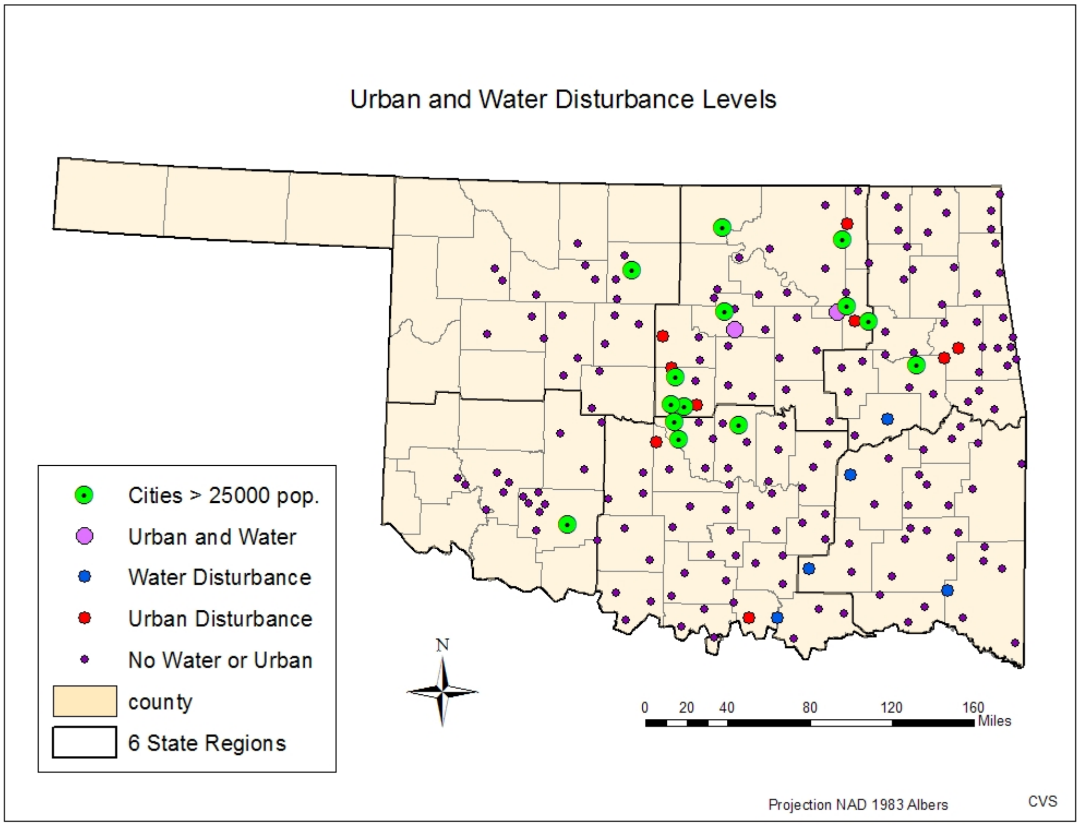

Figure 7 Map of urban and water disturbance showing geographic distribution and level where high equals significant plus complete disturbance, low equals minimal plus moderate disturbance and no means no urban or water disturbance.

Forest Type

Stands were located in the state's three dominant forest types. Most of the stands, 74%, were in the PO/BJ type and the other stands were nearly equally divided between the OA/HI, 12%, and OA/PI, 14% (Table 9). One stand located within the loblolly pine forest type was included in the OA/PI data. Statistical analysis confirmed a disproportionate level of disturbance in PO/BJ when compared to the OA/HI or OA/PI forest types ($\chi^2_{(6, N=194)} = 12.65$, $p = 0.049$). 83% of stands classified with significant to complete disturbance were in the PO/BJ forest type (Figure 8). That percentage increased to 90% if only the stands with complete disturbance levels were considered. Stands located in the OA/HI or OA/PI forest types fell primarily in the minimal disturbance level. Agriculture was the primary disturbance type for all the forest types (Table 10). Infrastructure was more important as a secondary disturbance type in OA/PI and rural development was more significant in OA/HI. All of the 11 urban sites were in PO/BJ.

Disturbance Level Percentages by Forest Type				
	A	**B**	**C**	**D**
(# Stands**)**	Percent of Total or Type			
Total (194)	44	25	15	16
PO/BJ (143)	37	28	15	20
OA/HI (24)	58	17	17	8
OA/PI (27)	67	19	11	4

Table 9 Disturbance level percentages within forest types

Disturbance Type Percentages by Forest Type					
	Agri-culture	**Infra-structure**	**Rural Dev't**	**Urban**	**Water**
(# Stands)	Percent of Total or Type				
Total (194)	64	36	30	6	4
PO/BJ (143)	65	40	34	8	4
OA/HI (24)	66	25	33	0	4
OA/PI (27)	56	30	7	0	4

Table 10 Disturbance type percentages within forest types

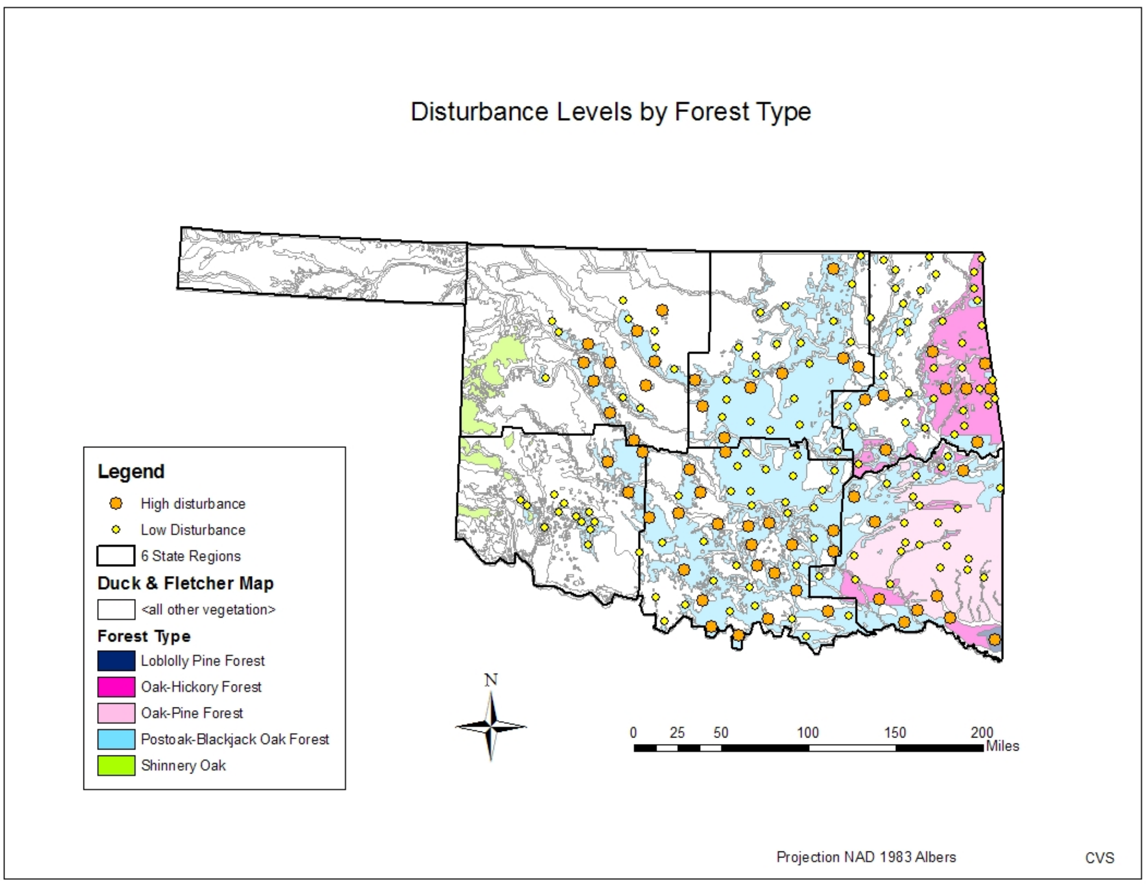

Figure 8 Map of disturbance levels showing geographic distribution by forest type where high equals significant plus complete disturbance and low equals minimal plus moderate disturbance

Stand Acreage

A representation of disturbance based on stand acreage showed that smaller stands, between 15 and 75 acres, comprised 47% of total stands, mid size stands, from 80 to 160 acres, represented 41% of total stands and the largest stand range, 200-800 acres, accounted for 12% of all stands (Table 11). An initial comparison showed the small stands had both a high percentage of minimally disturbed stands and completely disturbed stands indicating most of the original stand acres either remained or had undergone a total land use conversion. The larger sites were more likely, 78%, to be in the low disturbance classes. Statistical analysis of disturbance level by the stand size ranges however showed that discrepancies may not be significant ($\chi^2_{(6, N=194)} = 5.59$, $p = 0.470$). Geographically, small and mid size stands were distributed across the state fairly equally but the majority of large stands occurred in the SE (Figure 9). Agriculture was the primary disturbance type for all three acreage ranges (Table 12). Both the mid size and large stands were affected to a greater degree by infrastructure and the large stands were impacted to a greater percent by water than other ranges. Smaller size stands had 64% of identified sites with urbanization.

Disturbance Level Percentages by Stand Acreage				
	A	**B**	**C**	**D**
(# Stands)	Percent of Total or Range			
Total (194)	44	25	15	16
15 – 75 ac (92)	47	22	12	20
80 – 160 ac (79)	39	28	20	13
200 – 800 ac (23)	48	30	9	13

Table 11 Disturbance level percentages by stand acreage ranges

Disturbance Type Percentages by Stand Acreage					
	Agri-culture	**Infra-structure**	**Rural Dev't**	**Urban**	**Water**
(# Stands)	Percent of Total or Range				
Total (194)	64	36	30	6	4
15 – 75 ac (92)	63	27	28	8	2
80 – 160 ac (79)	65	44	35	4	4
200 – 800 ac (23)	65	48	26	4	9

Table 12 Disturbance type percentages by stand acreage ranges

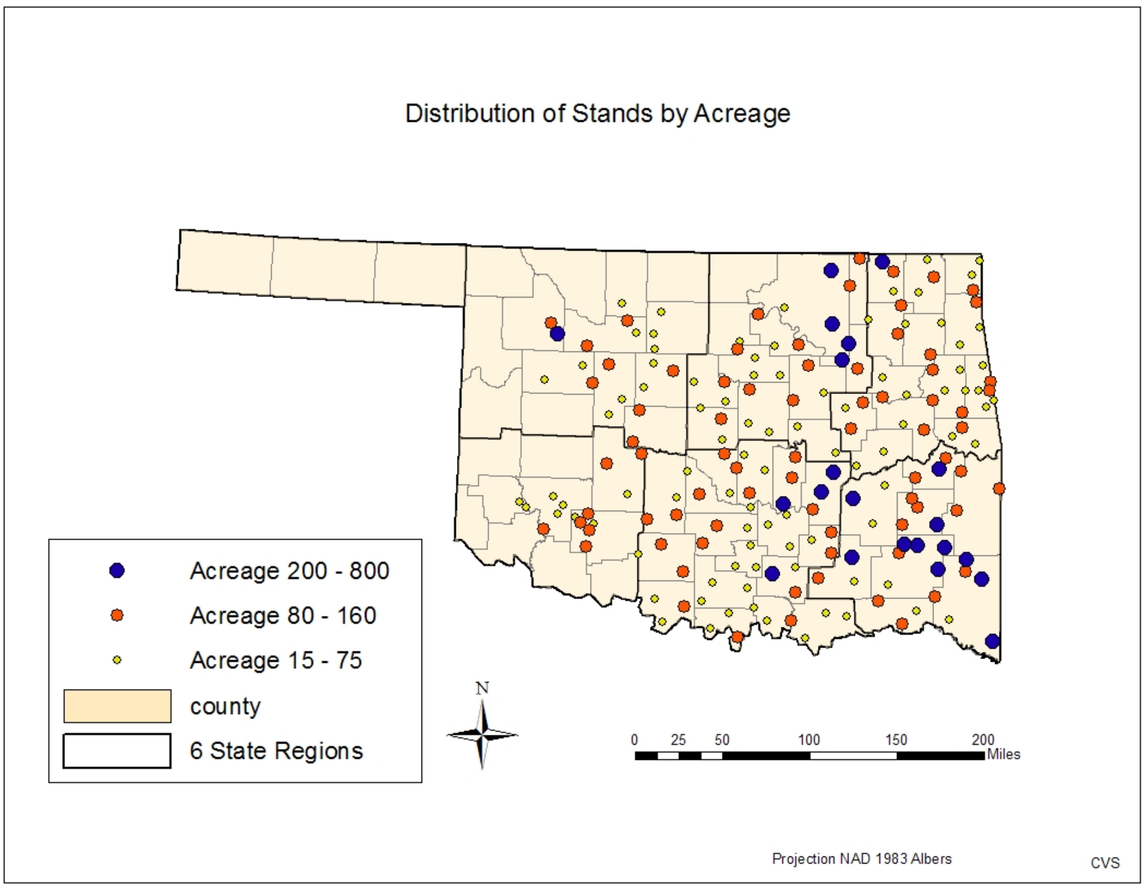

Figure 9 Map of geographic distribution by stand acreage

Urban Proximity

According to 2000 census data for Oklahoma, urban areas with greater than 50000 populations were classified as large cities and areas with greater than 25000 populations were labeled small cities. Geographically, 14 areas within the state were identified in these two designations (Figure 10). Buffer zones established around each urban center at 25 mile, 50 mile and 75 mile radii located stands situated within close proximity to those large and small cities. (Table 13) For all stands, 58% were within 50 miles of an urban center. Of those stands, only 28% suffered significant to complete disturbance. Therefore, when compared to statewide percentages, it appeared there was no strong correlation between high disturbance levels and close proximity to an urban area ($\chi^2_{(9, N=194)} = 6.64$, $p = 0.674$). Distribution by disturbance type however showed 75% of all stands with rural development disturbance and 91% of stands with urbanization were within 50 miles of an identified city (Table 14).

Disturbance Level Percentages by Urban Proximity				
	A	**B**	**C**	**D**
(# Stands)	Percent of Total or Proximity Radius			
Total 194)	44	25	15	16
0 – 25 miles (49)	45	24	14	16
26 – 50 miles (63)	40	35	13	13
51 – 75 miles (44)	41	20	18	20
> 75 miles (38)	52	16	16	16

Table 13 Disturbance level percentages for urban proximity radii

Disturbance Type Percentages by Urban Proximity					
	Agri-culture	**Infra-structure**	**Rural Dev't**	**Urban**	**Water**
(# Stands)	Percent of Total or Proximity Radius				
Total (194)	64	36	30	6	4
0 – 25 miles (49)	59	33	43	18	4
26 – 50 miles (63)	73	44	37	2	2
51 – 75 miles (44)	61	36	18	0	2
> 75 miles (38)	60	26	18	3	8

Table 14 Disturbance type percentages for urban proximity radii

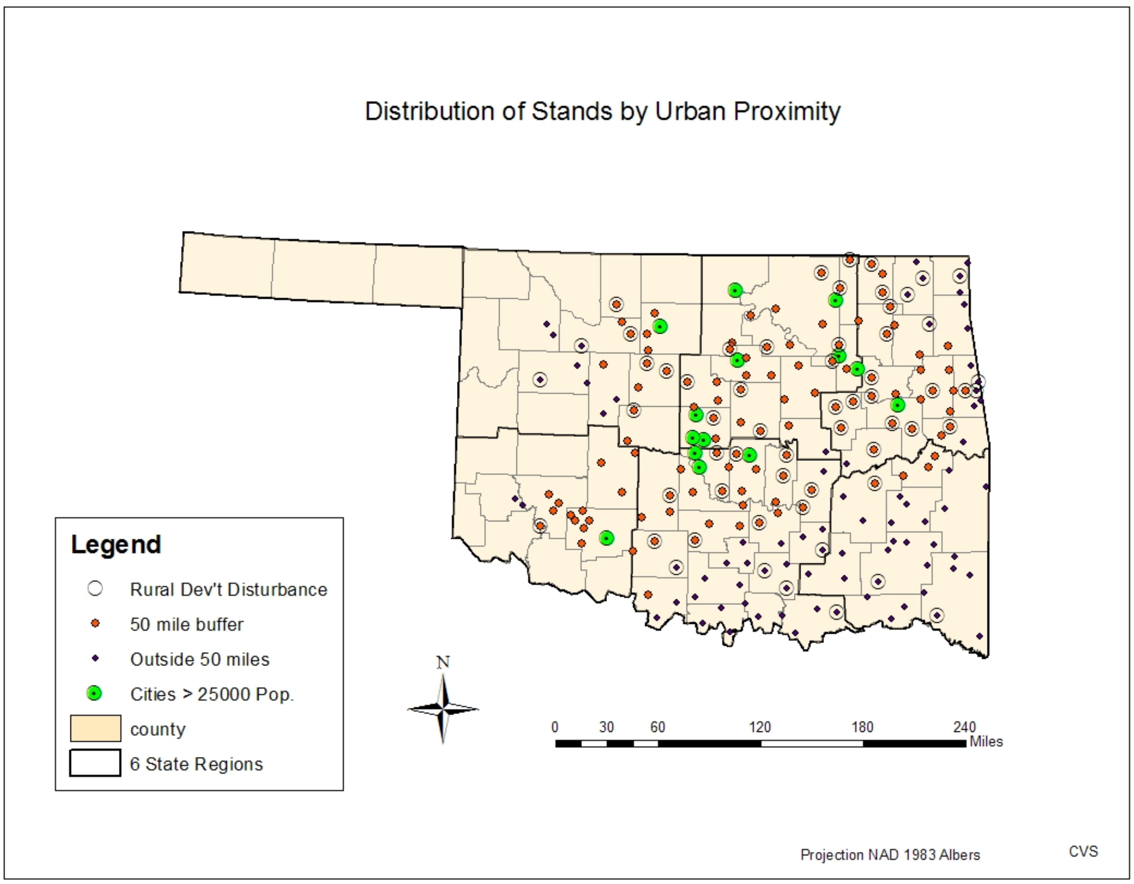

Figure 10 Map of geographic distribution by urban proximity with rural development

CHAPTER V

DISCUSSION

One of the major findings of this research was that a large percentage (69%) of the forested stands surveyed over 50 years ago were today nearly intact and had suffered only minimal to moderate disturbance. The areas of greatest disturbance were the NW and SC regions. The NE and SE regions had the least levels of disturbance. The leading cause of forest loss was agriculture affecting 64% of surveyed sites with the greatest impacts occurring mainly in areas where the commercial value of the forest was low and agricultural practices were already prominent. There was less forest cover loss where the economic value for forests was high. The PO/BJ forest type which had little commercial value for forest products and was often cleared for agriculture suffered a higher percentage loss than other forest types. Infrastructure, most commonly associated with oil and gas activity, when present was frequently (37%) the sole disturbance type but had overall low disturbance levels. Conversely, rural development was often associated with other disturbance types, primarily agriculture, but also had overall low disturbance levels. Another major finding was that proximity to urban areas did not result in higher disturbance levels. Finally, many of the SW region stands were in or near the Wichita National Wildlife Refuge. These were all classified as low disturbance with None as the disturbance type. This made comparisons between the SW and other regions more difficult.

Geography of Disturbance

The analysis of significant human disturbance showed the NW and SC regions experienced the highest overall disturbance level as a percent of stands in those areas. The NW had significantly fewer sites than other regions yet had the second highest number of stands in the high disturbance classes. The SC region had the greatest number of stands, but also had a disproportionate number of stands designated as high disturbance. Over half of the stands in both regions were less than 80 acres and they had the highest percent disturbance attributed to agriculture. One possible explanation was that droughts appeared to affect the western and central sections of Oklahoma about every 20 years (Johnson & Risser, 1975; Stahle *et al*., 2007). Rice and Penfound (1959) had begun to document the effects of a prolonged drought during the four years of their study and noted that following the severe drought of the 1930s, the woodlands and savannahs of the western half of the state seemed especially hard hit. High tree mortality may have reduced the amount of forest land. Over time the drought mortality combined with government incentive programs to clear forests and increase rangeland for cattle grazing may have explained such high conversion rates in these regions (Boren *et al*., 1997; Hoagland *et al*., 1999).

The NW and SC also had two of the highest disturbance levels in the infrastructure class which includes oil and gas activity. Following the oil boom of the early 20th century located primarily in the region between Tulsa and Oklahoma City, the areas of exploration began to move south and west (Johnson, 1998). Drilling activity from the 1950s to mid 1980s, when production peaked in Oklahoma, focused more and more on the reserves of the SC and NW regions (Boyd, 2006) and extractive activities come with associated roads pipelines and transmission lines that increased the overall impact of the industry (Leu *et al*., 2008). Although infrastructure occurred alone in one third of the stands where it was a disturbance type, study results indicated it infrequently led to high disturbance levels.

Probability of Continued Forest Cover Loss

Research in the area of native vegetation change produced new models that increased not only our understanding of what had already taken place, but assisted in predictive modeling as well. Three indicators in one study were identified as the leading factors in land change dynamics within forest ecosystems: suitability, proximity and extent (Schneider & Pontius, 2001). This model was useful in evaluating both the high disturbance areas identified and documented in this study as well as assessing what factors in the future might affect regions with currently low disturbance levels.

Suitability of forest types

The first factor in the deforestation model was the suitability of the forest type for conversion to another land use. Recent studies concerning the economic potential of Oklahoma’s forests focused on the eastern 18 counties that fit in the NE and SE regions of the Rice and Penfound study (Mills *et al*., 1989; Lewis, 2001, USFS, 2006). This area encompassed both the OA/HI and OA/PI forest types in Oklahoma and was valued for its economic benefit in terms of timber production, forest products and recreation. Agriculture, which includes logging and associated roads, was the most significant disturbance type in both the NE and SE region; however, overall disturbance levels were very low. This low level of disturbance in these forest types may have been due to their high economic value as forests. In the NE region, there was a strong association between agricultural activities and rural development disturbance which, unlike agriculture, was not often found as the only disturbance type. The stand sizes were almost all under 160 acres and this study found a high influence from 'ranchettes' or hobby farms and other small farms where the overall impact was fairly low per stand but the cumulative effect across the region was unknown. Percentages for disturbance types in the SE region were all below the calculated state averages and this region contained the greatest number of large size stands. Second to agriculture, the largest disturbance type was infrastructure and rural development disturbance was minimal.

The forests of the western three fourths of the state were primarily PO/BJ and were not commercially valuable for wood (Francaviglia, 2000). The PO/BJ forest type, with a grass dominated understory, prevailed in much of the state and because it was the focus of the original 1950s study, was the dominant forest type sampled in every region. This open type forest had been shown to be a sensitive and vulnerable ecotype and its history illustrated a particular suitability to grazing and other agriculture practices (Francaviglia, 2000; McEwan & McCarthy, 2008). Combined with its low value for wood products this may have provided a likely explanation for the high rate of conversion in the PO/BJ forests. Past research in this forest type had looked at connections between environmental factors and human disturbance. There appeared to be a strong correlation between slope and soil type where relatively flat, low lying areas with deeper soils were more suitable to agriculture related conversion and the woodlands that had survived were now found on the rockier, poorer soils (Johnson & Risser, 1975; Farley *et al*., 2002; Griffin *et al*., 2005). These low lying areas were not only the location suitable for agriculture, but also were the areas flooded during Oklahoma's lake building years which affected the PO/BJ forest type disproportionately (Griffin et al., 2005). Unfortunately, these lower lying areas were frequently found to have the highest biodiversity levels in a given location (Leu *et al*., 2008). Oklahoma's forests were also suitable for providing a host of ecosystem services to the citizens of the state which included watersheds around urban areas, preservation of biodiversity, recreation and certainly research opportunities in a unique yet limited ecoregion (Griffin *et al*., 2005; Engle *et al*., 2006).

Proximity to other land use areas

The second factor in the deforestation model was proximity to other types of land use surrounding the area being studied. The single greatest disturbance type in this study was agriculture which affected two thirds of the stands evaluated and surrounded many others. In half the sites where agriculture was present, it was the sole disturbance type and disturbance levels were high, indicating that clearing for agriculture had continued over the past 50 years. When not the sole disturbance type, agriculture was frequently associated with either rural development or infrastructure which caused both further native vegetation loss and increased fragmentation (Wallace *et al*., 2003; Leu *et al*., 2008). An interesting finding in the literature suggested that rural development was positively correlated with the presence of agriculture and negatively with distance to a road (Turner *et al*., 2007). As population increased within urban areas, the infrastructure from the city extended out further, making rural development possible, often on previously agricultural land. One exception may be the SW region where despite being in close proximity to an urban center, the presence of governmental protection and management may have allowed for lower overall disturbance levels (Pogue & Schnell, 2001).

Urbanization as a disturbance type seemed to defy the rules. Urban development normally continued to cause land cover conversion regardless of slope, soil type or vegetation type (Iverson, 1988). Urbanization had a greater impact on the NC region where it was often the sole disturbance type which may appear intuitive considering it contains both of the state's largest metro areas. Of the 11 stands statewide with urban as a disturbance type, the NC contained 7, or 25% of the stands in that area. Approximately two thirds of Oklahomans lived in an urban area (Lewis, 2001) but some studies suggested that as urban population pressure increased, disturbance from rural development actually increased faster than urbanization (Leu *et al*., 2008). This concept may support the findings of this study that found no distinct correlation between urban proximity and high disturbance levels but did find the presence of a high percentage of stands with rural development disturbance approximately at the 50 miles radius. As demonstrated in the NE region, high rural development disturbance did not usually lead to high disturbance levels overall unless paired with agriculture. This study also found that urbanization and agriculture can be mutually exclusive as demonstrated by the NC region in which high rural development levels coincided not with high agriculture levels but rather correlated to high infrastructure levels. The NC region was quite interesting in that it had high urbanization levels, high infrastructure including significant oil and gas influence, high rural development, moderate agriculture and high water disturbance levels. Even though NC had all the disturbance types, the overall disturbance levels were below the calculated state levels. Perhaps the forest land surrounding the urban centers had been kept largely intact for the benefits it provided to the state's urban population such as functioning watersheds and recreational opportunities. Other research had also documented the land use gradient that occurred extending outward from an urban core with decreasing development, human disturbance levels and forest cover loss. This gradient of decreasing land use conversion continued up to a radius at approximately 50 miles or 80 kilometers where suburban or rural development sharply increased (Medley *et al.*, 1995).

Extent of parcels

The third part of the deforestation model examined extent, or size of the parcels within the research area. In this study, there was not a strong connection between stand size and disturbance levels. Within the mid sized stands, from 80-160 acres, infrastructure had the greatest influence by disturbance type. The large stands, from 200-800 acres, were located primarily in the SE and were impacted to a much greater degree by water when compared to statewide numbers. An interesting finding showed the smallest sized stands, 15-75 acres, were equally likely to be in the lowest disturbance class as in the highest class and were impacted to a much higher degree by urbanization disturbance. Due to the high influence of agriculture disturbance across all of the study sites, other research in the areas of edge complexity and fragmentation became important. The edge effect between fenced agriculture lands and forest or woodland is well studied and included changes in habitat structure and soil chemistry (Pogue & Schnell, 2001; Foster *et al*, 2003). One of the issues with high agriculture influence in a landscape was the creation of a mosaic of agriculture and native vegetation with straight, narrow boundaries that destabilized or even eliminated the transition zones. As agriculture disturbance levels increased in an area, often patchiness also increased and native flora subsequently decreased with decreasing fragment size and edge complexity (Pogue & Schnell, 2001; Farley *et al.*, 2002). Historically, Oklahoma forests probably had lower tree density but a high degree of connectivity. As human influences in forested areas increased, edge complexity and biodiversity decreased (Iverson, 1988). Biodiversity and fragmentation may not seem relevant to this study from the perspective of determining the probability of future deforestation in the study areas. Research showed, however that parcels must be a minimum of 40% intact from the original area to minimize the likelihood of further loss (Leu *et al*., 2008). This might suggest that those stands in disturbance class **C (**less than 50% of the original tree cover remaining) were at particular risk of becoming a complete loss.

Research Opportunities

Several research opportunities were apparent based on other observations made in the field and information from the current research literature reviewed. First, using the stands from this study that fall within the lower disturbance classes, an investigation could be done within a GIS using a digital elevation map (DEM) and the National Land Cover Data (NLCD).Low lying areas and those with gentler slopes or certain soil types may be at greater risk for agriculture conversion particularly if that is the dominant surrounding land use type (Turner *et al*., 1995). Calculating the elevation and slope for these potentially at risk areas followed by a comparison to surrounding land use and soil type, could result in a useful probability model matching soil and topography to land use (Christensen, 1989; Ningal *et al*., 2008). Second, previous research showed a correlation between degree of land use, land cover change and alterations in habitat quality and biodiversity (Turner *et al*. 1995). These types of changes could also favor expansion of invasive and exotic species particularly for certain soil types and precipitation levels (Pearson *et al*., 1998; Leu *et al*., 2008). Selection of certain stands in the **B** and **C** disturbance level, where human disturbance was certainly a factor but fairly large segments of the original stand remained, might provide a foundation for such a study. Utilizing both FragStats and patch analysis within GIS would provide a means to analyze fragment clustering as well as a comparison between patch size, perimeter complexity and shape. Third, with over 60% of Oklahoma's population now living in urban areas, a study of the less disturbed sites that are in proximity to urban centers to learn the effects on quality of life enjoyed by urban dwellers may be important research in the area of urban forestry (Lewis, 2001; Schneider & Pontius, 2001).

Resource Management

The results of this study were of particular importance to forest management programs currently being implemented at the state level. One federal study underway in which Oklahoma is participating is the Southern Wildfire Risk Assessment. In much of Oklahoma's forests, fire regime had been disrupted since European settlement (Johnson & Risser, 1975; Abrams, 1992) and the altered structure and composition of native forests, driven primarily by human activity, affected their response to natural events (Foster *et al*., 2003). As grazing pressure increased in the understory of oak forests, the frequency of fire decreased allowing for woody encroachment into the grassland areas along the forest edge (Nuzzo, 1986; Abrams, 1992). Often the woody species were not the dominants of the forest overstory but were generalist or opportunistic species such as eastern red cedar (*Juniperus* v*irginian*a) (Pearson *et al*., 1998; Hoagland *et al*., 1999).With increases in rural development in certain parts of the state, the Rice and Penfound sites could be used to evaluate vegetation changes from historic levels in the wild land urban interface (WUI) and modeling may help assess trends in these areas including wild land fire risk (Leu *et al* ,2008) This becomes even more important given Oklahoma’s high level of private land ownership and the necessity of researching shifting population patterns(Lewis, 2001; Turner *et al*., 2007). A second federal program of particular importance in the state is the Southern Critical Forestland Assessment which seeks to identify critical forestlands and the services they provide. State completion of this survey is a precursor to future participation is future USFS Farm Bill funded programs. This forest resource assessment is based on ten GIS layers that are used to both evaluate forests and to identify threats and issues. A cooperative project with the state of Texas is already underway to specifically examine issues with management of the Cross Timbers on a landscape scale and evaluate past and current threats to this unique ecosystem. Human influence on the landscape cannot be removed from the equation but an understanding of the historical and cultural legacy of an area can provide valuable temporal and spatial information for sound management decisions (Foster *et al*., 2003; Lunt & Spooner, 2005; Turner *et al.*, 2007). Oklahoma’s forest lands offer both residents and visitors benefits including water and air quality, recreational activities forest products and climatic regulation making essential an understanding of the forces impacting those forest lands.

Implications

Forest cover for Oklahoma during the time of the Rice and Penfound study was estimated at 24% of total land area or about 4.2 million hectares (Johnson and Risser, 1972). Current forest cover estimates varied, but ranged from 18% to 20% of total land cover, equaling a loss over the past 50 years of approximately 700,000 ha or almost 17% of previous estimated state levels (Lewis, 2001; USFS, 2002). The total land area included in this study and in the original research was approximately 8500 ha. Known loss, calculated from those stands falling into disturbance level **D**, completely converted to another land use, totaled just over 1000 ha. This represented a 13% loss of the total area from the original study. If 50% of the stand area from class **C** was included, where we knew at least half of the stand was lost, this raised the total area lost to about 1800 ha or 21% of the original forest area sampled The findings of this research study supported broader changes seen and documented at a state scale. Clearly, Oklahoma's forests are at risk from a multitude of factors and quantifying loss of previously forested areas over the past 50 years has value both to natural resource managers and policy makers as well as to the scientific community.

Limitations

This study examined changes in forest cover and land use at two points, first in the 1950s and then again in the 2000s. It did not measure how much land was added to forests in the past 50 years. Similarly, it did not evaluate stands cleared and then abandoned where regeneration occurred. Some stands exhibited fragmentation due to roads and other land use types however; the integrity of the remaining stand was not part of the data collected.

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APPENDIX

Data Table for all 194 stands in this study

COUNTY	REGION	STAND #	# ORIGINAL ACRES	FRST TYP DK&FLTR	DISTURBANCE LEVEL	DISTURBANCE TYPE	DESCRIPTIONS	NOTES / DISCREPANCIES
ADAIR	NE	175	40	OA/HI	D	Agriculture	Grazing and small ponds	mostly in SE 1/4 of NW1/4, not SW/4 of NW/4 as written
ADAIR	NE	176	80	OA/PI	B	Agriculture, Rural Dev't	N 80 ac, some logging, grazing and small ponds, house	Mesic sites. 176/177 same , almost all of SE 1/4 of sect.16, This 80ac about half intact
ADAIR	NE	177	80	OA/PI	C	Agriculture, Rural Dev't	S 80 ac, some logging, grazing, houses/buildings	Xeric sites. This 80 ac mostly converted to ag. s 176 & 177 have 160 ac total
ADAIR	NE	178	70	OA/HI	A	Ag	Fairly open canopy with some thinning apparent, logging in area	Looks like NW1/4 of sec.14 (not NE 1/4) due to road placement, 2nd in NE 1/4 sec 15?
ADAIR	NE	179	30	OA/HI	A	Ag	Minor roads and clearings	Data sheet says E of Stilwell, so may be T15N R26E. Used 14N 26E as typed but likely sec 1 & 2, not 1 & 14. Road shape puts in sect 2
ADAIR	NE	180	60	OA/HI	C	Agriculture, Infra	Grazing, appears road moved	Just under 30ac left intact to the E and along current road.
ADAIR	NE	181	30	OA/HI	B	Agriculture, Infra, Rural Devt	Small ag clearing in NE corner, minor thru road, few buildings	Nice 20+ ac tract available in S portion of

ALFALFA	NW	208	30	PO/BJ	A	Rural Dev't, Ag	Open woodland savannah, minor pasture roads, grazing, buildings	Data sheet has no T/R or sect #. Based on distance from town and D&F forest type, most likely Sect 1 of 23N 11W
ATOKA	SE	26	80	PO/BJ	A	water	West edge of Boggy Creek SP, 6 ac lake built in	Nice site still left
ATOKA	SE	28	15	OA/HI	A	N/A	No human disturbance observed	Problem with map and hand notes, not matching but went with field map
ATOKA	SE	29	320	OA/PI	A	Agriculture	Logging with roads	Small clear cuts but mostly intact
BLAINE	NW	120	40	PO/BJ	C	Agriculture	crops	open savannah type , small piece intact, heavy ag area
BLAINE	NW	121	60	PO/BJ	A	N/A	No human disturbance observed	Black jacks dying in 1950s
BLAINE	NW	122	100	PO/BJ	C	Agriculture	crops	Approx 30% left plus some trees along a drainage ravine
BRYAN	SC	4	20	PO/BJ	A	Rural Dev't	Small clearings along side road	Still nearly all intact
BRYAN	SC	5	40	PO/BJ	D	Agriculture	grazing	Trees only along creek
BRYAN	SC	6	40	PO/BJ	A	Agriculture	Small clearing, looks like logged	Clearing in center of has small road in and appears to have been logged
CADDO	SW	59	30	PO/BJ	D	Agriculture	Primarily grazing	Nothing left
CADDO	SW	60	120	PO/BJ	D	Agriculture	Grazing and crops	Nothing left
CADDO	SW	61	80	PO/BJ	C	Agriculture, Infra	Grazing and crops, oil & gas	Surrounded by agriculture, highly terraced

CANADIAN	NW	119	90	PO/BJ	D	Infrastructure and Agriculture	Oil & gas with roads, old field with some grazing. Tress, mostly cedars, restricted to drainage ravines. Terracing all around	Field notes indicate "cedars getting thicker", also high drought impact
CANADIAN	NW	126	90	PO/BJ	B	Ag, Rural Dev't, Infra	Grazing & crops, pasture roads, several small ag ponds, few buildings, oil&gas pad	R&P note openness of the canopy. Right at 50% left including small areas in SE 1/4 of SE 1//4
CARTER	SC	14	70	PO/BJ	D	Agriculture	primarily grazing, small ag ponds	Map shows W1/2 of SE 1/4, not NE 1/4 as typed on data sheet
CARTER	SC	15	70	PO/BJ	A	Infrastructure	Primarily utility right of way	Fairly open in areas, clearing in center of
CARTER	SC	16	15	PO/BJ	B	Agriculture	Grazing	About 8 ac left intact, just over 50%
CHEROKEE	NE	182	40	OA/PI	A	Agriculture	#182=mesic sites, some clearing/logging with grazing	most likely sect 15& 14, NOT sec 19 & 15, goes with #183, no acres given but 80 ac total
CHEROKEE	NE	183	40	OA/PI	A	Agriculture	#183 = xeric sites, some clearing/logging with grazing	goes with #182, 80 ac total, divided total acres between 2 s
CHEROKEE	NE	184	40	PO/BJ	D	Urban, Ag, Rural Dev't	Trailer park in small section, housing division, some grazing	Very close to Tahlequah along Hgwy 62, next to HS, urban/rural interface area
CHEROKEE	NE	185	80	OA/HI	B	Agriculture	SE1/4 of logged, grazing	W 1/2 of intact, good areas all around

CHEROKEE	NE	187	90	OA/HI	A	Agriculture	logging and grazing clearings	Cookson WMA
CHOCTAW	SE	1	80	PO/BJ	D	Agriculture	cleared for grazing	
CHOCTAW	SE	2	40	OA/PI	D	Agriculture	cleared for grazing, small pond	
CHOCTAW	SE	3	80	OA/HI	D	Agriculture	cleared for grazing, small pond, crops	only about 5 ac in SW corner of
CLEVELAND	SC	66	65	PO/BJ	B	Rural Dev't, Ag	abandoned farm site, several ponds	About 40 ac left with some inner clearings
CLEVELAND	SC	67	160	PO/BJ	A	Infrastructure	Oil & gas pads with roads	Nearly all intact
CLEVELAND	SC	69	80	PO/BJ	C	Rural Dev't, Ag	5ac ranchettes, new road, old farm site, ponds, limited grazing,	Very close to Tinker AFB, lots of clearing on W side of
COAL	SC	30	80	PO/BJ	C	Rural Dev't, Ag	few houses, farm site, large pond	about 30 ac left in N part of
COAL	SC	32	80	PO/BJ	C	Agriculture	Opened up with grazing	about 15 ac left in N part of
COAL	SC	33	35	PO/BJ	B	Agriculture	grazing encroaching from surrounding areas, minor roads	fairly in tact but starting to show fragmentation with small clearings and roads
COMANCHE	SW	154	100	PO/BJ	A	N/A	WW Refuge property, no human disturbance	WWR- NE slope Mt Sheridan, field map shows SW1/4 of section probably in error
COMANCHE	SW	155	40	PO/BJ	A	N/A	WW Refuge property, no human disturbance	WWR- SW slope Mt Pinchot Sec. 28 & 27 or 22 & 27 NOT 25&27 as on field map

COMANCHE	SW	156	150	PO/BJ	A	N/A	WW Refuge property, no human disturbance	WWR - Deer Flats between creeks, field map likely off 1/4 sec, shift N and W
COMANCHE	SW	157	50	PO/BJ	A	N/A	WW Refuge property, no human disturbance	WWR- E slope Mt Roosevelt, field map likely off 1/8 sec
COMANCHE	SW	158	100	PO/BJ	A	N/A	WW Refuge property, no human disturbance	WWR- Sulphur Flats. Probably SE 1/4 of sect 24 3N R14W, not NW 1/4 sec 19, 3N R13W
COMANCHE	SW	159	90	PO/BJ	A	N/A	near WWR	Sect 15, NOT 115 as written on data sheet
CRAIG	NE	147	60	PO/BJ	B	Rural Dev't, Ag	rural home site with buildings, pond, grazing	about 8 ac cleared to expand grazing
CRAIG	NE	148	80	PO/BJ	B	Rural Dev't, Ag	rural home site, buildings, several ponds, patchwork openings	about 55 acres left
CRAIG	NE	149	70	PO/BJ	B	Agriculture, Infra	Grazing, abandoned mine pits	pond seems to be filled in pit, no buildings
CREEK	NC	100	130	PO/BJ	B	Infrastructure	Much of tree cover intact, high oil & gas activity, transmission line	covered with oil and gas pads and roads, highly fragmented, no evidence of buildings
CREEK	NC	102	80	PO/BJ	A	Infrastructure	Route 66 course altered, roadway and utility lines	good tree cover still in place, no buildings
DELAWARE	NE	172	90	PO/BJ	A	N/A	In PO/BJ but species description supports OA/HI	On the edge of D&F OA/HI, field map fits exactly if shifted W about 40 acres.

DELAWARE	NE	173	35	OA/HI	A	Agriculture	Nice stand intact, about 30+ ac. Surrounded by agriculture fields	Road may have moved but does not affect stand. Nearly 35 ac still intact. Heavy poultry area
DELAWARE	NE	174	70	OA/HI	A	Agriculture	Small 5 ac clearing in center	Lots of agriculture in area, but stand in good shape
DEWEY	NW	123	70	PO/BJ	C	Agriculture	crops	Small 7.5ac tract remains
DEWEY	NW	124	60	PO/BJ	A	Rural Dev't	small rural church and one other small clearing	Most of canopy still intact. High drought impact noted
DEWEY	NW	125	100	PO/BJ	D	Agriculture	Nearly all cleared	Some regeneration evident, heavy ag area
GARFIELD	NW	135	50	PO/BJ	B	Ag, Infra	Oil & gas pads with roads, grazing, pond	open savannah type , 35-40 acs intact, heavy ag area
GARFIELD	NW	136	50	PO/BJ	A	Ag	Small ponds, limited grazing	nearly all intact, open savannah type
GARFIELD	NW	137	75	PO/BJ	D	Agriculture	All converted to grazing and crops	Data sheet notes say SW 1/4 of sec while field map shows NW 1/4
GARVIN	SC	37	60	PO/BJ	D	Ag, Infra	Small clumps trees along ravines, small ponds, grazing, oil&gas	Nearly all cleared, several oil&gas pads with roads
GARVIN	SC	39	80	PO/BJ	A	Ag, Infra, Rural Dev't	Small ponds, limited grazing, few buildings, smaller utility lines	smaller scale utility lines, fairly intact with a few pocket clearings, old oil&gas sites
GARVIN	SC	40	160	PO/BJ	D	Ag, Infra	several ponds, high oil & gas impact with roads, grazing	Clumps of trees around ponds and along drainages. Mostly cleared, terracing in area

GRADY	SC	55	160	PO/BJ	D	Ag, Infra	Nearly all sect. cleared, oil & gas, several ponds, grazing	Data sheet says 560ac, but field map and other notes indicate only NW/4 160 ac sampled
GRADY	SC	57	95	PO/BJ	C	Ag	Several ponds, grazing	about 18 ac left in sec 33 and 8 ac in sect 28
GRADY	SC	58	40	PO/BJ	A	Rural Dev't	Few small clearings, trailer, barn	Nearly intact, small clearings, access roads
HASKELL	SE	44	100	OA/PI	A	Infrastructure	Major oil & gas service road thru the middle of , small utility line	Barely in OA/PI. Sects 20 & 29, big oil & gas in area, 50 ac in sect 29 probably along ridge top
HASKELL	SE	45	200	OA/HI	A	Agriculture	Ag pushing into S side of stand. Ridge starts in NW 1/4 sec 27	Primarily intact, some ag along edges. Map may be off 1/4 sect if you follow ridgeline
HASKELL	SE	46	100	PO/BJ	A	Ag, Infra	High transmission lines, ponds	Ag in the area comes right up to edge of . Nearly all intact.
HUGHES	SC	77	200	PO/BJ	B	Ag, Infra, Rural Dev't	Oil & gas, home sites, many ponds, grazing	Shape and location of road clearly puts in sec 6 NOT sec 5
HUGHES	SC	78	130	PO/BJ	B	Ag, Rural Dev't	Ag pushing in W side of , horse farm,ponds,home, oil & gas	The transmission line already noted in R&P data sheet. New interior roads. o&g site
HUGHES	SC	79	300	PO/BJ	B	Infrastructure	Heavy oil & gas activity, pads and roads, pipeline, utility line	No exact acres count given. Main road may have moved. No clear evidence of agriculture
JACKSON	SW	209	80	PO/BJ	A	Rural Dev't	Farm site, mostly intact canopy	Farm in SW corner, surrounded by ag, few pocket clearings, noted drought impacts

JEFFERSON	SC	165	20	PO/BJ	B	Agriculture	small ag clearing and pond	Mostly intact canopy, difficult to tell where s really were
JEFFERSON	SC	166	120	PO/BJ	B	Agriculture	Grazing, crops, ponds	Just over half of left intact,
JEFFERSON	SC	167	40	PO/BJ	B	Agriculture	Grazing, ponds, pasture roads	Just over half of left intact,
JOHNSTON	SC	25	35	PO/BJ	A	Infra	BSA camp, few camping clearings	Creek was dammed forming lake. is south side of dam, N of road, W of creek
JOHNSTON	SC	24	90	PO/BJ	C	Ag, Rural Dev't	Grazing, farmsite, several ponds, large access road	About 20 ac tract remains, multiple use ag
JOHNSTON	SC	23	275	PO/BJ	D	Ag, Rural Dev't	several acres cleared for farmsite, several ponds, grazing	Looks sprayed, very sparse cover
KINGFISHER	NW	132	20	PO/BJ	D	Agriculture	Mostly grazing, small ponds	essentially all gone
KINGFISHER	NW	133	160	PO/BJ	B	Infra, Ag, Rural Dev't	Oil &gas with service roads, grazing, ponds, outbuildings	Right at 50% intact
KINGFISHER	NW	134	30	PO/BJ	D	Ag, Rural Dev't	Irrigated crops and farmsite	is completely gone
KIOWA	SW	160	40	PO/BJ	A	N/A	Canopy looks intact	Granite and rocky
KIOWA	SW	161	20	PO/BJ	A	N/A	Canopy looks intact	grazing up to edge, oil & gas at base of mt., no second page of data sheet
KIOWA	SW	162	30	PO/BJ	A	Agriculture	Ag in area right up to edge	hard to say where original was, map may be off a bit. Some clearing at edge.
KIOWA	SW	163	50	PO/BJ	A	N/A	Quartz Mt area	on the side of mountain
KIOWA	SW	164	15	PO/BJ	A	N/A	Quartz Mt area	on the side of mountain

LATIMER	SE	188	80	OA/PI	A	Infrastructure	State Park roads and into WMA	Hard to tell where sec 24 is. Park roads, small clearings around dam. Mesic sites
LATIMER	SE	189	100	OA/PI	A	Infrastructure	Park roads, camping areas, sewer lagoons	Goes with # 188 in Robbers Cave SP & WMA, xeric sites. 180 ac total
LATIMER	SE	190	80	OA/PI	A	N/A	80 ac between creek and road, just west of Veterans Ctr	Nice intact along ridges. Sect 4 & 33 should be reversed on field map
LATIMER	SE	191	300	OA/PI	A	N/A	Between roads, along ridges and taking up parts of 3 sects	At least 300 ac sampled as drawn on field map. In same township as #190
LATIMER	SE	192	140	OA/PI	A	Infrastructure	Oil & gas roads and pads, old seismic patterns	Field map looks more like 140 ac NOT 640 ac as listed on data sheet
LeFLORE	SE	47	160	OA/PI	B	Agriculture	logging	60-80 ac clearcuts, service roads all over
LeFLORE	SE	49	100	OA/PI	A	Infrastructure	Ouachita Nat'l Forest, minor service roads	Along highway 271
LeFLORE	SE	50	80	PO/BJ	D	Infra, Ag	Grazing, ponds, pasture roads, minor oil & gas	80 ac W of Cty Rd and S of finger lake. Heavy poultry in area
LINCOLN	NC	92	90	PO/BJ	D	Ag, Rural Devt	Grazing and crops, ponds, few buildings	Hgwy 177 not Hgwy 40 on field map (renamed?), about 17 ac left and along ravines
LINCOLN	NC	93	65	PO/BJ	A	Rural Dev't	small interior opening & along road	Nice section still intact, smaller open areas
LINCOLN	NC	94	70	PO/BJ	A	Ag, Infra	Small ag clearings, transmission line	NW part of is fragmented but E part has 60 ac intact above transmission line

LOGAN	NC	89	40	PO/BJ	A	Ag, Infra	Small old clearings, pond, some oil & gas	Minor impacts, nearly intact
LOGAN	NC	90	45	PO/BJ	D	Ag, Rural Dev't Urban, Infra	Grazing, farmsite, all developed along Hgwy 74, oil & gas pad	Classic rural-urban interface
LOGAN	NC	91	90	PO/BJ	B	Ag, Infra	small pocket clearings, ponds, oil & gas in smaller piece	Borders Langston Lake, W/2 of 1/4 sect has nice 65ac intact
LOVE	SC	10	120	PO/BJ	D	Agriculture	Crops	nothing left, just circular crop fields
LOVE	SC	11	20	PO/BJ	B	Ag,Infrastructure	Ponds, small clearings, road	Hard to tell where actually was and road may have moved, fairly open but part intact
LOVE	SC	12	15	PO/BJ	D	Agriculture	crops	nothing left, just circular crop fields
MAJOR	NW	129	90	PO/BJ	C	Ag, Rural Dev't, Infra	Grazing and crops, pipeline, farmsites with lots of buildings	not sure about all of the structures, seems more than just farmsites, about 30ac left
MAJOR	NW	130	104	PO/BJ	B	Agriculture	Some land cleared for ag and smaller oil & gas clearings	Farm site in NW part of not included in as noted on R&P data sheet
MAJOR	NW	131	50	PO/BJ	C	Ag, Infra and Rural Dev't	Mixed Ag with ponds, buildings, new road	is south of creek, 2 farmsites, about 15-20 ac remains
MARSHALL	SC	7	15	PO/BJ	C	Urban, Infra	Hgwy 377 split in half, commercial dev't all along hgwy	about 6 ac on E side of hgwy intact, rest of highly fragmented

MARSHALL	SC	8	130	PO/BJ	B	Infra, Water	Road to a dock, RR with bridge and rest under Lake Texoma	About 100 ac of ridge left along Lake Texoma shore, valleys flooded. Old BSA camp
MARSHALL	SC	9	40	PO/BJ	A	Infra	Small service or shortcut road, minor oil & gas	Nearly all intact except for one minor road
MAYES	NE	143	160	OA/HI	C	Agriculture	Cleared for grazing	Only SW/4 of sec 25 evaluated, 160 acres. No map for other piece so not included in analysis.
MAYES	NE	144	25	OA/HI	B	Rural Dev't	Small clearings with homes and buildings	Most of 25 ac still intact. No clear evidence of ag other than in the area
MAYES	NE	145	40	PO/BJ	A	Agriculture	Grazing area pushed into small part of	Nice intact area E of farm. Grazing in area has pushed into W side of stand .
MURRAY	SC	20	30	PO/BJ	C	Ag, Infra	Mixed ag, quarry, oil & gas with service road	Sect 1 nearly gone to mixed ag and sect 36 has quarry to W and larger pond to E
MURRAY	SC	21	15	PO/BJ	D	Agriculture	Grazing, pond	Land cleared at one point, some regeneration
MURRAY	SC	22	15	PO/BJ	A	N/A	E and NE slopes on side of mt.	Just S of Turner Falls SP, between 2 minor service roads
MUSKOGEE	NE	113	100	OA/HI	A	Rural Dev't	Large home with out buildings	No Ag noted
MUSKOGEE	NE	114	100	PO/BJ	A	Urban, Ag	Nice housing addition, grazing, pond	grazing pushing into N side of , nice housing along road to S
MUSKOGEE	NE	115	50	PO/BJ	A	Rural Dev't	Recent small ranchette	New access road
McCLAIN	SC	62	45	PO/BJ	D	Urban	Housing additions with roads	Few acres in one area, highly fragmented

McCLAIN	SC	63	150	PO/BJ	C	Agriculture	Mixed agriculture, pond	Highly terraced, remaining trees restricted to ravines. About 25 ac left but in 3 sections
McCLAIN	SC	64	20	PO/BJ	B	Ag	minor pasture roads, grazing	Grazing in E side, about 8 ac left
McCURTAIN	SE	193	400	LO/PI	C	Agriculture	Logging with minor roads	Ouachita Nat'l Forest, about 160 ac left
McCURTAIN	SE	194	30	OA/HI	C	Rural Dev't and Agriculture	Almost all 5 ac ranchettes with limited grazing	All 5 ac lots with trailers and some livestock
McCURTAIN	SE	195	160	OA/PI	C	Water, Infra	Camping sites and roads, large lake	Part of is Little River SP, part is under Pine Creek Lk and about 40ac along shore
McCURTAIN	SE	196	250	OA/PI	A	N/A	No human disturbance observed	Mesic sites, goes with #197, nearly all of sect 11 except N 40 and S 30
McCURTAIN	SE	197	320	OA/PI	A	N/A	No human disturbance observed	Xeric sites, goes with #196, Broken Bow WMA
McCURTAIN	SE	199	120	OA/PI	A	Agriculture	small logging clearings	Mesic area between Hwy 144 and Cty road, goes with #200
McCURTAIN	SE	200	400	OA/PI	B	Ag, Infra	Large logging areas, cty and logging roads	Goes with # 199, xeric sites
McINTOSH	NE	81	25	OA/HI	A	Infra	Turnpike	Along ridgeline right up against Indian Nations Turnpike
McINTOSH	NE	82	20	OA/HI	C	Water, Rural Dev't	Lake Eufaula, house	is on/under shoreline of Lake Eufaula, nice lake house with access road, 8 ac left
NOBLE	NC	139	100	PO/BJ	B	Rural Dev't, Ag	Large new farm clearing in center, pond, grazing	Right on edge of Lk McMurtry, new access road, farms along E edge not in

NOWATA	NE	150	70	PO/BJ	A	Rural Dev't, Ag	Some clearing along flat, buildings	Edge of Oolagah WMA, good tree cover on slopes, minimal impact on
NOWATA	NE	151	100	PO/BJ	A	Infra	new roads, few small clearings	R&P had farm on original data sheet
NOWATA	NE	152	320	PO/BJ	B	Infra, Rural Dev't, Ag	Trailer clearings, oil&gas roads throughout, ag clearings, ponds	Covered with oil & gas from 1920s to present. About 50% left but fragmented
OKFUSKEE	NC	83	60	PO/BJ	A	Infra	transmission line	cover nearly all intact
OKFUSKEE	NC	85	40	PO/BJ	A	Agriculture	small clearing in north part of	between road to W and creek to E
OKLAHOMA	NC	86	30	PO/BJ	C	Urban	Housing additions with roads	NW Edmond
OKLAHOMA	NC	87	80	PO/BJ	A	Rural Devt	Heavy grazing but canopy intact. Small rural home site	Arcadia area
OKLAHOMA	NC	88	70	PO/BJ	C	Urban	Housing additions and other urban	Choctaw expansion, small piece in N part
OKMULGEE	NE	103	110	PO/BJ	A	Ag, Rural Dev't, Infra	New road with houses, farmsites, pipeline, oil & gas, grazing	E edge of broken up-new road, houses, farmsite, ponds, grazing. Rest of intact
OKMULGEE	NE	104	60	PO/BJ	B	Rural Dev't, Ag, Infra	grazing, house, pond, oil & gas	Based on actual road location and data sheet info field map likely off, shift road E to sect. center
OKMULGEE	NE	105	120	PO/BJ	D	Ag, Rural Dev't	farmsites, grazing, ponds	all cleared
OSAGE	NC	106	90	PO/BJ	A	N/A	only contains 90 ac or W/2	Evaluated SE/4 of sect. as on map, not datasheet NW/4
OSAGE	NC	107	60	PO/BJ	B	Ag	grazing coming in on all sides	About 25 ac left in each piece, S of road

OSAGE	NC	108	200	PO/BJ	B	Ag, Infra	Grazing, ponds, new county road, oil & gas with roads	Hard to tell if area is just open naturally or sprayed
OSAGE	NC	109	640	PO/BJ	C	Infra, Rural Dev't, Ag	oil & gas, few houses, ponds, grazing	Road clearly places in sect 36, not 35. Just S off Hgwy 10. Looks sprayed
OTTAWA	NE	168	50	OA/HI	B	Agriculture	canopy intact but has been opened up or thinned, grazing	Map indicates about 50 ac surveyed, NOT 500ac
OTTAWA	NE	169	45	OA/HI	A	Rural Dev't	Housing, farm on E edge	nearly all intact
OTTAWA	NE	170	80	OA/HI	A	Infrastructure	New county road thru	Nice and intact. Xeric, goes with #171
OTTAWA	NE	171	80	OA/HI	A	Infrastructure	New county road thru	Nice and intact. Mesic, goes with #170
PAWNEE	NC	98	70	PO/BJ	B	Rural Dev't, Ag	House, grazing, ponds oil & gas	NW piece in good shape, NE piece 10ac left. Just north of Cimarron Tnpk
PAWNEE	NC	99	120	PO/BJ	B	Infra, Ag	Oil & gas, some grazing, ponds	Oil &gas road in middle of with pad sites
PAYNE	NC	95	40	PO/BJ	B	water, urban	large pond, commercial area	commercial dev't from Perkins
PAYNE	NC	96	70	PO/BJ	A	Ag	ponds	Nearly intact, small clearings around ponds
PAYNE	NC	97	70	PO/BJ	C	Ag, Infra	Grazing, ponds, transmission line	Fragmented but almost 50% remaining
PITTSBURG	SE	41	40	PO/BJ	D	Agriculture	Crops	Appears to be primarily planted
PITTSBURG	SE	42	800	PO/BJ	C	Ag, Infra, water	pipeline, county rd, grazing, ponds, 30 ac lake, oil & gas with roads	looks systematically cleared in 40ac sections, remaining ac in sec 28 around lake

PITTSBURG	SE	43	60	PO/BJ	B	Infra, Rural Dev't	houses, new lake access road	on shore of Lk Eufaula, road in middle of , nice lake homes on bluff
PONTOTOC	SC	34	35	PO/BJ	D	Agriculture	Old clearing, evident tree regeneration, some grazing	A few larger trees noticed
PONTOTOC	SC	35	50	PO/BJ	B	Infrastructure	Horse farm just to S, oil&gas	One well with road, nearly all intact
PONTOTOC	SC	36	40	PO/BJ	C	Ag, Rural Dev't	Grazing, small ponds, house	Fragmented. Just analyzed 40ac in NE/4 as listed on data sheet
POTTAWATOMIE	SC	70	40	PO/BJ	B	Ag, Rural Dev't, Infra	farmsites, grazing, ponds, pipeline	is E of road, highly fragmented, maybe 30ac remaining
POTTAWATOMIE	SC	71	65	PO/BJ	B	Infra	transmission line	in good shape except for utility line
POTTAWATOMIE	SC	72	80	PO/BJ	A	Ag	grazing, ponds and pasture roads	irregular shape but looks fairly intact
PUSHMAHTAHA	SE	198	640	OA/PI	A	Ag	logging, roads Old Dierks property	intact except covered with logging roads
PUSHMAHTAHA	SE	201	100	OA/PI	B	Ag	logging, roads. Old Dierks property	100ac of mesic sites. Goes with #202. #201 and #202 includes all of sec 18 (640 ac)
PUSHMAHTAHA	SE	202	500	OA/PI	B	Ag	logging, roads Old Dierks property	500 ac of xeric sites. Goes with #201. Sec 24 has no map so not included here
PUSHMAHTAHA	SE	203	300	OA/PI	A	Ag	logging, roads Old Dierks property	300 ac mesic sites, goes with # 204
PUSHMAHTAHA	SE	204	340	OA/PI	A	Ag	logging, roads. Old Dierks property	340 ac xeric sites, goes with # 203, all of sec 3. Very minor impacts to canopy

PUSHMAHTAHA	SE	205	100	OA/PI	A	Ag	logging	W of road and S of creek, canopy looks good
PUSHMAHTAHA	SE	206	600	OA/PI	A	N/A	No human disturbance observed	not even any logging roads noted
PUSHMAHTAHA	SE	207	60	OA/HI	A	Rural dev't	Interior farmsite may not be in but access road is	Some clearings but almost all intact
ROGERS	NE	112	15	PO/BJ	B	Ag	Ag clearings coming in on all sides	About 12ac left, just a thin strip along creek
ROGERS	NE	146	80	PO/BJ	B	Infra, Rural Dev't, Agriculture	Road to S changed location, old ag clearings, ranchettes	Lots of agriculture in area but is in fairly good shape
ROGERS	NE	153	80	PO/BJ	B	Rural Dev't, Ag	House s along edges and old farmsites, grazing	Close to Claremore, heavy ag area, about 50 ac remains but in good shape
SEMINOLE	SC	73	320	PO/BJ	A	Infra	oil & gas pads, roads. Tanks	in good shape except for oil & gas
SEMINOLE	SC	74	80	PO/BJ	B	Infra, Ag, Rural Dev't	House clearings, grazing, ponds, pipelines, some oil & gas sites	E side of in good shape, W side fragmented
SEMINOLE	SC	75	100	PO/BJ	B	Agriculture,Infra, Rural Dev't	Old clearings, grazing, oil & gas, new home site	looks like some interior thinning, 80 ac intact
SEQUOYAH	NE	52	20	PO/BJ	A	N/A	No human disturbance observed	all 20 ac intact
SEQUOYAH	NE	53	30	PO/BJ	C	Infra	I-40 goes right thru middle of	about 8ac intact just E of Interstate
SEQUOYAH	NE	54	100	OA/HI	A	Rural Dev't, Infra	Railroad moved, rural housing	New homes along county road on E edge

STEPHENS	SC	17	150	PO/BJ	D	Rural Dev't, Infra, Agriculture	Housing site, oil & gas pads with roads, ponds, grazing, utility lines	nearly gone, just a few ac in NE part of
STEPHENS	SC	18	70	PO/BJ	A	Agriculture	grazing, pond	Over 60ac intact, heavy ag all around, shape looks just like R&P map
STEPHENS	SC	19	120	PO/BJ	A	Ag, Rural Dev't	farm or house site, pond, pasture roads, grazing	canopy nearly all intact, some interior roads, large lake comes right up to SE edge
TULSA	NC	116	100	PO/BJ	D	Urban	housing additions, mixed urban	urban dev't, some green space, 71st & Yale
TULSA	NC	117	200	PO/BJ	A	Rural Dev't, Infra	Houses, new road,	Legal is21N 12E,NOT 12N. Correctional sect, nearly all intact, right on Osage Cty line
TULSA	NC	118	225	PO/BJ	C	Urban, Infra, Ag, Water, Rural Dev't	Housing, transmission lines, rural housing, farmsites, grazing, ponds	has it all-mixed urban, utility lines, mixed ag, ranchettes. About 100 ac left in SW/4
WAGONER	NE	140	30	PO/BJ	A	Ag	some grazing on edges	1 mile from OA/HI which dominants suggest
WAGONER	NE	141	70	PO/BJ	B	Ag, Infra, Rural Dev't	several houses, road moved, grazing right up to edges, ponds	Expansion from Coweta, several houses and fairly fragmented
WAGONER	NE	142	150	PO/BJ	D	Rural Dev't, Ag	farmsite, grazing, terraced, ponds	S of creek, nearly totally cleared, Broken Arrow expansion right up to edge

WASHINGTON	NC	110	110	PO/BJ	A	Rural Dev't, Infra	house sites, county road	grazing on edges, right on edge of Copan WMA, nearly all intact
WASHINGTON	NC	111	100	PO/BJ	B	Rural Dev't, Infra, Ag, Urban	farmsites, ponds, grazing, crops, neighborhood and urban	Mountain top is housing addition, urban sprawl from Bartlesville, ag on flat, slopes intact
WOODWARD	NW	127	320	PO/BJ	A	Infrastructure	pipelines	canopy is intact, open savannah type
WOODWARD	NW	128	140	PO/BJ	A	Infrastructure	Oil & gas pads with roads	Very open canopy, oak savannah

VITA

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Candidate for the Degree of

Master of Science

Thesis: ANALYSIS OF LAND USE, LAND COVER CHANGE IN THE UPLAND FORESTS OF OKLAHOMA: A COMPARISON BETWEEN THE 1950s AND 2000s

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Title of Study: ANALYSIS OF LAND USE, LAND COVER CHANGE IN THE UPLAND FORESTS OF OKLAHOMA: A COMPARISON BETWEEN THE 1950s AND 2000s

Pages in Study: 88
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Scope and Method of Study: To investigate human disturbance of Oklahoma forests, a 1950s survey of forest stands was reexamined using field inspection and GIS analysis. Historic data for 194 sites in 60 counties with acreages from 15 to 800 acres were surveyed within three forest types. Stands were analyzed for both disturbance level and disturbance type resulting in forest loss.

Findings and Conclusions: Most stands (69%) suffered less than 50% disturbance. Higher disturbance was found in northwest and south-central regions with lower disturbance in northeast and southeast regions. The leading cause of deforestation was agriculture, 64% of stands, located predominantly in areas with low timber value and widespread agricultural practices. Forest loss decreased where forest economic value was high. Post oak/black jack forest suffered greater disturbance than other forest types. Infrastructure, including extractive activities, had lower disturbance levels. Rural development associated primarily with agriculture. Proximity to urban areas did not result in higher disturbance levels.

ADVISER'S APPROVAL: Dr. Stephen Hallgren