ECOLOGICAL DYNAMICS OF NATIVE BOTTOMLAND PECAN COMMUNITIES

IN THE EDWARDS PLATEAU OF TEXAS

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ABSTRACT

ECOLOGICAL DYNAMICS OF NATIVE BOTTOMLAND PECAN COMMUNITIES IN THE EDWARDS PLATEAU OF TEXAS

by

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Native bottomland pecan (*Carya illinoiensis*) communities exist as fragments along river systems of the Edwards Plateau. They persist in this sub-humid rangeland environment because of the unique hydrologic regime of the riparian zone. Bottomland sites are currently dominated by an over story of mature pecan trees with little woody understory or replacement pecan seedlings. The lack of pecan recruitment might result in the loss of these native bottomland pecan communities as adult trees senesce and die. Objectives of my study were to: 1) determine the extent of change in these communities over several decades, 2) assess current age structure of these communities, 3) assess impact to recruitment due to herbivory and grove management, and 4) construct a computer-based conceptual model of community behavior to identify factors having the potential to affect native pecan bottomlands. Sites were selected based on species composition, accessibility, herbivore pressure, and management history (natural, harvested, harvested/groomed). Twenty pecan trees from each site were cored and cores were sent to a dendrochronology lab for aging. Results show that these pecan communities have changed little in size over the past 60 years. These communities exist primarily as mature trees with few younger age classes. Deer densities are extremely high within these communities indicating that herbivory is likely influencing recruitment rates. Computer simulation modeling identified factors affecting recruitment and mortality of native pecan trees in bottomland communities.

CHAPTER I

INTRODUCTION

Riparian corridors are recognized for their disproportionately high contribution to landscape-level ecological diversity (Naiman et al. 1993). Riparian pecan (*Carya illinoiensis*) woodlands in the western Edwards Plateau exist as fragments in an otherwise arid to subhumid rangeland environment and persist only because of the unique hydrologic regime of the riparian zone (Naiman et al. 1993). These communities provide critical habitat for many wildlife species. Rio Grande Wild Turkeys (*Meleagris gallopavo*) depend on these communities for roosting sites, which support large wintering concentrations (Thomas et al. 1966, Cook 1973). In the western part of its range the fox squirrel (*Sciurus niger*) is restricted to riparian woodlands and is dependent on stands of mature pecans for food and shelter (Davis and Schmidly 1994). Numerous bird species also rely on riparian woodlands in west Texas, including Northern Cardinal (*Cardinalis cardinalis*), Carolina Wren (*Thryothorus ludovicians*), Lesser Goldfinch (*Carduelis psaltria*), Golden-fronted Woodpecker (*Melanerpes aurifrons*), and Eastern Wood-pewee (*Contopus virens*).

In the western Edwards Plateau, many riparian communities have high densities of white-tailed deer (*Odocoileus virginianus*) and exotic deer, such as axis (*Cervus axis*). In these areas, the woody riparian understory is sparse, degraded, or absent (T. Wayne

Schwertner, personal observation), suggesting these riparian woodland communities are not evolutionarily adapted to high levels of ungulate herbivory. Lack of woody plant recruitment might eventually result in the loss of riparian woodland communities as adult trees senesce and are not replaced. Alternatively, these woodland communities might be replaced by those having different species composition due to removal of current woody species by selective browsing and subsequent ecological release of less palatable species such as honey mesquite (*Prosopis glandulosa*) and Ashe juniper (*Juniperis ashei*) (Horsely and Marquis 1983).

Most studies concerning the impact of ungulate herbivory on woody plant recruitment in a forest community have been conducted in the eastern United States (Stromayer and Warren 1997). However, riparian communities in the Hill Country of Texas are subject to unique circumstances related to their arid environment. Moreover, white-tailed deer herbivory in this region may be exacerbated by periodic shifts of deer into these communities during drought, when riparian zones may offer the only available green forage (T. Wayne Schwertner, personal communication, Healy 1997).

In many parts of the eastern United States and south eastern Canada white-tailed deer are currently so abundant that many observers suggest or assume that deer are having a major impact upon the vegetation of this region (Alverson et al. 1988, Behrend et al. 1970, Buckley et. al 1998). Browsing by white-tailed deer limits woody plant recruitment in deciduous hardwood communities (Horsely and Marquis 1983, Tilghman 1987, Healy 1997). Russell and Fowler (2002) hypothesized that browsing by white-tailed deer was the primary factor behind the widespread failure of Texas oak (*Quercus buckleyi*) recruitment in the eastern Edwards Plateau. However, actual effects on specific communities vary with the life history traits of the species involved (Liang and Seagle 2002). Microhabitat effects may further confound conclusions concerning the interaction of ungulate herbivores and seedling recruitment. These effects might arise from secondary vegetative dynamics resulting indirectly from deer herbivory and creating an alternative stable state of the plant community.

The concept of multiple stable states in communities was articulated for a wide array of ecological systems by Holling (1973). The concept has been refined further for application to herbivore-vegetative dynamics in rangeland systems (Archer and Smiens 1991, Friedel 1991, Laycock 1991). Stromayer and Warren (1997) argued that herbivory by white-tailed deer might be creating alternate stable states in eastern United States forests, with heavy browsing by deer analogous to overgrazing by livestock in a rangeland situation. The existence of multiple stable states would greatly complicate managing overabundant white-tailed deer herds to increase plant diversity. If a long history of over browsing has caused a plant community to shift to an alternate state, then simply reducing deer densities would not be sufficient to restore the plant community; additional high-energy inputs would be required to move the system away from its current equilibrium (Stromayer and Warren 1997).

Heavy browsing by white-tailed deer for >60 years has shifted the riparian pecan communities of the western Edwards Plateau to an alternative steady state (Schwertner, personal observation). The plant community of these sites is currently dominated by an overstory of mature pecan trees with very little woody understory. At ground level, the community is dominated by a dense mat of herbaceous vegetation, primarily grasses such as Texas wintergrass (*Nasella leucotricha*) and rescue grass (*Bromus unioloides*). This current community is the result of the interaction among white-tailed deer, woody understory species (including immature pecan), and grasses (Schwertner, personal observation). Prior to the dramatic increase in deer densities in the early Twentieth Century, shade tolerant shrubs and small trees might have dominated the understory of previous stable communities. Some of these trees would have been pecan saplings that would eventually replace mature individuals, allowing continual regeneration of the overstory. As deer densities increased, the shrub layer was slowly degraded and eventually removed, reducing competition for light, water, and nutrients. Grasses took advantage of the reduced competition and invaded the site, creating the present community. It is reasonable to assume that competition from grasses and deer herbivory restricts or eliminates germination of woody plants, such as the native pecan tree. Russell (1999) argued that the effect of an overabundance of deer on vegetation is probably the cause of reduction in hardwood recruitment, which is not a recurring pattern that fluctuates dynamically but will be lasting unless deer densities are reduced.

The pecan tree and its fruit have become important factors in human lifestyles in the southern and southeastern United States. The pecan tree is native to a region of southern United States, bordering the Gulf of Mexico and extending northward along the Mississippi valley to southwestern Wisconsin (Billings 1946). From the Mississippi River, the belt of native pecan trees spreads much farther west than east, extending westward into eastern Kansas, Oklahoma, and Texas, where it reaches across the Rio Grande into northeastern Mexico. Native pecan groves in the western states, particularly in Texas and Oklahoma, commonly inhabit waterways, and sometimes in a broader forested area (Billings 1946). The groves usually have varying proportions of pecans, interspersed with trees of other species. Along larger streams, where lowlands extend from the watercourse, pecan trees may be scattered among the forest trees covering broad areas of alluvial flood plains (Manaster 1994). In order to predict the fate of native pecan groves, simulation modeling can provide useful information on future dynamics of these communities.

Like all ecosystems, forests undergo changes which operate on long-time scales. Thus, simulation modeling is a useful means of inference on long-term forest dynamics (Busing and Mailly 2004). In order to predict the fate of native pecan groves given a number of alternative management regimes, simulation (individual-based) modeling can be used to simulate the performance and fate of individual pecan trees in the overall community. Individual-based models are successful at determining long-term forest dynamics for three reasons: first, information on the biology and life history of individuals is available thus facilitating model parameterization; second, the breadth of information that is generated from these models is sufficient to address a wide range of problems from individuals to ecosystems, and; third, individual-based models are particularly effective at time scales of decades, where traditional modeling has proven difficult (Busing and Mailly 2004).

The objectives of this research are to determine 1) the extent of change in native bottomland pecan communities over the past several decades using Geographic Information Systems (GIS), 2) the current state of these communities by describing various demographic variables such as mortality, recruitment, and age structure within stands, 3) determine the density of deer populations within native pecan bottomland communities to describe potential impact to these bottomlands, and 4) construct a computer-based conceptual model of community behavior to identify factors that have the potential to affect native pecan bottomlands.

CHAPTER II

STUDY AREA

The Edwards Plateau occupies the central portion of Texas. It is bounded sharply on the east by the Balcones Escarpment and south, grading gradually into the Rolling Plains and High Plains on the north, and the Trans-Pecos region on the west (Van Auken et al. 1979). The eastern half of the Edwards Plateau is considered as dry sub-humid and the western half as semiarid. The eastern portion is known as the Hill Country and is deeply eroded; whereas, the western portion remains a relatively flat elevated plateau. The Edwards Plateau is capped by hard Cretaceous limestones. Local streams entrench the plateau as much as 549 meters in 24 kilometers (The University of Texas at Austin 1996). The upper drainages of streams are waterless draws that open into box canyons where springs provide permanently flowing water. With decreasing rainfall to the west, the vegetation grades from live-oak (*Quercus fusiformis*) and mesquite (*Prosopis glandulosa*)–juniper (*Juniperus ashei*) brush woodlands westward into creosote bush–tarbush shrublands (The University of Texas at Austin 1996).

The soils are typically shallow and calcareous Tarrant-Brackett Association Soils for the upland sites with the deeper Venus-Frio Trinity Association soils occurring in valleys (Taylor et al. 1966). The Edwards Plateau is an uplifted region originally formed from marine deposits of sandstone, limestone, shales, and dolomites 100 million years ago during the Cretaceous Period when this region was covered by an ocean (Texas Parks and Wildlife 2007). Mean annual temperature in the Edwards region is 19.5^{o} C depending on the location (NOAA 2007). Mean annual rainfall within the Edwards Plateau region is 71.12 cm with mean temperatures fluctuating from 4^{o} C in January to 36^{o} C in July (NOAA 2007).

The Edwards Plateau region has a very interesting flora and fauna and has been treated as a separate biotic province and physiographically discrete unit (Van Auken et al. 1979). The major woody plant species are live oak and ashe juniper on the plateaus, pecan, bur oak (*Quercus macrocarpa*), elm (*Ulmus crassifolia*) and hackberry (*Celtis occidentalis*) in the stream bottoms, and mesquite on the sandy stream terraces (Tharp 1939).

Historically, the Edwards Plateau appears to have been a stable grassland or savannah community dominated by tall-grass species and fire-tolerant woody species (Smeins et al. 1997). The climax condition of this region likely was maintained by the dynamic interaction of climatic factors, fire, vegetation, and herbivory (Fonteyn et al. 1988, Van Auken 1993). The Edwards Plateau region contains about 1.6 million white-tailed deer. Much of the Edwards Plateau contains high deer densities of about 1 deer/1.62 hectares (Russell 1999), the highest density of deer in Texas, and in the nation (Beechnoir 1986).

The study sites were seven native bottomland pecan communities located in Kimble County along the South Llano River (South Llano River State Park and Texas Tech University-Junction Center), in San Saba County along the San Saba River (Harkey Pecan Farms, Ellis Pecan Farms, and Johnson Ranch), in Real County along the Frio

River (Bovista Real Ranch), and one in Hays County along the Blanco River (Way Ranch) (Fig. 1). Sites were selected based on species composition, accessibility, herbivore pressure, and management history (natural, harvested, or unharvested and improved). The current harvesting practices at Harkey and Ellis Pecan Farms include harvesting of the native pecans by mechanical trunk shakers. Way Ranch, Bovista Real Ranch, and Texas Tech University-Junction Center were unharvested and improved. Johnson Ranch and South Llano River State Park were natural and unharvested. Maps of the seven study sites are included in Appendix 1.

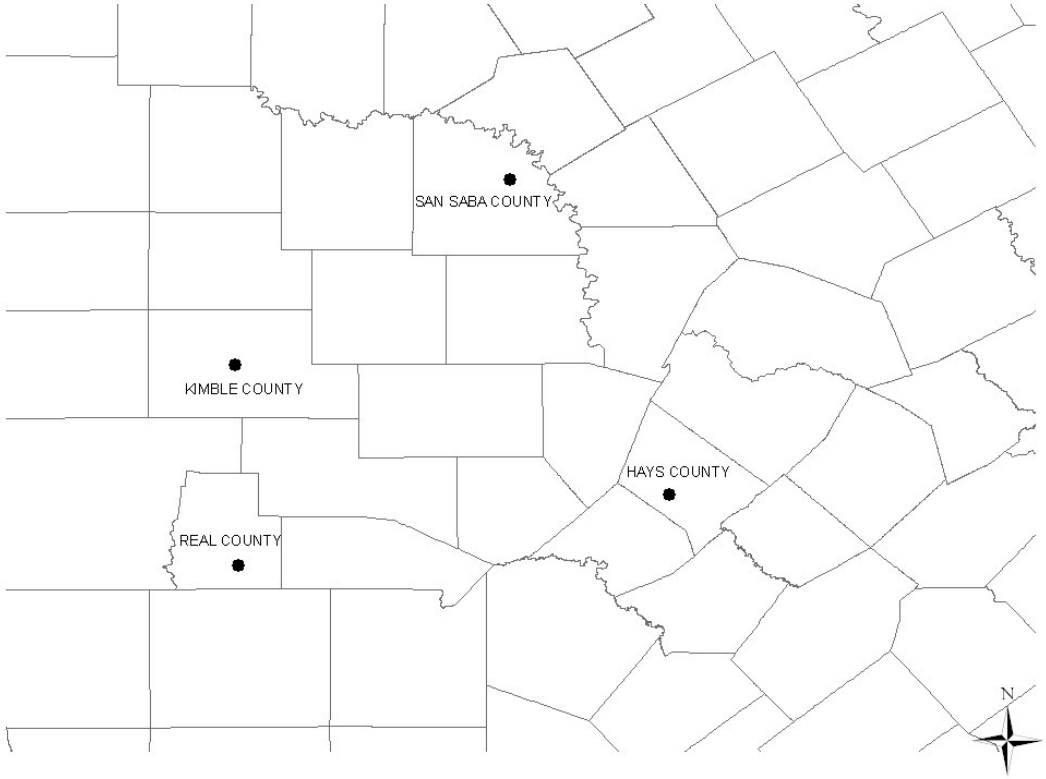

Figure 1. Map showing the location of the seven native pecan bottomland communities. Three sites were located in San Saba County; two sites in Kimble County; one site in Real County; and one site in Hays County.

CHAPTER III

MATERIALS & METHODS

Historical Aerial Imagery/GIS Analysis

I obtained historical aerial images and Digital Orthoimagery Quarter Quadrangle (DOQQ) maps from the Texas Natural Resource Information System (TNRIS) in Austin, Texas. Historical aerial images were not spatially scaled. In order to use these images in ArcMap of ArcGIS version 9.2, I georeferenced each image with a current (2004) DOQQ map. The georeferencing process involved finding pairs of ground control points on each historical aerial image; such as road intersections, buildings, or bridges (Price 2007). I georeferenced at least five points on each historical image to the same five points on the 2004 DOQQ, so that each historical aerial image would spatially match with the DOQQ when inserted as a map layer in ArcMap.

Once points were defined, I applied a geometric transformation to convert the image to the same coordinate system (Price 2007). I delineated the boundary of the native pecan bottomland in each year of images for each study site by drawing a polygon around each bottomland. Using XTools Pro extension of ArcMap, I calculated the approximate area in hectares for each of the three aerial images for all seven study sites. From these data, I determined the increase or decrease in area of each native pecan bottomland over the last 60 years.

Current Demographics of Bottomlands

To determine the current demographics of these native pecan bottomlands, several methods were used for the collection of data. I collected current demographics during May and June 2007. Demographics included, tree age and diameter-at-breast height (dbh). For aging, five of the smallest, five of the largest, and ten randomly selected pecan trees within each bottomland were selected for coring. I extracted a total of 140 cores from the seven bottomlands. All pecan trees were cored using a three-thread forestry increment borer (0.508 centimeter, Mattson, Inc. Fremont, CA). All cores were extracted at dbh (1.38 meters). I inserted the increment borer into the tree in the direction of the pith (center of tree) until the approximate center of the pith was reached. When a pith pocket (a decayed spot in the tree’s xylem) was encountered while coring, I removed the increment borer and selected an alternative coring location on the tree. After I removed the core, the tree self-sealed the borehole with sap.

Because increment cores were very small and fragile, I handled them with extreme care. Increment cores must stay intact with the bark attached so a dendrochronology lab can accurately age the cores. After the increment core was removed from the extractor, I placed it inside a common drinking straw. I stapled one end of the straw closed and left the other open so that the core would dry and prevent the core from molding. I labeled each straw with study site and tree identification. I then placed the straws inside a poster tube for protection and shipped them to the Rocky Mountain Tree Ring Laboratory in Fort Collins, Colorado.

I measured at breast height each of the 140 pecan trees that were cored using a circumference to diameter forestry tape measure (Forestry Suppliers, Inc., Jackson, MS).

In addition, I measured the dbh of each tree in each of the seven bottomlands. With the age determined from the cored trees, I calculated a simple regression equation to extrapolate the age of each pecan tree in groves. A mean dbh and age was calculated for each bottomland.

Vegetative Analysis

Transect sampling was conducted to document current vegetative characteristics of each native pecan bottomland. The line intercept method was used to measure the canopy cover of all woody vegetation within the bottomland. Transect density was one transect per three hectares (Fig. 2). I located each 100-m transect perpendicular to the river. Percent cover of each species was expressed as the percent of the total transect length. I measured herbaceous vegetation composition using the Daubenmire method (Daubenmire 1959). Daubenmire frames (1 m by 1 m) were placed every 20 m along the 100-m transect. Percent cover of bare ground, grasses, forbs, and leaf litter was measured. I used 0.1 ha circular plots to determine the density of pecan trees within each bottomland. I placed one circular plot with a radius of 17.8 m at the 50 m location along each transect and counted the pecan trees within this 0.1 ha plot.

Figure 2. Map showing vegetation transects and the location of cored trees within a native pecan bottomland community in San Saba County, Texas. Yellow lines indicate the transects and the flags represent GPS locations of cored trees.

Deer Spotlight Surveys

Traditional spotlight surveys were used to estimate deer densities. One driving line was established within each study site (Fig. 3), with the starting point at the entrance to each site. Transect lengths varied according to the size of bottomlands. All transects also included area outside the native pecan bottomland because deer located in this area have the potential to enter the bottomland. I surveyed each transect once a day for two consecutive days during October and November 2007. Surveys began 1 h after darkness to coincide with time of highest deer activity (Montgomery 1963, Progulske and Duerre 1964).

At the start and end of each survey, I recorded climatic conditions. I recorded sex and age (fawn or adult) of deer sighted. At each 0.32 km along each line, I measured strip width with a laser rangefinder. Strip width was then used to calculate an approximate survey area (ha). Deer densities were calculated from this strip width and the mean number of deer spotted during the two night survey period.

Figure 3. Map showing a transect (yellow line) used for spotlight deer surveys that traverses the native pecan bottomland.

Computer-based Conceptual Model

I used a computer-based modeling program (STELLA-ISEE Systems, Inc., Lebanon, NH) to construct a conceptual model of community behavior to identify factors having the potential to affect native pecan bottomlands. Factors having the potential to affect recruitment and mortality were identified by a literature review.

CHAPTER IV

RESULTS

Evaluation of Historical Growth Patterns

Growth patterns of native pecan bottomlands varied slightly ($\bar{x}$ = 0.876 ha. SD = 4.19) over the last 60 years. Among the seven study sites, Ellis Pecan Farms, Way Ranch, and South Llano River State Park increased in size, while Harkey Pecan Farms, Johnson Ranch, Bovista Real Ranch, and Texas Tech University-Junction Center decreased in size (Table 1). Way Ranch had the largest increase of 7.72 ha and Bovista Real Ranch had the largest decrease of -3.71 ha. GIS maps of growth patterns are included as Appendix 2.

Demographic Variables of Bottomlands

Native pecan trees at all seven study sites consisted of only one age class: mature trees. Tree diameter (dbh) ranged from 0.315 m to 0.577 m ($\bar{x}$ = 0.458 m, SE = 0.037). The larger trees occurred at two sites along the San Saba River and the smaller trees at the Hays County site (Table 2). Age of each bottomland ranged from 64 to 85 ($\bar{x}$ = 75, SE = 3.092) years. Bottomlands were dominated by large mature trees with few smaller younger trees. Sample sizes, which was approximate number of trees measured for diameter within each bottomland, ranged from 136 to 602 trees ($\bar{x}$ = 382, SE = 198.95).

Age distribution histograms for each of the seven native pecan bottomlands are included as Appendix 3.

The dendrochronology laboratory had difficulty counting annual rings on the pecan cores. These pecan cores had indistinct rings, which limited the ability to determine true or false ring boundaries. The ring structure was somewhat ring-porous (with vessels formed in the earlywood) but they appeared also to have false rings with secondary vessel formation later in the ring. There were slight indications on some terminal parenchyma cells that formed latewood boundaries, but these were not consistent even within the same core. These problems prevented the dendrochronology lab from accurately aging all cores. Accurate ages were determined for 34 faster growing trees with more open and distinct ring structure.

With accurate ages and diameters for 34 of the cored trees, regression analysis using an inverse transformation yielded a coefficient of determination (r^2) of 0.61. The intercept and slope of the regression were 0.007366 and 0.096678, respectively. This relationship between tree age and tree diameter was a positive linear relationship.

Table 1. Growth patterns of seven native pecan bottomland communities in the Edwards Plateau of Texas. Data represent the size (hectares) of each bottomland in that corresponding year. Change refers to the increase or decrease in the bottomland from 1948 to 2004.

Year	Ellis Pecan	Harkey Pecan	Johnson Ranch	Way Ranch	Bovista Real Ranch	Texas Tech-Junction	South Llano River State Park
1948	13.75	17.10	8.86	6.63	22.54	6.96	100.17
1965	11.45	14.96	No Data	10.36	24.73	No Data	No Data
1996	11.60	15.97	8.36	10.78	23.03	6.60	112.67
2004	14.66	15.77	7.25	14.35	19.32	5.62	115.66
Change	0.91	-1.33	-1.61	7.72	-3.71	-1.34	5.49

Table 2. Current demographics of seven native pecan bottomland communities in the Edwards Plateau of Texas. Mean diameter represents diameter-at-breast height, mean stand age represents the overall age of each bottomland, and sample size is the number of trees measured for dbh within each bottomland.

	Llano State Park	Ellis Pecan	Harkey Pecan	Johnson Ranch	Way Ranch	Bovista Real Ranch	Texas Tech-Junction	South River
Mean Diameter (m)	0.572	0.577	0.353	0.315	0.472	0.462	0.457
Mean Stand Age	85	85	66	64	76	75	75
Sample Size (# of trees)	340	226	136	553	598	219	602

Vegetative Characteristics

Pecan tree density per site ranged from 22 to 86 trees per ha ($\bar{x}$ =52, SE = 8.51). The highest density was at Way Ranch along the Blanco River. The lowest density occurred at Harkey Pecan along the San Saba River (Table 3). The total number of trees per site ranged from 182 (Johnson Ranch-San Saba River) to 7,229 (South Llano River State Park-South Llano River). Pecan canopy cover among the sites was relatively open and ranged from 19.4% to 49.6% ($\bar{x}$ = 38.2, SE = 7.52). Percent canopy cover was higher among the five study sites that were not harvested for commercial use. However, the percent composition of grasses and forbs stayed consistent among all seven study sites (Table 3). Five of the seven study sites were mowed and shredded, which gave the bottomland the appearance of a “city park”. These five sites were dominated by grasses and forbs on the forest floor and the understory absent or minimal (Table 3).

Deer Densities

The mean deer density including all sites was $\bar{x}$ = 1.65 ha per deer, SE = 0.639 and ranging from 4.09 ha per deer to 0.109 ha per deer. The deer density at each site was as follows: Ellis Pecan Farms 0.874 ha/deer; Harkey Pecan Farms 2.574 ha/deer; Johnson Ranch 4.091 ha/deer; Way Ranch 3.468 ha/deer; Bovista Real Ranch 0.247 ha/deer; Texas Tech University-Junction Center 0.109 ha/deer; and South Llano River State Park 0.210 ha/deer. Johnson Ranch had the lowest density and few native pecan saplings were observed within the bottomland. The density was lower at this study site because there was no active deer management occurring and most of the land outside the bottomland was plowed and unplanted. Hunting was allowed at this site and adjoining properties.

Texas Tech University-Junction Center had the highest deer density. There were no saplings observed and hunting was restricted. This site was dominated by large mature pecan trees with a lack of diversity in age and size.

Table 3. Summary of vegetation surveys conducted at seven native pecan bottomlands in the Edwards Plateau of Texas. (Daubenmire Results = % of Grass, Forbs, Bare Ground, Leaf Litter)

Llano State Park	Ellis Pecan	Harkey Pecan	Johnson Ranch	Way Ranch	Bovista Real Ranch	Texas Tech-Junction	South River
Total # Trees	709	348	182	1,234	1,160	337	7,229
Density: Trees per 1 ha	85	85	66	64	76	75	75
% Canopy Cover (Pecan)	34.0	22.6	13.6	55.3	59.8	21.9	60.2
Daubenmire Results	50-40 5-5	70-25 20-5	50-20 25-5	60-30 5-5	75-10 25-0	50-10 40-0	75-5 5-15
# Transects	6	7	6	5	5	5	8
# Frames	36	42	30	23	30	30	48

Computer-based Conceptual Modeling

This conceptual model (Fig. 4) identifies several factors that I think are affecting both recruitment and mortality of these bottomlands. Factors affecting recruitment include planting of nuts and removal of nuts by both humans and wildlife. Factors affecting mortality include; land-use management, deer herbivory, disease, insects, and mortality rate.

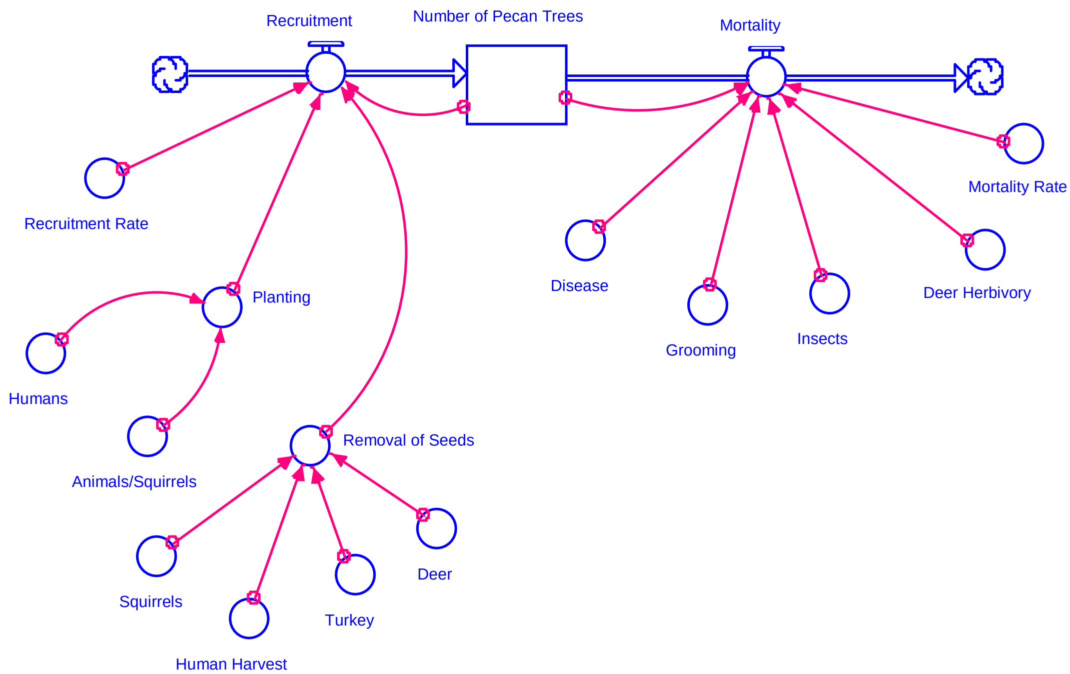

Figure 4. Diagram of the conceptual model identifying factors affecting native pecan bottomland communities. This conceptual model was developed using the computer program STELLA (ISEE Systems, Lebanon, NH).

CHAPTER V

DISCUSSION

Populations of native pecan trees occupying bottomland environments within the Edwards Plateau lack diversity in size and age classes. These bottomlands are dominated by older and larger trees. The results of my study predict that the state of native pecan bottomlands is not at a critical point of decline because the change in size (hectares) of all seven sites was minimal and indicates these bottomlands are relatively stable. However, a lack of seedling recruitment will fail to maintain the bottomlands as mature pecan trees senesce and die. As older trees senesce, this will result in a decreased overall size of the bottomland, which in turn has the potential to affect various wildlife species and alter the spatial and ecological dynamics of this landscape. Based on the results of my study, I predict these bottomlands will start to decrease dramatically in size in approximately 40 years. This prediction is based on age distributions and the current demographics of each bottomland.

The plant community of these bottomlands is currently dominated by an overstory of mature pecan trees with very little woody understory. At ground level, the community is dominated by a dense mat of herbaceous vegetation, primarily grasses. This current community is probably the result of an interaction between white-tailed deer herbivory on woody understory species (including immature pecan). With an emergence of grasses because of limited competition with the saplings of woody plants, this interaction has progressed rapidly with the increase in deer populations over the last 60 years. Prior to this study, no baseline data existed on the historical composition of these bottomlands in the Edwards Plateau. I suggest using the current vegetative composition of the unharvested and natural bottomlands of this study as a semblance of what previously existed prior to human disturbance and increased deer herbivory because of a more diverse age and size structure.

Deer herbivory has been shown as a cause of reduction in hardwood recruitment (Russell 1999). The absence of pecan seedlings in my study indicates that no seedlings or young saplings are surviving deer herbivory. The overabundance of deer populations may be a limiting factor in pecan seedling recruitment. The presence of livestock within these bottomlands may also limit recruitment. Since deer intensively select plants, such as native pecan (Tilghman 1987), the amount of the plant population remaining in the bottomland community will depend upon its fitness, which is a function of survival and fecundity (Russell 1999). All above ground biomass of pecan seedlings is susceptible to herbivory. The results of my study predict that the overabundance of deer most likely reduces recruitment of native pecan seedlings by altering plant morphology and decreasing growth rates of native pecan bottomland communities. This same limiting factor has been documented in Texas oak seedling recruitment (Russell 1999). This indicates the frequency and intensity of herbivory on the survival of this population. The absence of pecan seedlings indicates that no seedlings are surviving deer herbivory to become saplings or adult trees. The absence of saplings will significantly affect the rate of succession within these communities (Russell 1999). A change in succession (mesquite or cedar encroachment) might alter the species makeup of these bottomland communities to a less desirable or invasive species.

Land-use management strategies within these native pecan bottomlands must change. The mowing and shredding operations in these bottomlands might also prevent seedling recruitment. Several factors have been identified that are affecting these bottomlands. The planting of seeds by humans or animals (squirrels) increase recruitment. However, the removal of seeds by humans (commercial harvest) or animals (squirrels, turkey, or deer) might decrease the potential for recruitment. The mowing or shredding of these bottomlands for commercial harvest could significantly increases mortality of native pecan saplings. Bottomlands that are exposed to these operations are less diverse in their size and age classes (Rickey Jones, personnel observation). Reducing or halting these operations will potentially allow seedling recruitment. However, reducing or halting these operations is not economically viable for the landowners that rely on harvesting of these bottomlands for financial stability. So, in order to increase recruitment rate within these bottomlands, a give and take relationships must be developed to balance out the biological and economical significance.

MANAGEMENT IMPLICATIONS AND FURTHER STUDY

Russell (1999) argued that the effect of an overabundance of deer on vegetation is probably the cause of reduction in hardwood recruitment, which is not a recurring pattern that fluctuates dynamically but will be lasting unless deer densities are reduced. Given the deer densities within the Edwards Plateau, it is recommended that these deer densities be reduced through intensive hunting so that seedling recruitment can occur within these native pecan bottomland communities. The goal of deer removal would be to promote stability in the ecosystem (Russell 1999). Further studies are recommended to look into the future status of these bottomlands. This could be done through exclosures studies that could look at seedling recruitment rates in the absence of deer. Exclosures would prevent deer herbivory, which in turn would allow seedlings to become saplings and then mature trees. Another recommended study would be an extensive modeling program to try and predict the fate of these native pecan bottomland communities given different management regimes. The conceptual model developed in this study could be used as a baseline model in a more extensive modeling study. Finally, this study documents the baseline ecological dynamics of native pecan bottomlands that can serve as the foundation for future studies regarding this economically and biologically important community.

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APPENDIX I

Maps of the seven study sites and pecan bottomland communities in the Edwards Plateau of Texas

Map of Bovista Real Ranch located along the Frio River in Real County, Texas.
GPS Coordinates (29^{o} 48’ 08.35”N 99^{o} 46’ 20.16”W)

Map of Ellis Pecan Farms located along the San Saba River in San Saba County, Texas.
GPS Coordinates (31^{o} 11’ 10.55”N 98^{o} 54’ 21.67”W)

Map of Harkey Pecan Farms located along the San Saba River in San Saba County, Texas.
GPS Coordinates (31^{o} 12’ 31.78”N 98^{o} 48’ 53.38”W)

Map of Johnson Ranch located along the San Saba River in San Saba County, Texas. GPS Coordinates (31^{o} 13’ 24.42”N 98^{o} 39’ 38.32”W)

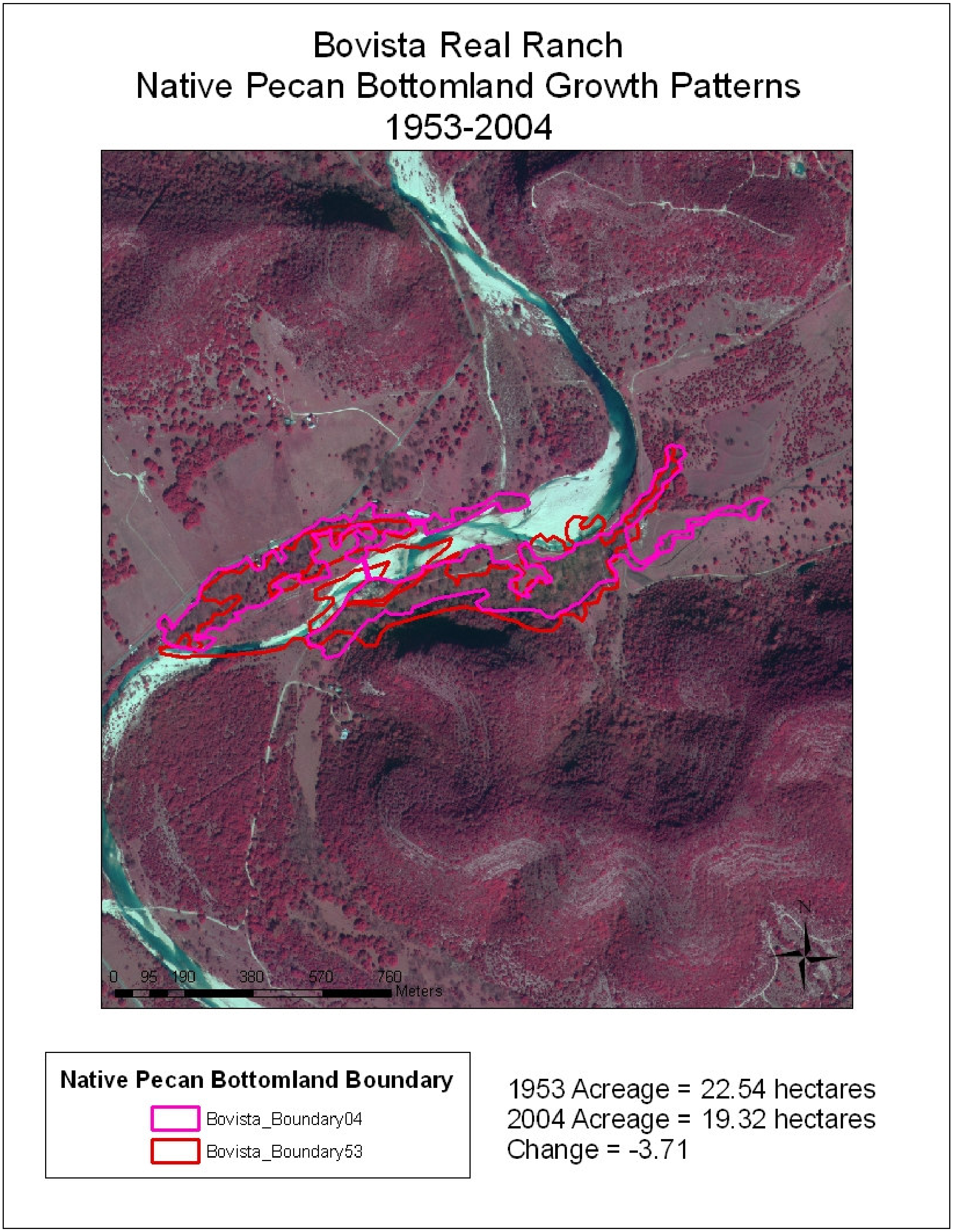
Map of South Llano River State Park located along the South Llano River in Kimble County, Texas.
GPS Coordinates (30^{o} 26’ 44.42”N 99^{o} 48’ 15.32”W)

Map of the Texas Tech University-Junction Center located along the South Llano River in Kimble County, Texas.
GPS Coordinates (30° 28’ 18.99”N 99° 46’ 50.28”W)

Map of Way Ranch located along the Blanco River in Hays County, Texas.
GPS Coordinates (30^{o} 00’ 36.43” N 97^{o} 58’ 01.81”W)

APPENDIX II

GIS maps depicting the growth patterns over the last sixty years of seven native pecan bottomland communities in the Edwards Plateau of Texas.


Bovista Real Ranch
Native Pecan Bottomland Growth Patterns
1953-2004
0 95 190 380 570 760
Meters
N
Native Pecan Bottomland Boundary
Bovista_Boundary04
Bovista_Boundary53
1953 Acreage = 22.54 hectares
2004 Acreage = 19.32 hectares
Change = -3.71

Ellis Pecan Farms
Native Pecan Bottomland Growth Patterns
1948-2004

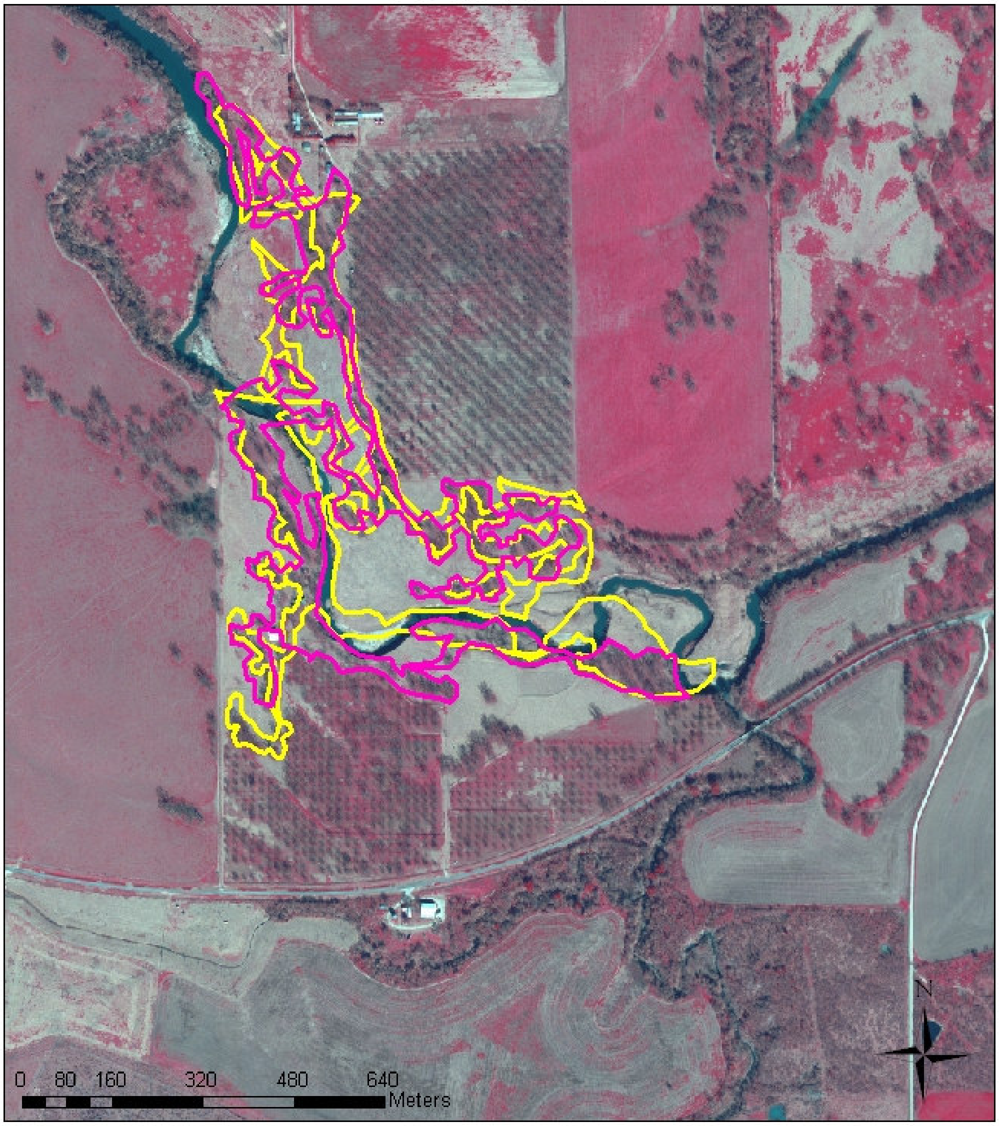
Native Pecan Bottomland Boundary

Ellis_PecanBoundary1948

Ellis_PecanBoundary2004_Shapefile

1948 Acreage = 13.75 hectares
2004 Acreage = 14.66 hectares
Change = 0.91

Harkey Pecan Farms
Native Pecan Bottomland Growth Patterns
1948-2004



Native Pecan Bottomland Boundary

- Harkey_Boundary04
- Harkey_Boundary48

1948 Acreage = 17.10 hectares
2004 Acreage = 15.77 hectares
Change = -1.33

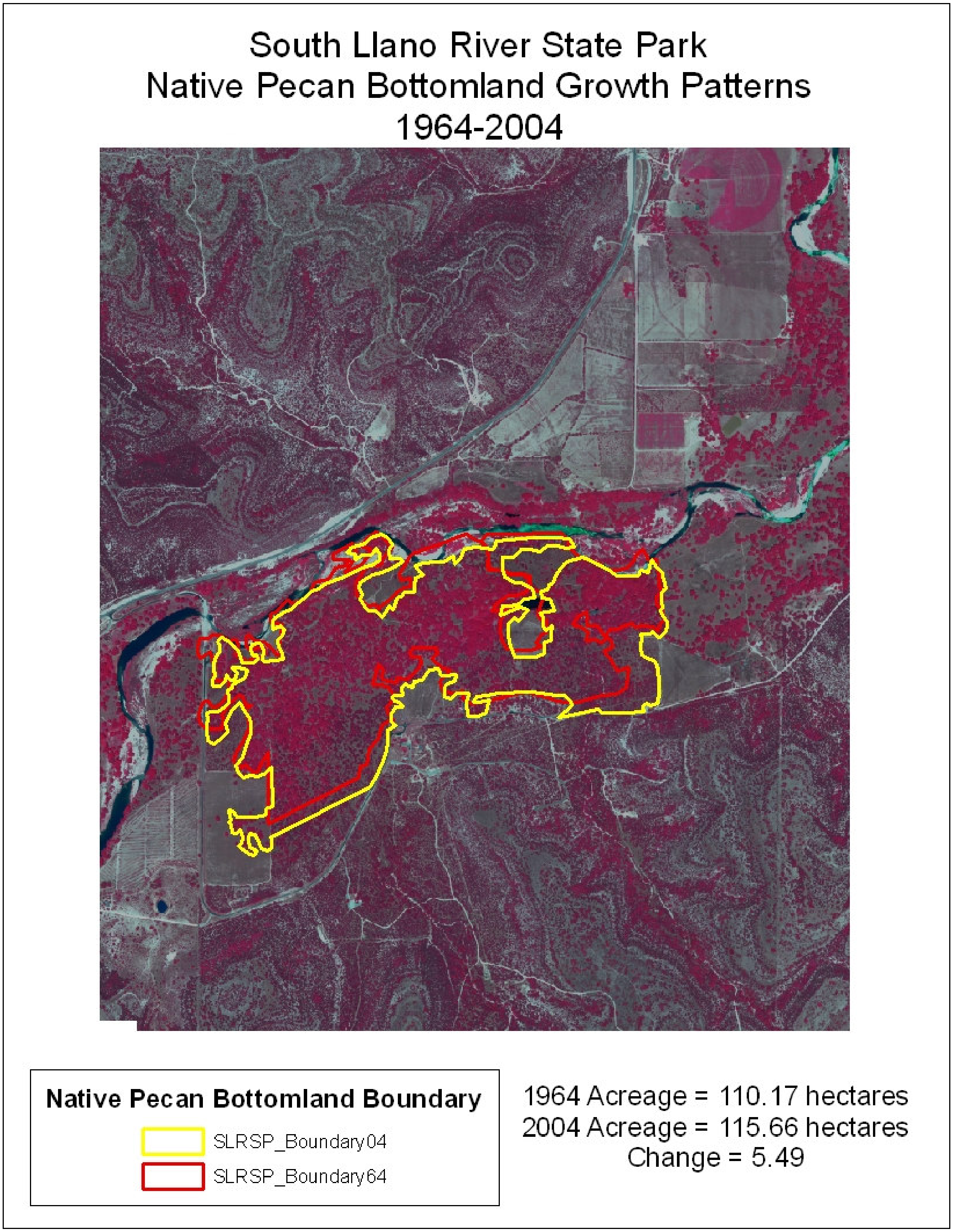
Johnson Ranch
Native Pecan Bottomland Growth Patterns
1948-2004

Native Pecan Bottomland Boundary

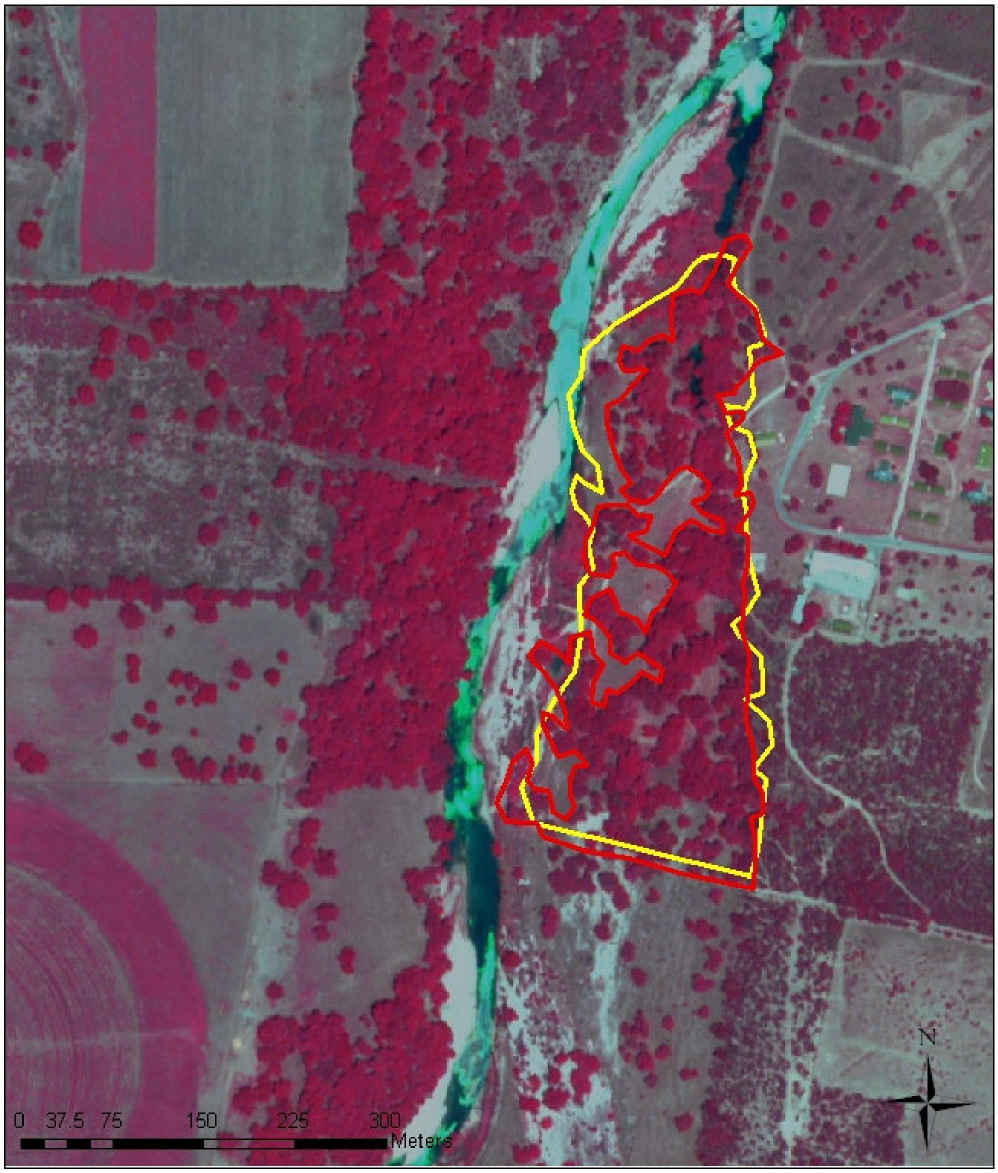
Johnson_Boundary04

Johnson_Boundary48

1948 Acreage = 8.86 hectares
2004 Acreage = 7.25 hectares
Change = -1.61


South Llano River State Park
Native Pecan Bottomland Growth Patterns
1964-2004
Native Pecan Bottomland Boundary
SLRSP_Boundary04
SLRSP_Boundary64
1964 Acreage = 110.17 hectares
2004 Acreage = 115.66 hectares
Change = 5.49

Texas Tech University-Junction
Native Pecan Bottomland Growth Patterns
1955-2004

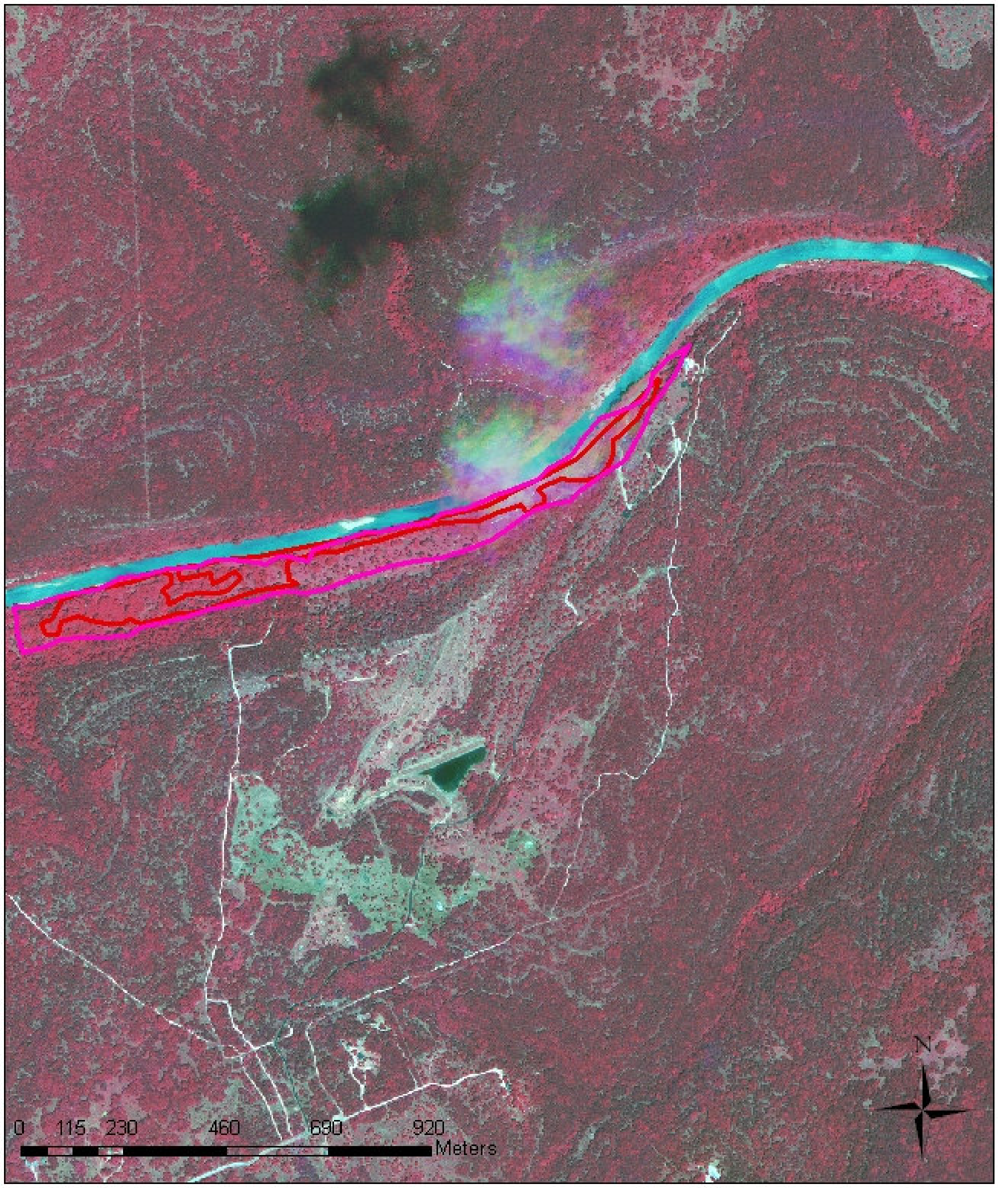


Native Pecan Bottomland Boundary

TTJunction_Boundary04
TTUJunction_Boundary55

1955 Acreage = 6.96 hectares
2004 Acreage = 5.62 hectares
Change = -1.34

Way Ranch
Native Pecan Bottomland Growth Patterns
1958-2004



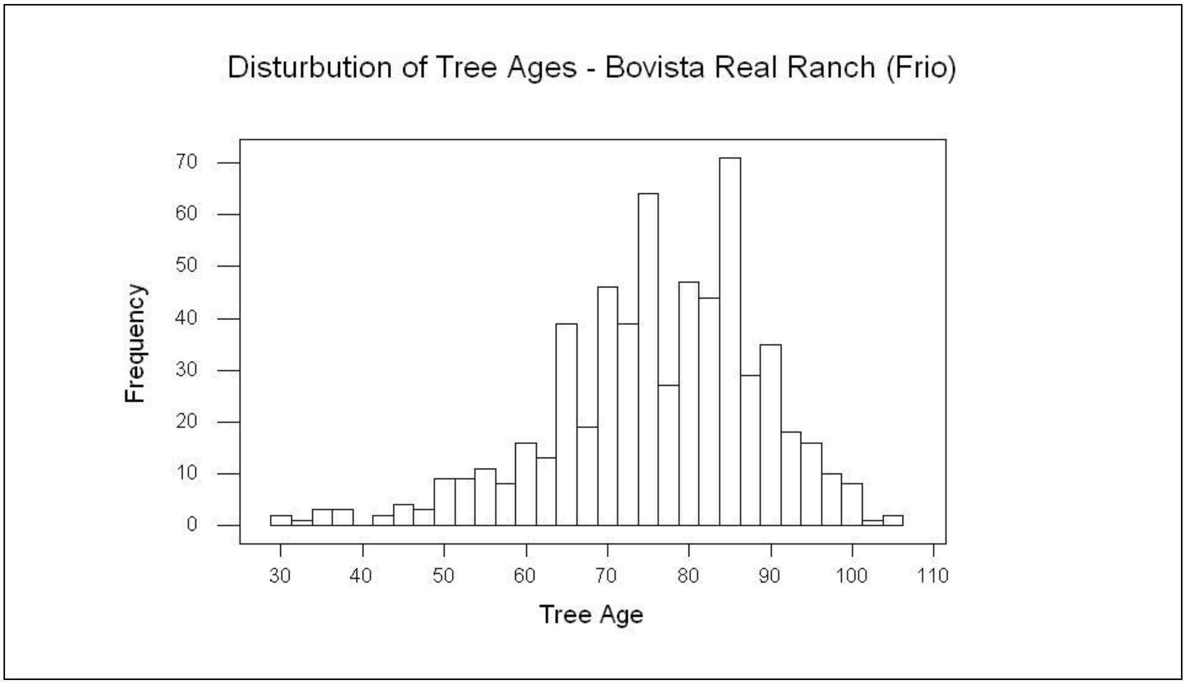
Native Pecan Bottomland Boundary

Way_Boundary04
Way_Boundary58

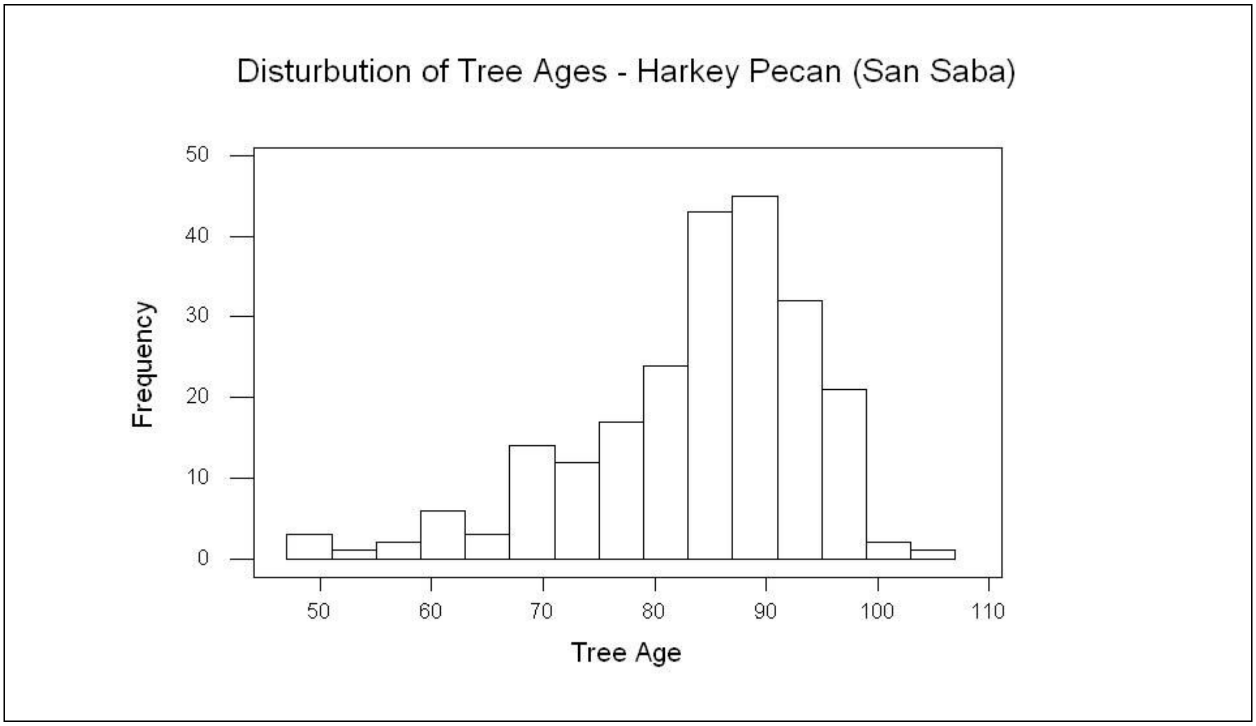
1958 Acreage = 6.63 hectares
2004 Acreage = 14.35 hectares
Change = 7.72

APPENDIX III

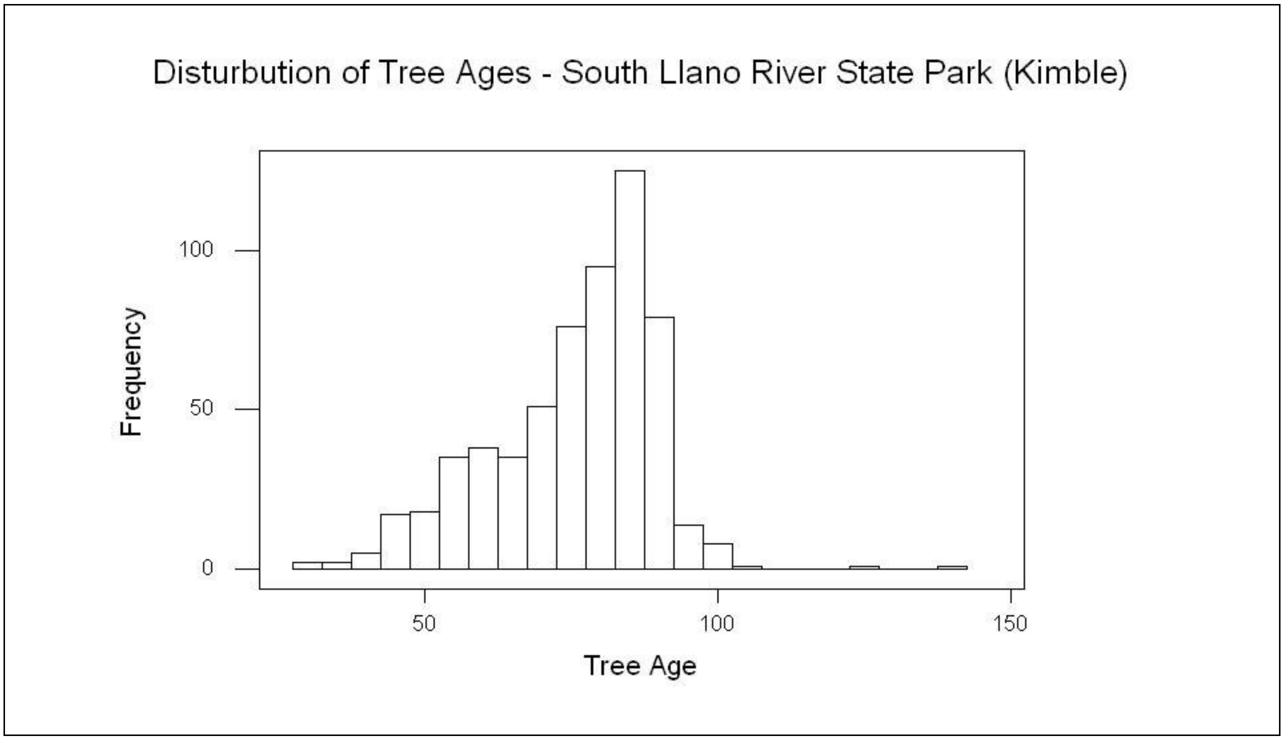
Age distubution histograms for each of the seven native pecan bottomland communities occurring in the Edwards Plateau of Texas.

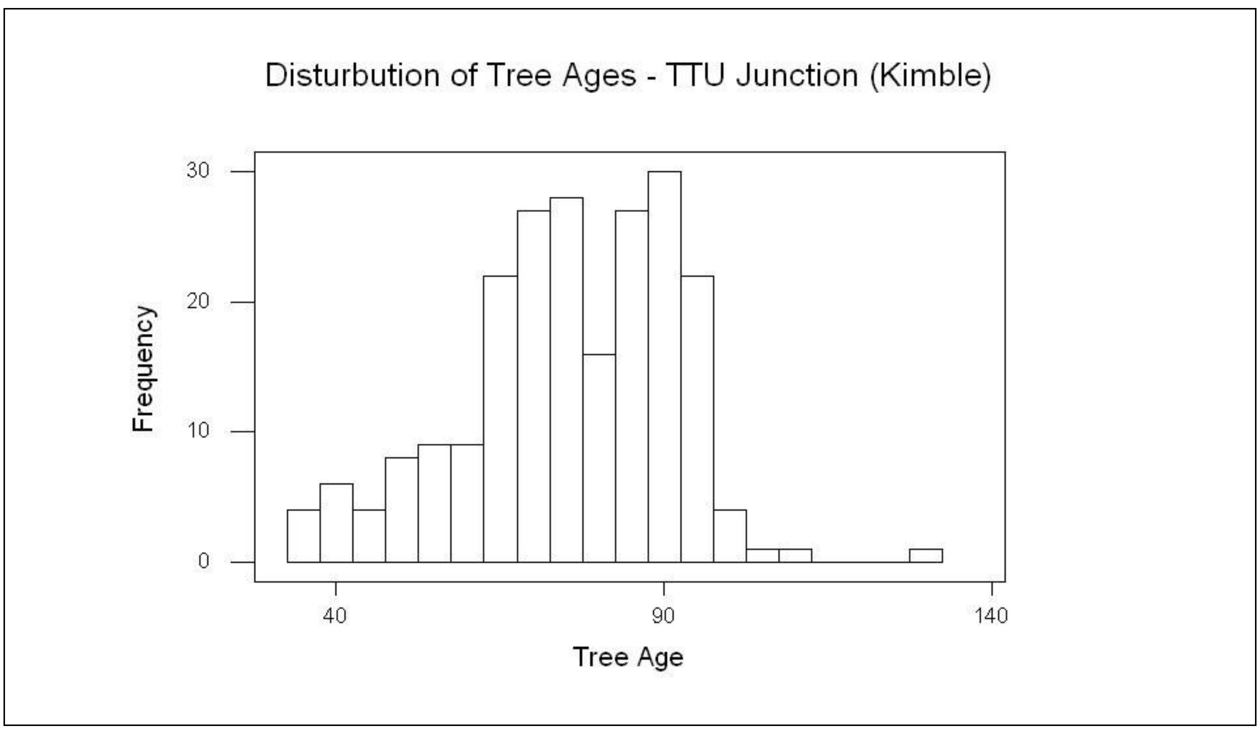

Disturbution of Tree Ages - Bovista Real Ranch (Frio)
Frequency
0
10
20
30
40
50
60
70
30
40
50
60
70
80
90
100
110
Tree Age

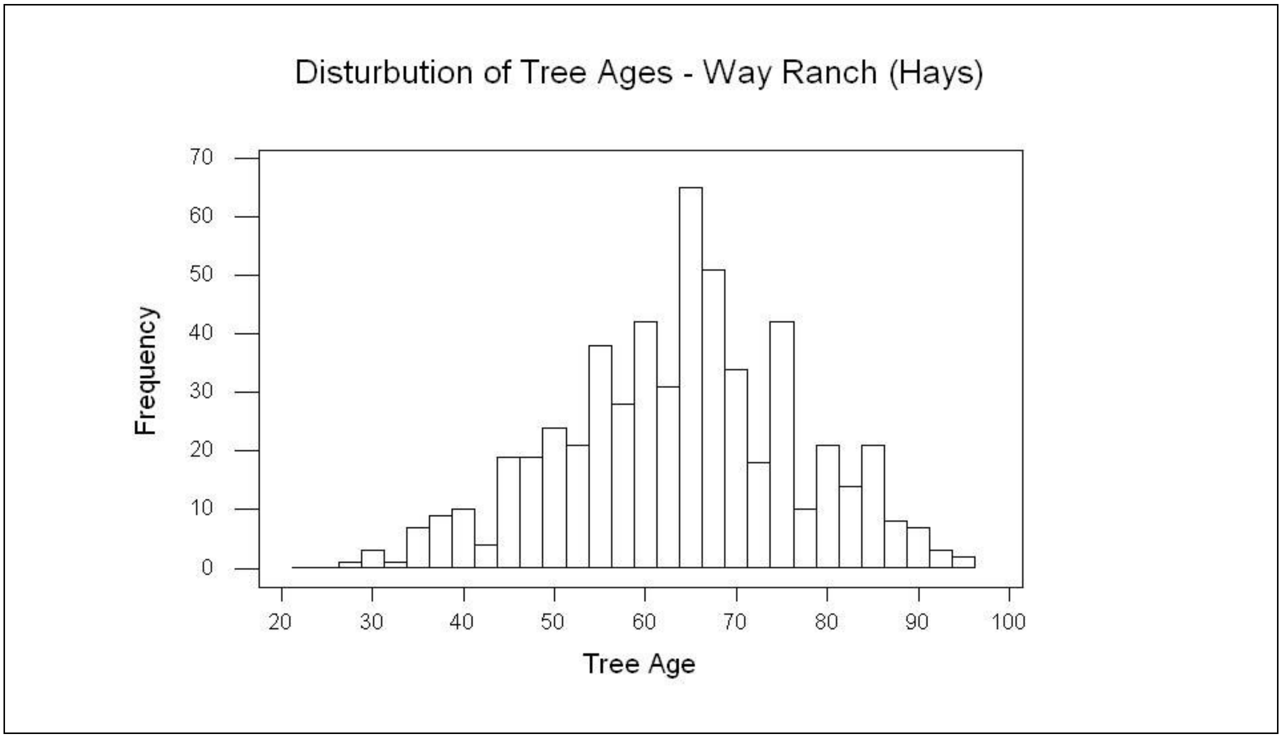

Disturbution of Tree Ages - Ellis Pecan (San Saba)
Frequency
0
10
20
30
40
50
60
70
80
90
50
100
150
Tree Age


Disturbution of Tree Ages - Harkey Pecan (San Saba)
Frequency
Tree Age
0
10
20
30
40
50
50
60
70
80
90
100
110


Disturbution of Tree Ages - Johnson Ranch (San Saba)
Frequency
Tree Age
0
5
10
15
0
50
100


Disturbution of Tree Ages - South Llano River State Park (Kimble)
Frequency
100
50
0
50
100
150
Tree Age


Disturbution of Tree Ages - TTU Junction (Kimble)
Frequency
30
20
10
0
40
90
140
Tree Age


Disturbution of Tree Ages - Way Ranch (Hays)
Frequency
70
60
50
40
30
20
10
0
20
30
40
50
60
70
80
90
100
Tree Age

VITA

Rickey Jones was born in 1981 in La Junta, Colorado. He graduated from Wiley High School in 2000. During high school, Rickey was accepted to the University of Northern Colorado in Greeley. He attended the university from 2000 to 2003 and was awarded a Bachelor of Science degree with a major in Organismal Biology. After graduation, Rickey began his career as a biologist with Kleinfelder, Inc., a consulting firm located in Colorado Springs, Colorado that specialized in natural resources planning and permitting. He worked on a diverse range of projects from writing Comprehensive Conservation Plans for the United States Fish and Wildlife Service conducting surveys on threatened and endangered species, writing environmental impact statements, and compiling environmental assessments for the National Park Service. Rickey left Kleinfelder in 2006 to pursue a Master of Science degree at Texas State University-San Marcos where he served as a research assistant for Dr. Thomas R. Simpson.

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