COMPARING THE STRUCTURE AND COMPOSITION OF RIPARIAN WOODLANDS IN THREE NORTHEAST KANSAS LAKE WATERSHEDS

by

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Abstract

Riparian forests are more effective than other land cover types at stabilizing stream banks during high water events. Tree trunks and roots can slow flood-waters, thus retaining sediment deposition within riparian areas instead of downstream in reservoirs. This project is part of a larger, multi-agency study on reducing sedimentation of federal reservoirs. Between August 2010 and May 2012, riparian forests were assessed in the watersheds of three northeast Kansas lakes: Atchison County, Banner Creek, and Centralia City. The predominant land use in those watersheds is agricultural, with Atchison and Centralia watersheds dominated by cropland and Banner dominated by grassland. Plot dimensions were 50ft by 30ft (1500 ft^2) measured from the top of the streambank outward to the extent of the predetermined active channel width (ACW). Forty-four plots were assessed across the three watersheds. Data collected in each plot were used to determine the basal area (BA) in ft^2 per acre, trees per acre (TPA), tree height by crown class, and quadratic mean diameter (QMD) by species. Results showed some trends in BA and TPA among the three watersheds, however differences were not significant. The average BA of trees in riparian woodlands in the Centralia watershed was 155 ft^2 (dominated by cottonwood (*Populus deltoides)* with some honeylocust (*Gleditsia triacanthos*)); the Atchison and Banner watersheds showed an average BA of 120 ft^2. The Atchison watershed was dominated by honeylocust and walnut (*Juglans nigra*) but the Banner watershed was dominated by bur oak (*Quercus macrocarpa*) and hackberry (*Celtis occidentalis*). However, the Atchison watershed had the most TPA (194), as well as the tallest trees of the three watersheds. The Atchison watershed had the highest QMD in oak, whereas the Banner and Centralia watersheds had the highest QMD in cottonwood. Banner watershed had more plots with seedlings, whereas Atchison watershed had more plots with saplings. Overall, forest regeneration primarily comprised hackberry seedlings and saplings, with hickory saplings more common in the Banner watershed. For each watershed, the composition and structure of riparian vegetation differed but not significantly.

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Dedication

To my great husband David Gonzales, my grandparents Juan Maradiaga and Ruperta Amador, my parents Eduardo Martinez and Amanda Rodriguez, and my sisters Paty, Katterin, Meylin, and Iris.

Chapter 1 - Introduction

The State of Kansas has a large number of large and small reservoirs and lakes built for multiple purposes. Unlike lakes that form as a result of geologic processes such as glacial melting or scouring, reservoirs are man-made, transforming part of a flowing water body (lentic) into a still water body (lotic) by construction of a dam to hold back the water. Generally, reservoirs are built in areas with few natural lakes; a typical characteristic of these areas is the highly erodible soils that are easily disturbed by human activities (Baker and deNoyelles 2008).

According to Putnam and Pope (2003) and Juracek (2008) most of the reservoirs and small watershed lakes in Kansas were created as a response to the Flood Control Act of 1944 (PL78-534) and the Watershed Protection and Flood Prevention Act of 1953 (PL83-566). Reservoirs are not only necessary for flood control and prevention but also for water supply for human uses, habitat for aquatic life, and navigation supplementation. Federal reservoirs provide a source of drinking water for more than ⅔ of the Kansas population; in addition, they serve as recreation areas and habitat for aquatic life while providing a reserve to supplement streamflow, enhancing water quality (Streeter 2008). As Hargrove (2008) has noted, reservoirs built by the U.S. Army Corps of Engineers and the Bureau of Reclamation have an expected lifetime of 150 to 200 years. However, recent studies have shown that they will not meet even the 150 years of life expectancy. Streeter (2008, p. 3) stated that "by their nature, reservoirs act as settling basins; they gradually fill with sediment, which reduces their capacity to store water to meet our needs." In Kansas and all over the United States, the issue of sedimentation in streams and lakes is of vital importance not only because sedimentation affects water quality, which is significant to human and aquatic life, but also because it affects the reservoir water storage capacity (Juracek and Ziegler 2007).

This report is part of the Sediment Baseline Study Group led by the Kansas Water Office (KWO), aimed at reducing sedimentation of federal reservoirs. The report presents findings of the riparian forest assessments conducted in three northeast Kansas lake watersheds: Atchison County, Banner Creek, and Centralia City Lake (Figure 1.1). This study focused on these watersheds because previous studies have shown a wide range of sedimentation in these areas, coming from both streambank erosion and surface-soil erosion (KWO 2009).

Atchison County Lake

Atchison County Lake is in northeast Kansas, 3 miles north and 2 miles west of Atchison, Kansas. The lake structure was built in 1956, with an earthen dam on a tributary of Independence Creek in Atchison County (KWO 2010a). The Kansas Department of Wildlife, Parks, and Tourism owns and controls the lake, which is used primarily for recreation. In 2009, the reservoir had a total volume of 178.6 acre-feet and a maximum depth of 6.8 feet (KWO 2010a). Of the three watersheds studied, Atchison County Lake is the smallest (Figure 1.2). It has an estimated drainage area of about 9.3 mi^2 (about 24 km^2), mostly in Atchison County. Land use in the county is primarily agricultural. Juracek and Ziegler (2009; after Kansas Applied Remote Sensing Program 1993) reported that from 1988 to 1990, cropland represented the highest percentage (75.6%) land use, followed by grassland (21.9%), while water was 1.4%, and only 1% of land was in woodland.

Sedimentation issues require understanding the sediment contribution in each watershed, so the percentage of a basin in cropland or grassland is important. The amount of sediment contributed by cropland to a stream or reservoir depends on soil type, slope, tillage practices, crop type, precipitation, and distance to the stream channel (Juracek and Ziegler 2009). Many studies note that streambanks act as main sediment source. For Atchison County Lake, both channel bank and surface soil serve as sources of sediment deposited within the lake, with sediment from surface-soil contributing the most (Juracek and Ziegler 2007). A bathymetric study done in 2010 by KWO (2010a) reported that silt percentages were highest (70%) at the inflow end and lowest (12%) at the dam end.

Banner Creek Lake

Banner Creek Lake is the largest of the three watersheds studied and lies approximately 1½ miles west of Holton, Kansas. Its construction was completed in 1997 and provides water for Holton as well as Jackson County. In addition, it serves as a recreational center for northeast Kansas. In 2009, the reservoir had a total volume of 7395 acre-feet and a maximum depth of 36.6 feet (KWO 2010b). Banner Creek Lake watershed comprises a total area of 19 mi^2 (about 49 km^2) within the Jackson County (Figure 1.3). Unlike the Atchison County Lake watershed, from 1988 to 1990, grassland represented the main land use (75.6%) for this watershed while cropland represented 12.5%, water 4.5%, and woodland 7.4% of the basin area (Juracek and Ziegler 2009; after Kansas Applied Remote Sensing Program 1993).

A study by the Gulf South Research Corporation [GSRC] and The Watershed Institute [TWI] (2010) used fluvial geomorphology surveys in six locations, including stream segments of Atchison County Lake, Banner Creek Lake, and Centralia City Lake watersheds, reporting that of the three watersheds studied, Banner Creek Lake had the highest predicted stream sediment erosion rate (0.45 tn/ft/yr) while Centralia had the lowest erosion rate (0.05 tn/ft/yr). Juracek and Ziegler (2007) reported that the channel banks as well as surface soil are sources of sediment transported to and deposited in Banner Creek Lake. However, increasing sedimentation comes from human activities such as cropping, grazing, livestock operations, urbanization, and erosion of stream beds and channels (Devlin and Barnes 2008).

Centralia City Lake

Centralia City Lake is 2 miles south and 1 mile west of Centralia, Kansas. Its structure was completed in 1991 and has since been managed by the City of Centralia (KWO 2010c). KWO (2010c) indicated that, in 2009, the lake had a volume of 4000 acre-feet and a maximum depth of 27.4 feet. The Centralia City Lake watershed is 63% of the size of the Banner Creek Lake watershed (Figure 1.4). The Centralia Lake basin covers 12 mi^2 (about 31 km^2) of Nemaha County. According to GSRC and TWI (2010), 80% of the Centralia Lake basin is in cropland.

The Centralia City Lake provides recreational activities like boating and fishing; however, bathymetric results have shown that silt percentages are very high (KWO 2010c). In addition, of the three lakes, Centralia City Lake had the highest concentration of chlorophyll-a and higher values of phosphorous and total nitrogen as compared to Banner Creek Lake (GSRC and TWI 2010).

Importance of the Study

Since the mid 1970s, evaluating vegetative cover in riparian areas has become more important; much research has been published in an effort to better understand the composition and structure of vegetation on these areas, as well as the environmental and economic value they provide (Winward, 2000). Management and policy decisions require knowledge of the structure and composition of riparian vegetation, not just in Kansas but elsewhere, before damage to such systems becomes irreversible. Understanding the role of vegetation in riparian areas should help in maintaining healthy streams and watersheds.

Plants are important in the food chain, but they are also important in stabilizing streambanks, an issue of concern around the world because of sedimentation of streams and reservoirs. One objective of the Kansas Water Plan [KWP], developed by the KWO, is to decrease the sediment carried to reservoirs and other bodies of water because sediment can be detrimental to the quality and amount of water available for Kansas (Putnam and Pope 2003).

Riparian managers often use riparian vegetation strips to stabilize streambanks (Simon 2002), which increases the strength of bank sediments, improving bank resistance by decreasing pore water pressure and fortifying the bank with roots. Roots can enhance soil strength, especially where slopes are not stable, including those related to streambank steadiness (Abernethy 2001). We do not know enough about how plant roots improve bank material although much work in the United States and other countries like Australia has attempted to document the effect of roots in stabilizing streambanks. Research into the root systems of two Australian riparian tree species, swamp paperbark (*Melaleuca ericifolia*) and river red gum (*Eucalyptus camaldulensis*) by Abernethy (2001) found that interspecies differences in the strength of living roots are less significant in bank reinforcement than interspecies differences in root distribution.

Streambank stability depends on the type of soil, climate, and land use management. Soils in these riparian areas form in sedimentary materials from a diversity of sources and parent rocks, so they differ greatly in texture, depth, degree of wetness, and rock fragment content (Myers 1987), making some streambanks more erosion resistant than others. During high water events, large masses of streambank may move as gravitational and hydraulic forces act within the channel and streambank. According to Pollen-Bankhead and Simon (2010; after Simon et al. 2000), these activated forces interact during a large rainfall event, making streambanks less stable through four mechanisms: a) infiltration of water into bank soil that increases the weight of the soil and increases the forces acting on the bank; b) loss of matric suction and cohesion, which thus reduces the resistant force of the bank; c) creation of positive pore-water pressures within the bank that reduce frictional strength of bank material making the bank less stable; and d) removal of the confining pressure of the water in the channel.

To date, although many strategies can prevent soil surface erosion and stabilize streambanks, riparian forests are more effective during high water events. They can slow flood waters through their roots and leaves, retaining sediment within riparian areas instead of downstream in reservoirs. Devlin et al. (2003) stated that establishing vegetative buffer strips – a moderately sloping area of vegetative cover that runoff water flows through before entering a stream – may reduce runoff by 50% when used as best management practices (BMP's) to reduce edge-of–field soil losses in conventionally tilled fields and soil losses in no-till fields.

Controlling soil and streambank erosion requires significant investments of money (Juracek and Ziegler 2009; after Pimentel et al. 1995; Shields et al. 1995; Morris and Fan 1998; and Tegtmeier and Duffy 2004). Such investments are necessary because sediment not only decreases the water quality of streams that serve as municipal water supplies but also reduces the storage capacity of reservoirs, limiting the water availability during drought. In addition, sedimentation is a threat to the health of some aquatic animals and plant species (Juracek 2010). Therefore, decreasing siltation will extend the lifespan of reservoirs, especially for water storage capacity, and decrease the rate of nutrients entering the reservoirs improving the water quality.

Objective of Research

As part of the sediment baseline study group led by the Kansas Water Office aimed at reducing sedimentation of Federal Reservoirs, the purpose of this research was to assess and compare riparian woodlands in the watersheds of three northeast Kansas lakes and develop a method to document the composition and condition of riparian forests within the State of Kansas, considering specifically:

a. Basal area (BA) in ft^2 per acre by species and by timber harvest potential
b. Trees per acre (TPA) by species and by timber harvest potential
c. Trees height by crown class
d. Quadratic mean diameter (QMD) in inches, and
e. Riparian forest regeneration (sapling and seedling TPA).

The Kansas Water Office chose these watersheds because they exhibited a high range of sedimentation rates. The riparian woodlands were compared to find possible reasons for the observed variation in rates, and to help inform a strategy to promote riparian forestry.

Figures and Tables

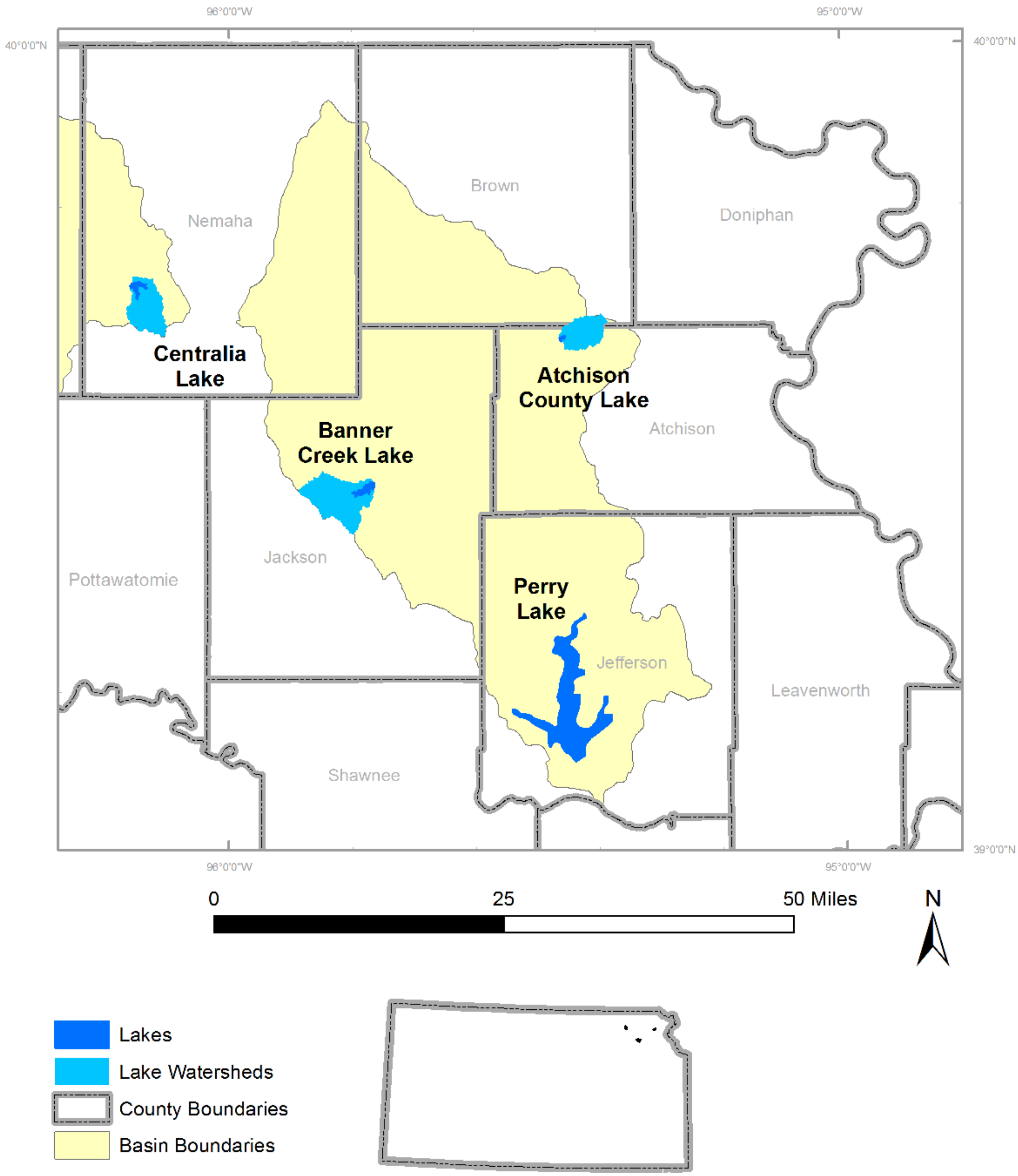

Figure 1.1 Watershed study sites.

Source: Jeff Neel 2012

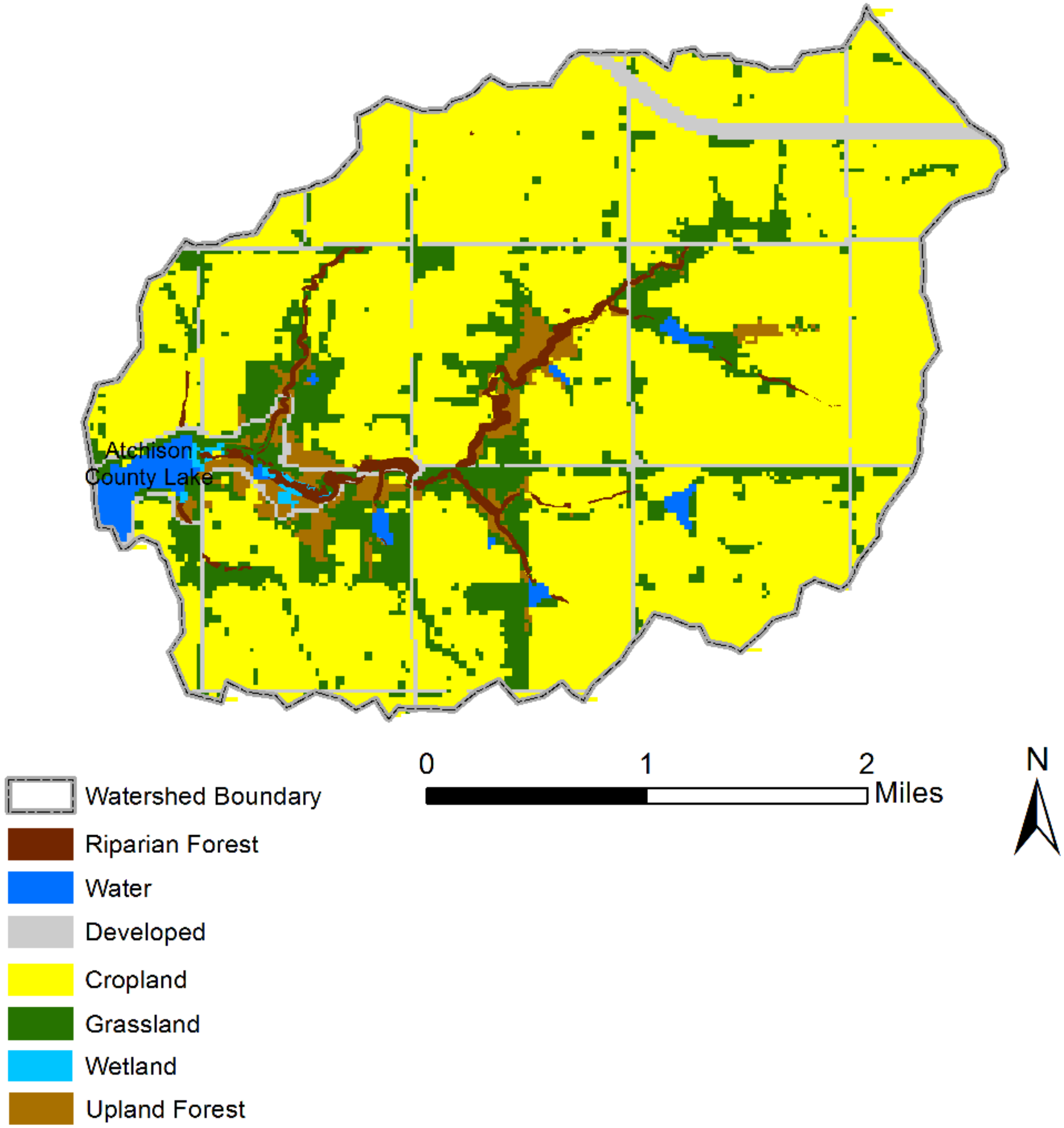

Figure 1.2 Land use in Atchison County Lake watershed.

Source: Jeff Neel 2012

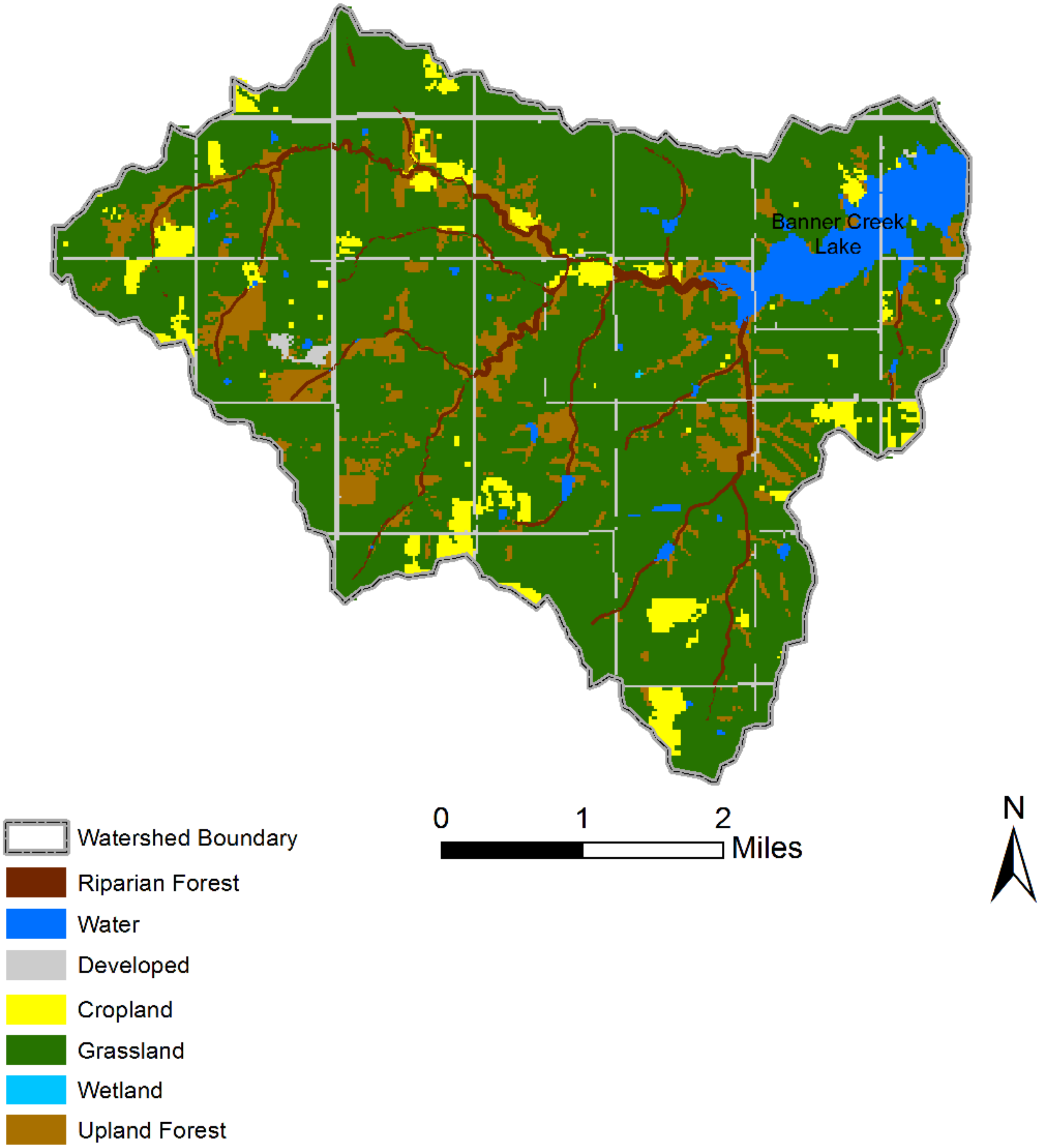

Figure 1.3 Land use in Banner Creek Lake watershed.

Source: Jeff Neel 2012

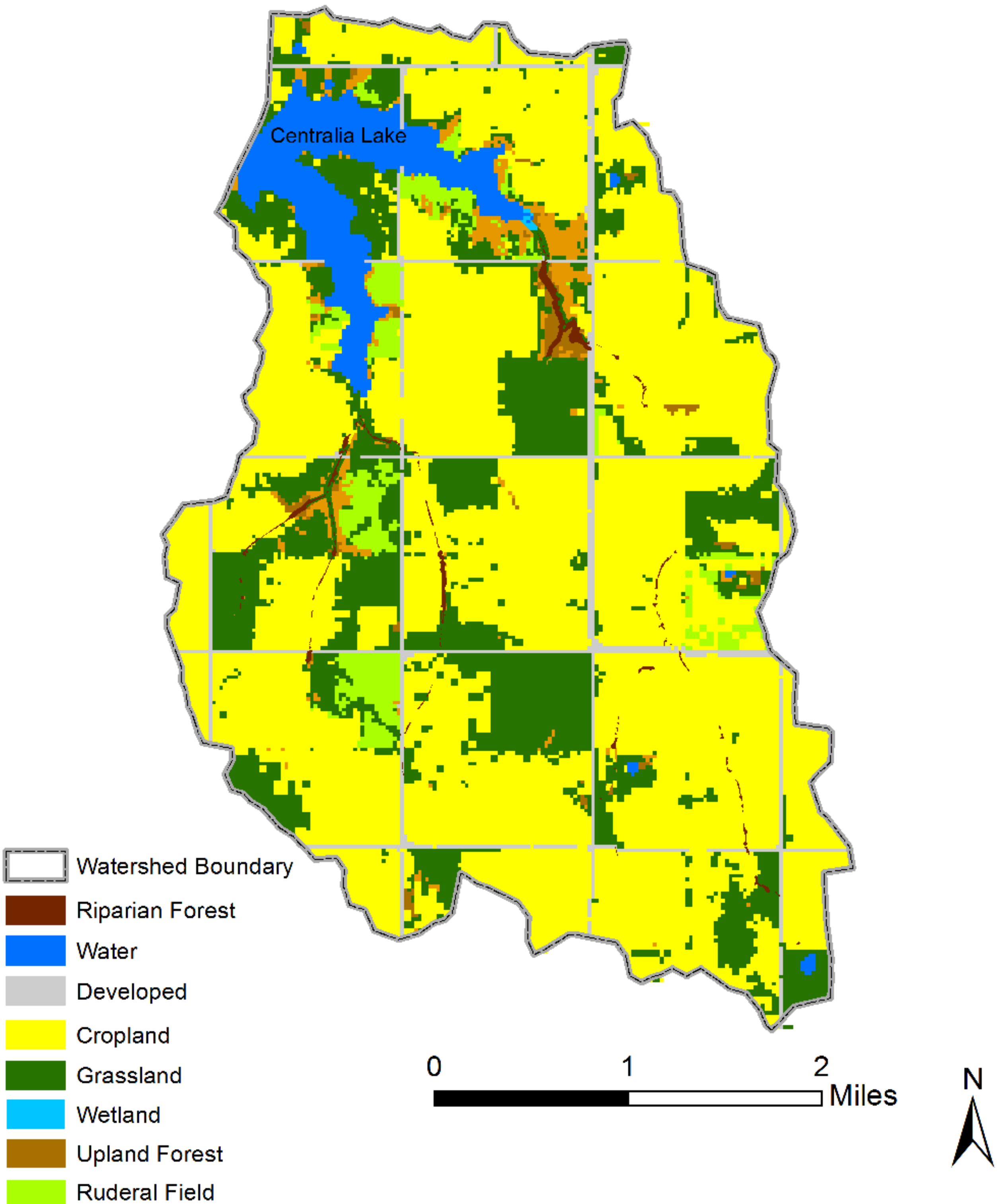

Figure 1.4 Land use in Centralia City Lake watershed.

Source: Jeff Neel 2012

Chapter 2 - Background

Elzinga et al. (1998 p.3) stated that “inventory can be described as a point-in-time measurement of the resource to determine location or condition.” Inventorying and monitoring riparian areas vegetation is not a new task for foresters, ecologists, botanists and other researchers in this area. In the past, significant effort has focused on inventorying, classifying, restoring, improving, and protecting riparian-wetland areas, but unfortunately, this effort has not been successful. To date, many management techniques have been developed in the U.S. to facilitate evaluating and monitoring natural resources in riparian-wetland areas. One of the main objectives of developing these tools is to restore and maintain resources in good condition, and therefore, available for future generations. For the development of this study the author adapted methods from three documents “Stream Visual Assessment Protocol Version 2 (USDA and NRCS 2009)”, “Riparian Proper Functioning Condition (Barrett et al. 1998)”, and “Monitoring the Vegetation Resources in Riparian Areas (Winward 2000).”

Stream Visual Assessment Protocol Version 2 (SVAP2)

The United States Department of Agriculture (USDA) and the Natural Resources Conservation Service (NRCS) designed the SVAP2 in 2009 to use in the field in assessing with the land owner the condition of riparian and aquatic ecosystems related to shallow, perennial, or intermittent streams. The evaluation involves scoring (from 0 to 10) sixteen elements of the stream and riparian area to determine the health of the stream, which is measured by its ability to recover from floods, fire, and drought (USDA and NRCS 2009; after Meyer 1997); classification of the stream according to location or ecological setting to accurately measure the effect of natural variation; and reference sites, which represent the conditions existing for a particular stream, with least impaired and most impaired reference sites. The elements scored are channel condition, hydrologic alteration, bank condition, riparian area quantity and quality, canopy cover, water appearance, nutrient enrichment, manure or human waste presence, pools, barriers to aquatic species movement, fish habitat complexity, aquatic invertebrate habitat, aquatic invertebrate community, riffle embeddedness, and salinity. For this study, the author has adapted the evaluation of riparian area quantity and quality and hydrologic alteration.

To assess riparian area quantity, SVAP2 rates the extent of riparian vegetation of the property. Assessment covers the area from the edge of the stream toward the outer edge of the forested area on both sides of the stream and takes the average of the two sides. The highest score is given when vegetation extends two or more bankfull widths and the lower score when it extends less than one-third of the bankfull width. For riparian area quality, the SVAP2 basically looks for the density and structure of the vegetation. It gives the highest score (9 or 10) to sites with dense, natural and diversified riparian woodland and no invasive species. A lower score (0 - 2) is given when little natural vegetation occurs and more than 50% of the vegetation consists of invasive species.

SVAP2 assesses the hydrologic alteration by considering the frequency of bankfull, overbank, and low flows. The maximum score involves natural flow regime, when the higher flow occurs every 1 to 2 years and when no water control structures are present. When bankfull rarely occurs, a lower score is assigned. To identify the frequency of these conditions, the operator examines the edge of the active channel, looking for type and age of vegetation present on channel bars, and marks of high water events on streambanks, trees, or rocks, or other indicators of high and low flow.

Riparian Proper Functioning Condition (PFC)

The manual for assessing Riparian Proper Functioning Condition (PFC) was developed in 1993 by the Bureau of Land Management (BLM), which manages about 269 million acres of public lands (Barrett 1998; after USDI 1992) used and protected for the benefit of future generations. These acres include riparian-wetland areas that are highly valuable resources. The BLM's manual defines riparian areas as a "form of wetland transition between permanently saturated wetlands and upland areas; that exhibit vegetation or physical characteristics reflective or permanent surface or subsurface water influence" (Barrett et al. 1998, p.7).

According to Barrett et al. (1998), three components interact constantly in a natural riparian-wetland area: vegetation, soil, and hydrology. Therefore, an interdisciplinary (ID) team must identify whether a riparian-wetland area is functioning properly. The BLM team classifies riparian-wetland area into 4 categories: a) proper functioning, b) functional-at risk, c) nonfunctional, and d) unknown. Riparian-wetland areas that function properly are characterized by the presence of appropriate vegetation, landform, and large woody debris, which help to dissipate stream energy during high water events. All these characteristics help reduce erosion and sediment deposition within the stream, enhance water quality, filter sediment, and develop a floodplain, which improves flood-water retention and ground water recharge, increasing vegetation and root mass for streambank stabilization and a diversity of habitats for aquatic life. A riparian-wetland area is functional-at risk when it is susceptible to degradation due to imbalance in existing soil, water, or vegetation. A riparian-wetland area is considered nonfunctional when it clearly lacks all that a functional riparian wetland will provide. Finally, unknown riparian-wetland areas are those that the BLM cannot determine because of lack of adequate information.

The BLM noted that to assess PFC, a clear understanding of the attributes and processes taking place in a riparian-wetland area is required. Those include attributes and processes in hydrogeomorphic, vegetation, erosion or deposition, soils, and water quality, as well as the capability and potential of the riparian-wetland area and the condition of the entire watershed.

Monitoring the Vegetation Resources in Riparian Areas

Alma Winward (2000) created a method to inventory and monitor riparian vegetation using three sampling procedures: Vegetation Cross Section Composition, Greenline Composition, and Woody Species Regeneration. The first procedure allows us to compute the contribution of each community type in a particular complex and indicate the level of disturbance in the complex. Winward (2000, p.3) defined Greenline as “the first perennial vegetation that forms a lineal grouping of community types on or near the water’s edge.” This method should provide information to complete the data collected in the first procedure. Vegetation available in the greenline area can indicate streambank stability during water events as well as the health of riparian area. Greenline sampling should be done within one riparian complex of at least 363 feet (lineal distance) on both sides of the stream. The woody species regeneration procedure involves measurements in the same transect as the greenline method. This method requires a 6 ft length. The vegetation (age class) in this last method is categorized as sprout, young, mature, decadent, and dead.

Chapter 3 - Materials and Methods

This chapter presents the materials and methods used to assess riparian woodlands in the watersheds of three northeast Kansas lakes. In each watershed, the drainage area differed. Atchison County Lake watershed had the smallest drainage area (9.3 mi^2), followed by Centralia City Lake (12 mi^2), and Banner Creek Lake (19 mi^2) watersheds. Due to this difference in drainage area, each watershed had a different number of sampling plots. A total of 12 plots were evaluated at Atchison County Lake, 18 plots were evaluated at Banner Creek Lake, and 14 plots at Centralia City Lake watershed.

The extent of riparian vegetation in these watersheds was quantified using Geographic Information System (GIS) by a contract with Blue Earth Consulting (Neel, 2012). GIS is a tool that has become useful in riparian vegetation mapping and management (Yang 2007; after Muller 1997; Narumalani et al. 1997; Congalton et al. 2002). The on-the ground data collection started in August 2010 and ended in May 2012. Photographs and maps from GIS were required before doing field work and conducting observations. The field work data and observations were used to strengthen the GIS data, as well as provide guidance for voluntary forestry programs and technical assistance for achieving the best water quality for the three lakes.

Sampling Design

Sites were selected using a representative sample design because the extent of riparian vegetation had already been estimated by the GIS. The GIS placed the areas of interest, (riparian zone of one active channel width) into three classes: forests in need of protection, forests in need of management, and forests in need of establishment. For this study, the only riparian woodland sites assessed were the ones that were classified as “in need of protection.”

Forest Width (FW), Active Channel Width (ACW), and Plot Location

The FW was measured perpendicularly from the top of the streambank to the edge of the forested area using a reel fiberglass tape meter. To measure the horizontal ACW (or bankfull width) a LaserAce™ 1000 Rangefinder manufactured by Trimble® was used. The indicator for the ACW was a green line of vegetation or a change in slope in the streambank. In addition, a global positioning system (GPSmap 76CSx) manufactured by Garmin® was used to record the location of each watershed plots. Having the exact location of each plot will be of great help in future research.

Data Collection on Plots of 1500 ft² (≥50ft×30ft)

Population of interest

Experts generally suggest the area of interest would cover one active channel width (ACW) perpendicular to the stream channel. However, very small streams had a narrower ACW, so we used a minimum 50 ft ACW for the following reasons:

a) It gives a consistent plot size within similar reaches, and

b) The ACW does not vary much along the course of a waterway of consistent stream order.

Overstory trees: plot shape, size, and number

Rectangular area plots were used to assess overstory species. An effective sampling design with a plot of adequate size and shape (Elzinga 1998) involved using rectangular plots, which made it simpler to determine which trees were within the plot boundaries. Each plot was 50 ft by 30 ft, for a total area of 1500 ft². For each plot, a transect line (50 ft long) was run from the top of the streambank outward to the extent of the predetermined ACW. Then, 15 ft on each side of this line was marked off to form the area of interest (Figure 3.1). The sampling unit was permanent in all the plots. To meet targets of precision and power of data collected, a total of 44 plots were located in the three watersheds: 12 plots at Atchison County Lake, 18 plots at Banner Creek Lake, and 14 plots at Centralia City Lake (Figure 3.2 - 3.4). All measurements were recorded on a data sheet and entered in a computer using the program Microsoft Excel 2010.

Tree species

Tree species were identified by examining different parts of the tree: type, arrangement of leaves, bark color and structure, and twigs.

Tree height

At each survey site, for the overstory tree the height was measured from the ground level to the top of the tree. The hypsometer used to measure the tree height was the Suunto Clinometer PM-5 manufactured by Suunto. This tool used worldwide by a variety of users because it allows not only for the measurement of height, but also vertical angles and slopes (Suunto 1936). To measure tree height using a Suunto clinometer, first a horizontal distance of 66 ft (about 20 m) was measured using a tape measure from the base of the tree. Then, by looking through a peep-hole in the clinometer, the users were able to see two scales and a horizontal line indicating when it crosses the top of the tree or the base of the tree. The users used the right scale in the clinometer which allowed them to see through the peep-hole. Measurements were taken at both the top and base of the tree, which then were added up or subtracted, depending on the sign of the reading, to get the total height.

Diameter at breast height (dbh)

Diameter at breast height (dbh) was measured on the uphill side of the trunk an average of 4.5 ft above the ground. The dendrometer was a steel diameter tape, used to measure the circumference of the tree. Larger trunks required using a diameter tape because other instruments are difficult to handle in thick brushwood (Avery and Burkhart 1994). In this study, only those trees with a dbh equal or greater than 5 in were measured.

Canopy class

Trees were classified according to the position they occupied in the forest canopy within the area of study: dominant, co-dominant, intermediate, and overtopped. A tree was defined as dominant when the top extended beyond the general level of the main canopy thus receiving full light from above and all sides. All trees that formed part of the main canopy level and consequently were receiving full light from above but little from the sides were classified as co-dominant. Likewise, a tree was defined as intermediate when it occupied an average canopy level but was shorter than the co-dominants trees and hence receiving just a little light from above (Helms 1998).

Seedling and sapling regeneration: plot shape, size, and number

Because the number of woody regeneration stems that fell in the rectangular plot was very large, a different plot shape and size was used for this measurement. Therefore, to determine density of seedling and sapling regeneration, circular plots with area of 88 ft^2 were used. Two circular plots were assessed within the rectangular plot. At each side of the transect line, woody species regeneration was measured within a circular plot with radius of 5.3 ft. To select the sampling point, two numbers were selected from a random number table. The first number indicated the position within the transect line. The second number indicated the sample point perpendicular to the position of the first number in the transect line of the rectangular plot. Once the sample point was obtained, a pin was inserted and a rope with radius of 5.3 ft was used to mark out the plot. All seedlings (< 1 in in diameter) and saplings (> 1 in but < 5 in in diameter) found in each plot were recorded.

Qualitative notes

Qualitative notes were also recorded in the three watersheds. Within the 44 plots, observation of livestock and management of the entire riparian area were recorded. In addition, the percentages of plots that had the second ACW occupied by forest, grass, and crop land were determined.

Field work sheet

A two page field work sheet was used to record the measurements (Appendix A.1). It was ensured that data sheets were completely filled out and stored in a safe place to prevent them from getting lost or wet.

Basal area (BA) per acre and quadratic mean diameter (QMD) computation

Once the data were collected and recorded on the computer, the next step was to calculate the basal area (BA) per acre, and the quadratic mean diameter (QMD). According to Avery and Burkhart (1994), the basal area (BA) of a tree is defined as the cross-sectional area at breast height and is computed using the following formula:

$$BA(ft^2) = \frac{\pi dbh^2}{4(144)} = 0.005454\ dbh^2$$

where *BA* is the basal area of the tree, *dbh* is the diameter at breast height, and π is the mathematical constant 3.14159. Then, the basal area per acre was obtained by summing the basal areas for trees in one acre. The quadratic mean diameter ($\overline{dbh_q}$) or (QMD) in inches was also computed. Calculating the QMD, required us to determine the mean basal area ($\overline{BA}$) in square feet per tree, and then substituting it into the following formula:

$$\overline{dbh_q} = \sqrt{\frac{\overline{BA}}{0.005454}}$$

Data Analysis Procedures

The data were evaluated and analyzed for statistical significance in summer 2012 using the statistic program SAS (SAS Institute, Inc., Cary, NC, USA). Most of the data had a gamma distribution; therefore for the analysis a generalized linear model with a gamma link function was used. The procedure used was GLIMMIX.

Figures and Tables

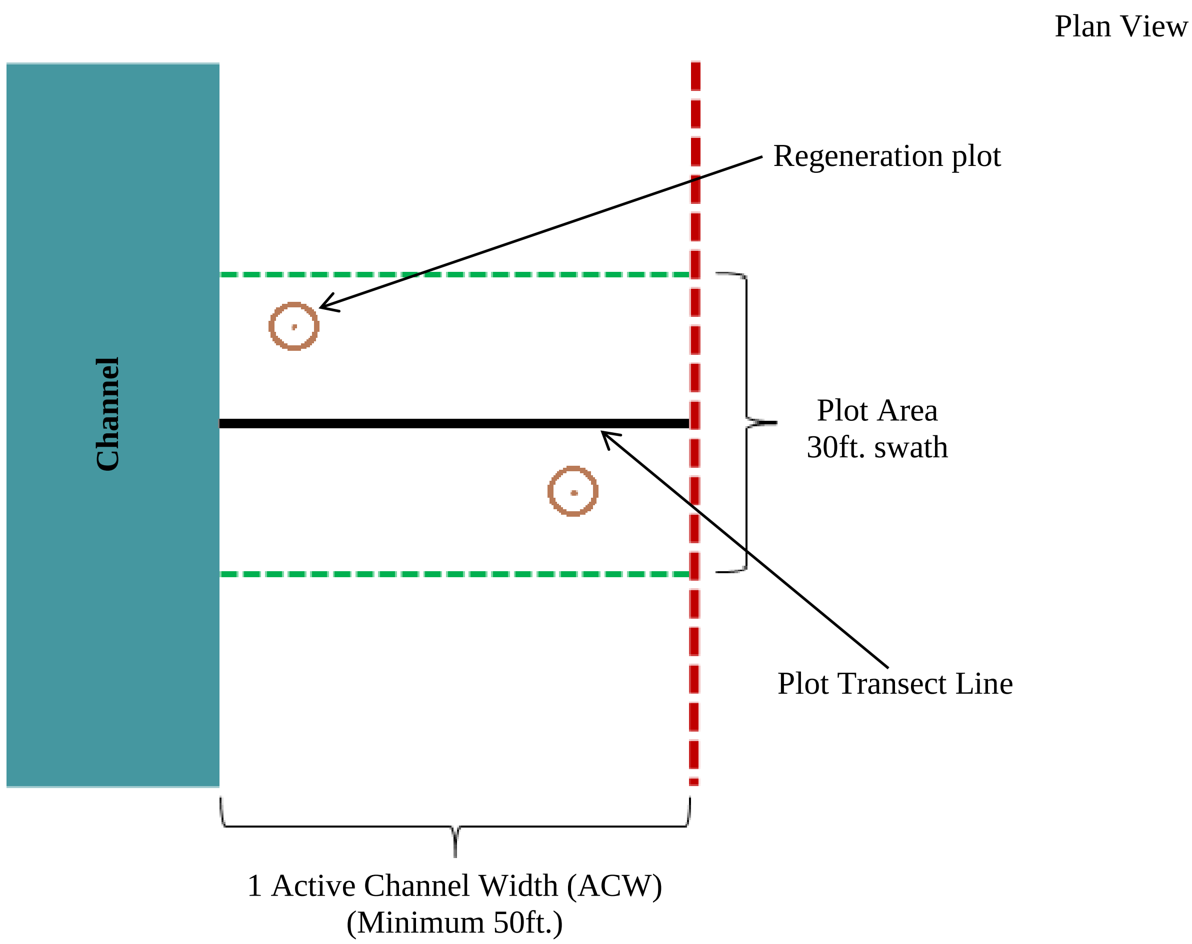

Figure 3.1 Rectangular plot design.

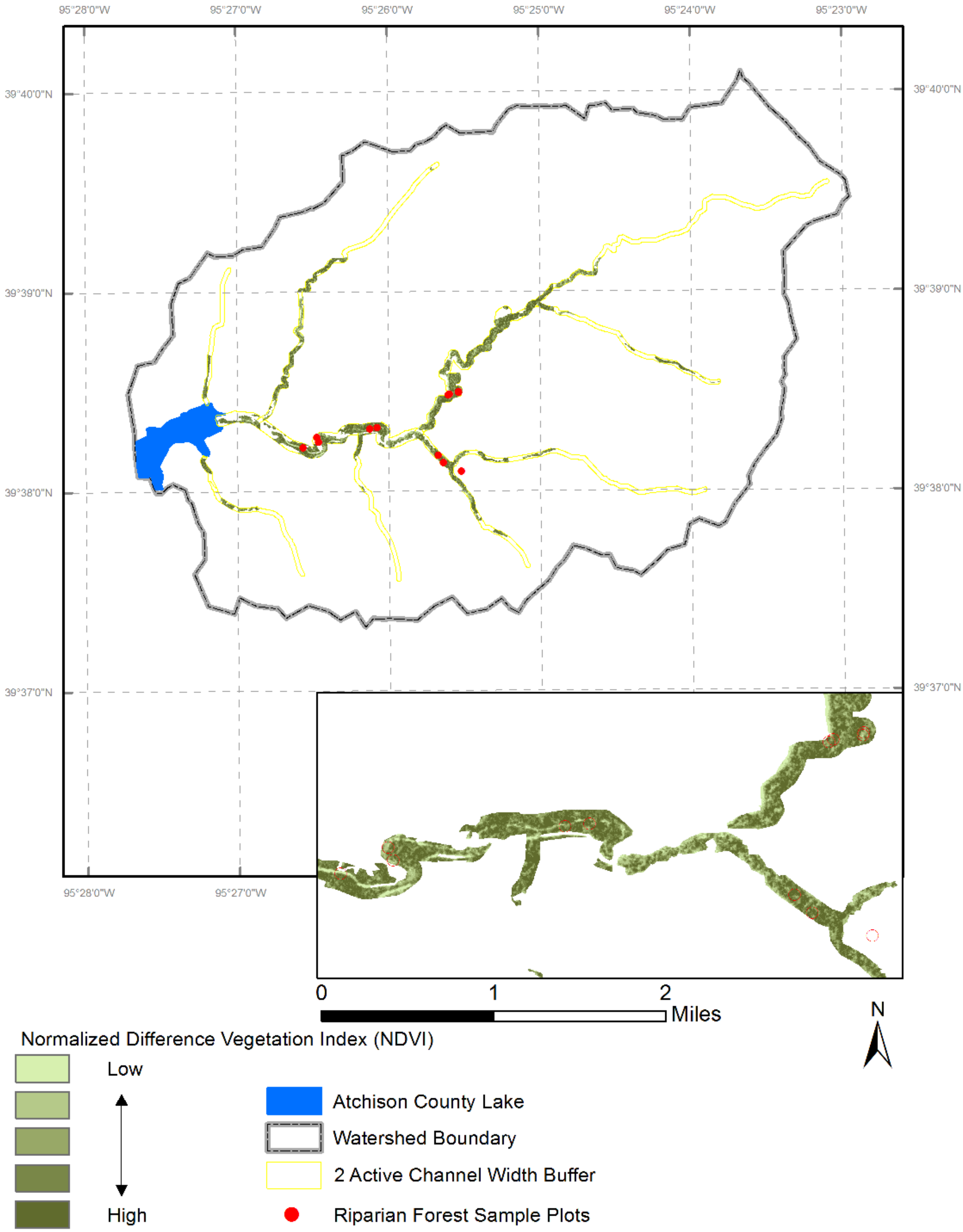

Figure 3.2 Riparian forest and sample plots in Atchison County Lake watershed.

Source: Jeff Neel 2012

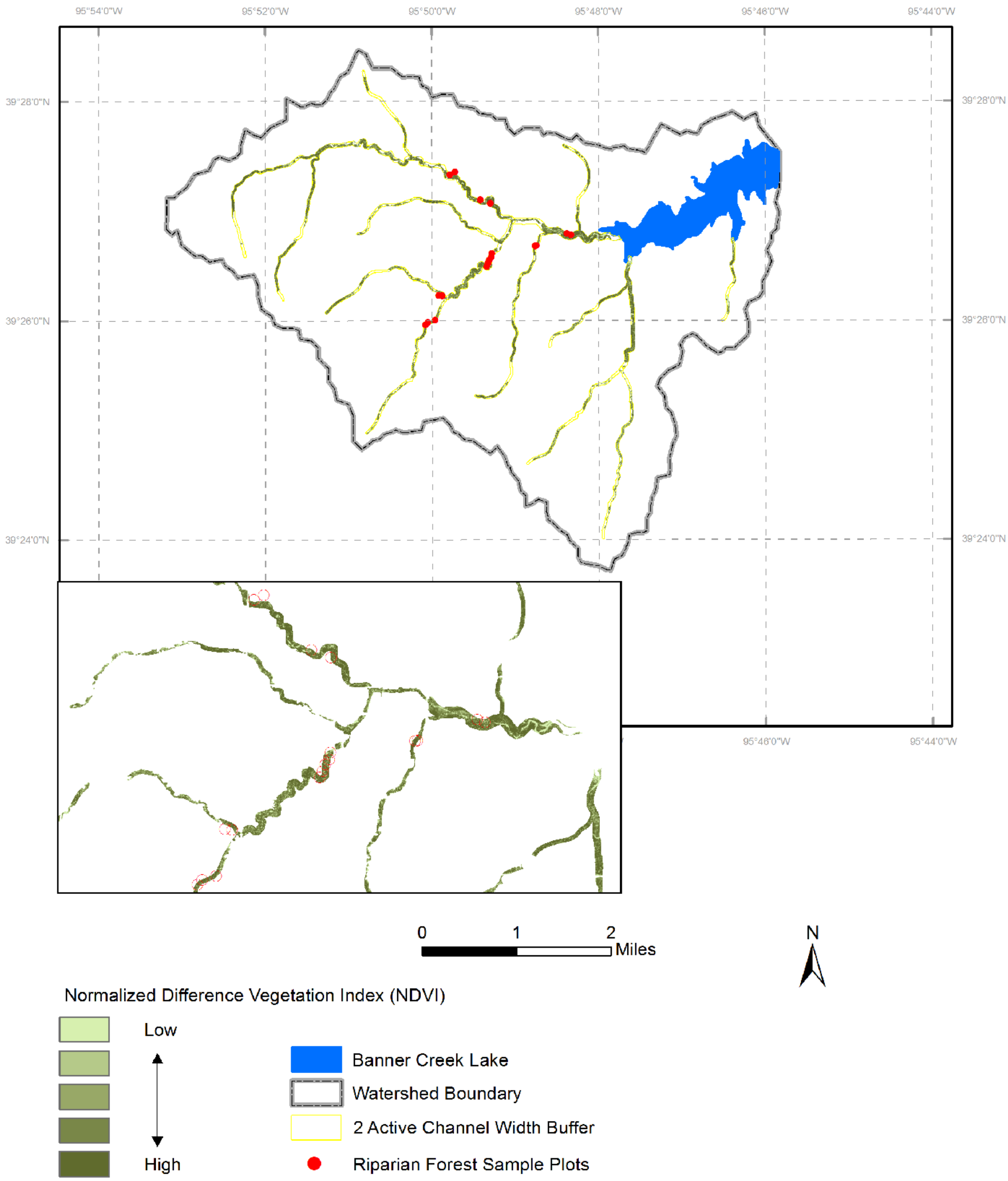

Figure 3.3 Riparian forest and sample plots in Banner Creek Lake watershed.

Source: Jeff Neel 2012

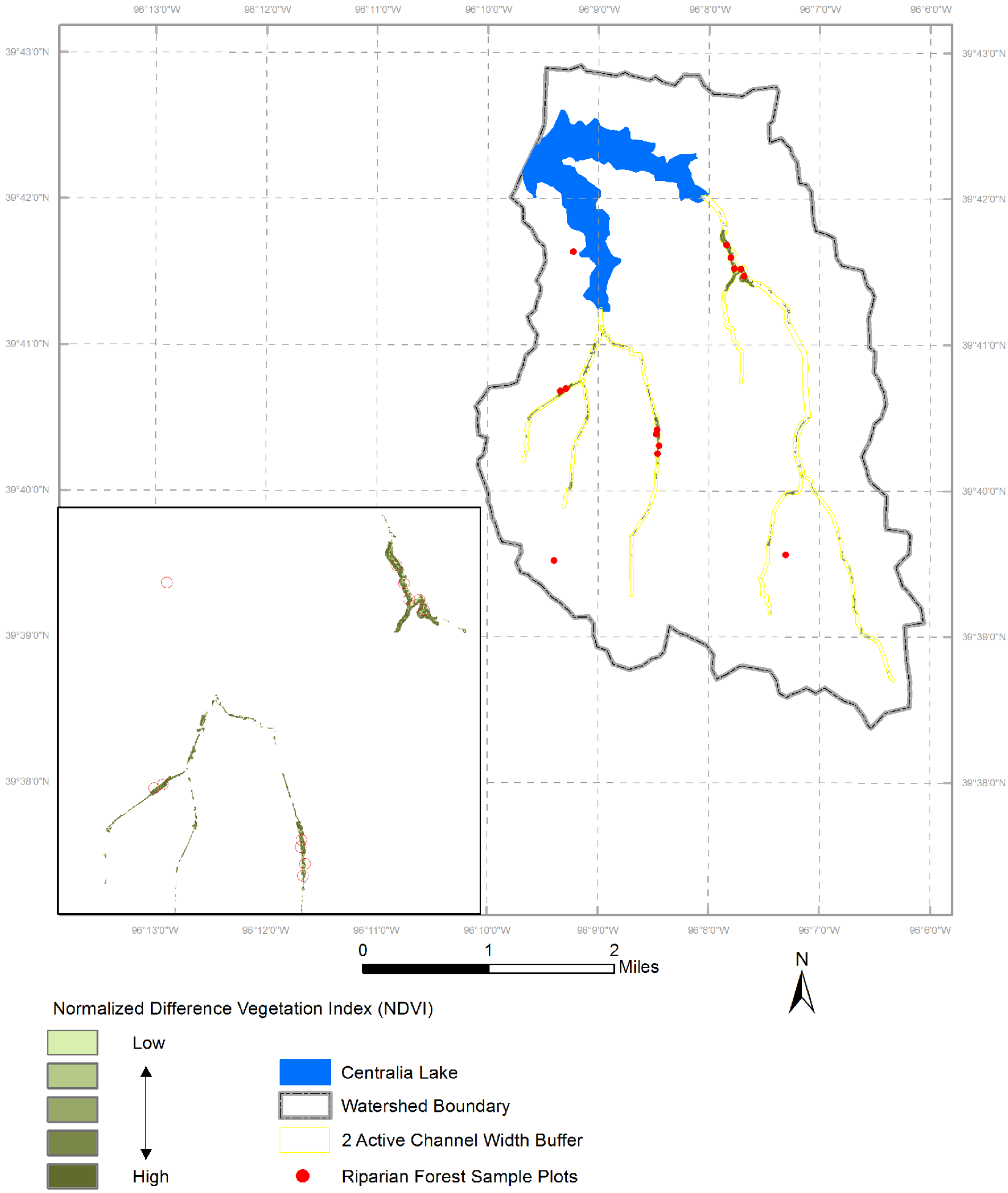

Figure 3.4 Riparian forest and sample plots in Centralia City Lake watershed.

Source: Jeff Neel 2012

Chapter 4 - Results

For each watershed, the composition and structure of riparian vegetation differed. Although differences among watersheds in basal area (BA) and trees per acre (TPA) were not statistically significant($P < 0.05$), there were some trends in BA in ft² per acre and TPA among the three watersheds (Figure 4.1). Centralia City Lake watershed had tree BA of 155 ft² while Atchison County Lake and Banner Creek Lake watersheds had BAs of 120 ft². TPA showed the opposite trend. Centralia City Lake watershed, with BA of 155 ft², had the fewest TPA. Centralia was dominated by one species (cottonwood). Atchison County Lake watershed had a TPA of 194.

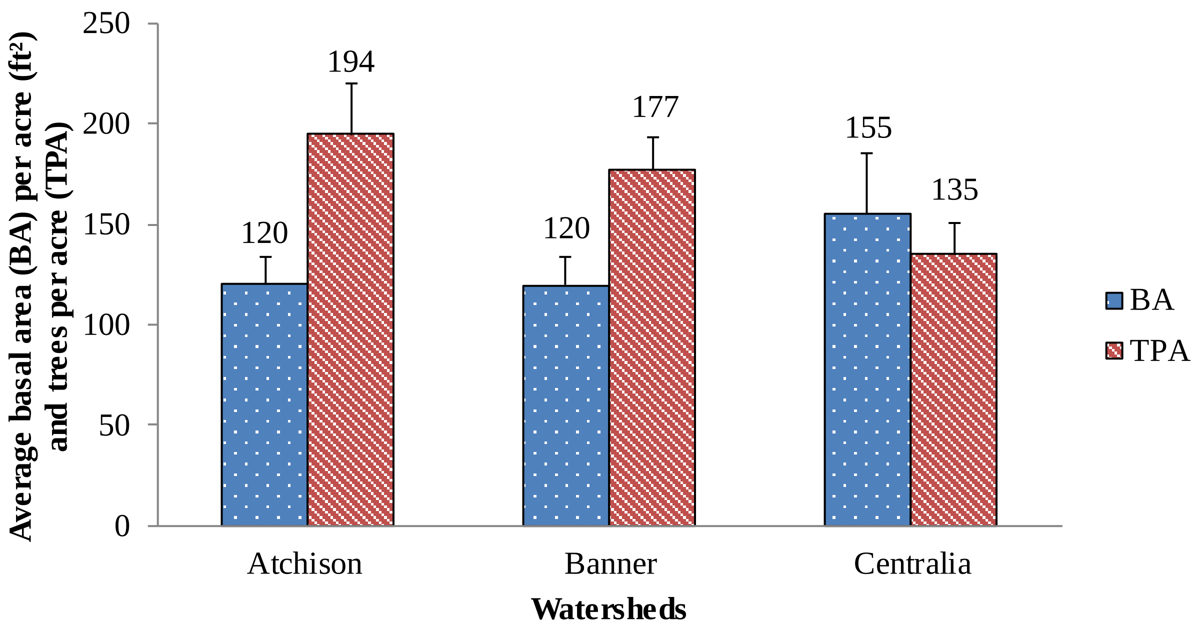

Figure 4.1 Comparison of basal area (BA) in ft² per acre and trees per acre (TPA) in Atchison County Lake, Banner Creek Lake, and Centralia City Lake watersheds.

A highly diverse group of tree species was found especially in the Banner Creek Lake and Atchison County Lake watersheds (Table 4.1). The overstory had a total of 15 species in the Banner Creek Lake watershed. Fewer tree species were found in the Atchison County Lake watershed, but the Centralia City Lake watershed had the fewest species with 8. Among the species found in all watersheds were honeylocust (*Gleditsia triacanthos*), one of the species with the highest BA in Atchison and Centralia Lake watersheds, followed by hackberry (*Celtis occidentalis*), which was one of three species with high BA in the Banner Creek lake watershed, along with hedge (*Maclura pomifera*), american elm (*Ulmus americana)*, and walnut *(Juglans nigra)*. Walnut had high BA in the Atchison County Lake watershed as well; however, in the Centralia City Lake watershed, the BA of walnut was less than 1 ft^2.

Table 4.1 Watersheds with the basal area (BA) in ft^2 per acre by species.

Atchison		Banner		Centralia	
Species	**BA acre (ft^2)**	**Species**	**BA acre (ft^2)**	**Species**	**BA acre (ft^2)**
Honeylocust	34	Oaks	27	Cottonwood	63
Walnut	16	Hackberry	23	Honeylocust	49
Oaks	15	Walnut	16	Mulberry	16
Ash	12	Elm	13	Hackberry	10
Boxelder	12	Hedge	9	Hedge	8
Hickory	10	K. coffee	8	Elm	3
Hackberry	10	Honeylocust	6	Ash	2
Elm	5	Hickory	6	Walnut	<1
Hedge	3	Cottonwood	5		
Maple	2	Mulberry	3		
Mulberry	1	E. redcedar	2		
E. redcedar	1	Black cherry	1		
		Boxelder	1		
		Buckeye	<1		
		Black locust	<1		

Banner Creek Lake watershed had more species diversity than Atchison County Lake watershed, which ranked second, and then Centralia City Lake watershed. An average of 46 walnut trees per acre was found in the Atchison County Lake watershed, the dominant species in this watershed. Elm on the other hand, dominated in the Banner Creek Lake watershed averaging 38 stems per acre. In the Centralia County Lake watershed, honeylocust had the highest number of trees per acre, with an average of 62 stems per acre. It was also the second most common species in the Atchison County Lake watershed. Other species such as black cherry (*Prunus* *serotina)*, boxelder *(Acer negundo)*, black locust *(Robinia pseudoacacia)*, and eastern redcedar (*Juniperus virginiana)* were found in small numbers (Table 4.2).

Table 4.2 Watersheds with the trees per acre (TPA) by species.

Atchison		Banner		Centralia	
Species	**Avg. TPA**	**Species**	**Avg. TPA**	**Species**	**Avg. TPA**
Walnut	46	Elm	38	Honeylocust	62
Honeylocust	32	Hackberry	33	Hackberry	19
Ash	29	Hickory	22	Hedge	17
Hackberry	17	Hedge	21	Mulberry	12
Elm	17	Walnut	15	Cottonwood	10
Hickory	15	Oaks	12	Elm	6
Hedge	9	Honeylocust	10	Ash	4
Boxelder	7	K. coffee	10	Walnut	2
Buckeye	7	Mulberry	5		
Oaks	7	Buckeye	3		
Mulberry	5	E. redcedar	3		
Maple	2	Black cherry	2		
E. redcedar	2	Boxelder	2		
		Black locust	2		
		Cottonwood	1		

Tree height was analyzed according to crown class. Crown class was divided into four categories based on the crown position relative to nearby trees: Dominant, Co-dominant, Intermediate, and Overtopped. Significant differences ($P < 0.05$) among watersheds were found in the height of co-dominant and intermediate crown class stems. In the co-dominant category, Atchison County Lake and Banner Creek Lake watersheds average height was significantly greater than in Centralia City Lake watershed (Figure 4.2). Atchison County Lake watershed had significantly taller trees than Centralia City Lake watershed in the intermediate category, possible because in most plots in Centralia City Lake watershed trees were suppressed by large cottonwoods or were broken in recent ice storms.

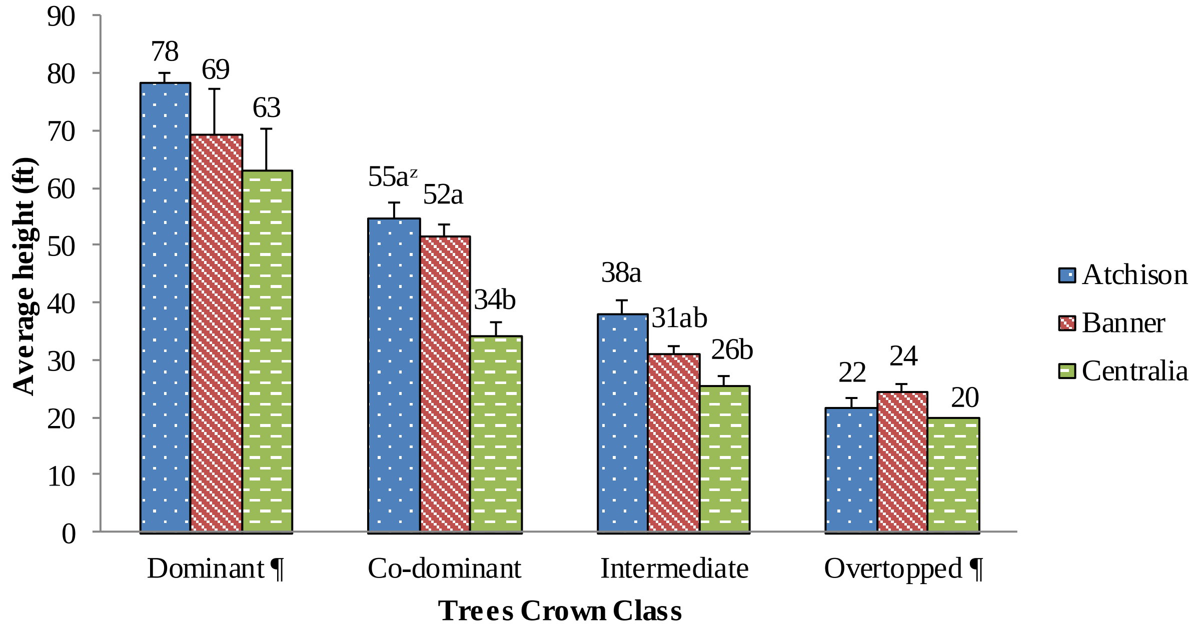

Figure 4.2 Average height by trees crown class in each of the three watersheds.

[z] Means followed with the same letter within crown class are not significantly different ($P < 0.05$).

¶ No significant differences among watersheds.

Note: data had a gamma distribution and a generalized linear model with a gamma link function was used. In addition, a Tukey-Kramer adjustment was used for the multiple comparison procedure.

The quadratic mean diameter (QMD) was used because it assigned greater weight to larger trees. The QMD is also the diameter of the tree of average basal area. There were some trends on the QMD in the three watersheds. Visual observation in figure 4.3 revealed that Atchison County Lake watershed's QDM was predominantly in species like oak, honeylocust, and hickory. Cottonwood, oaks, and walnut were the species with the largest QMD in the Banner Creek Lake watershed, whereas in the Centralia City Lake watershed it was cottonwood, mulberry, and walnut. Atchison County and Banner Creek Lake watersheds had greater species diversity, with 12 and 15 respectively, whereas Centralia City Lake watershed only had 8 species.

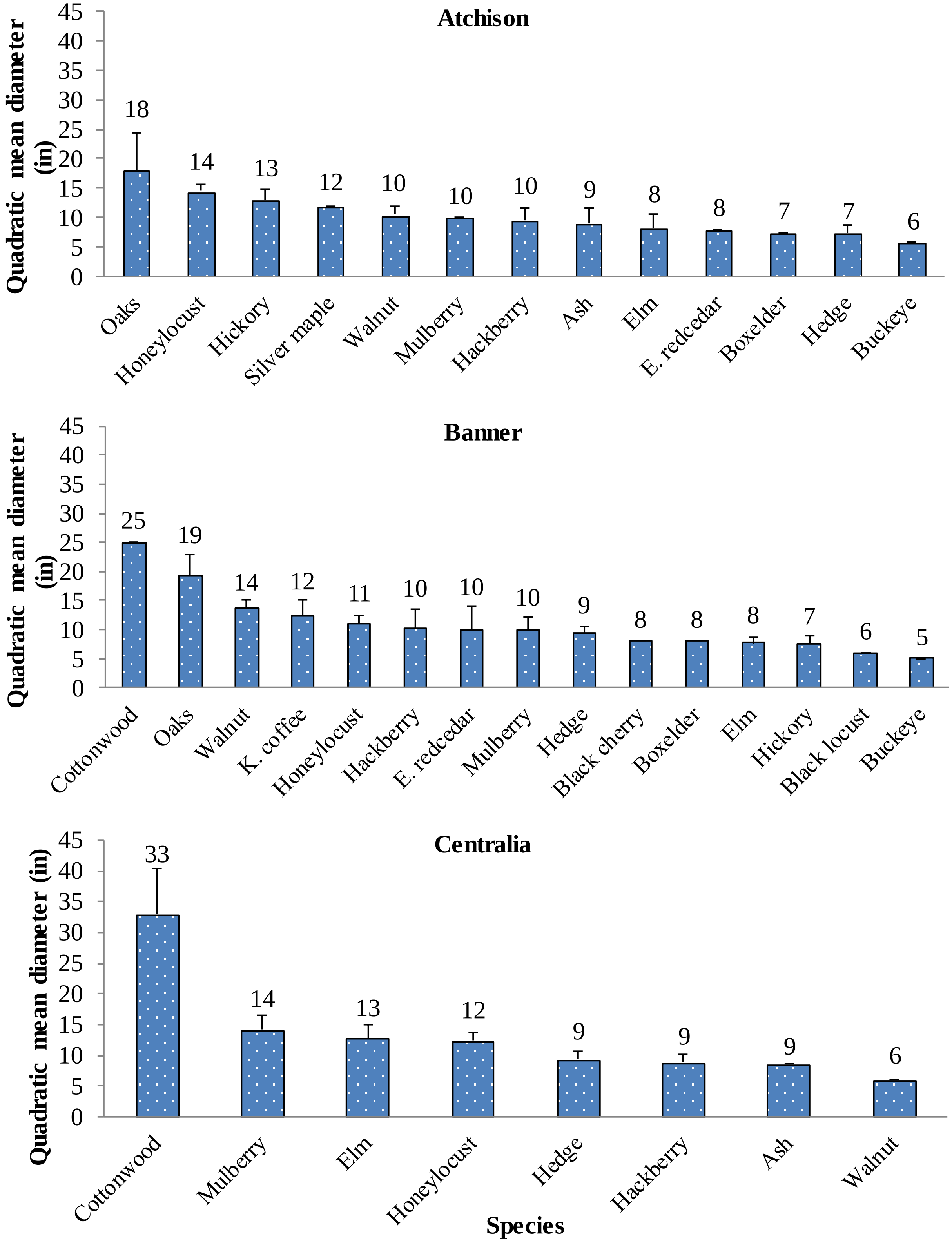

Figure 4.3 Quadratic mean diameter (QMD) of tree species in each watershed.

More than one species of oaks were found in the assessed watersheds, but bur oak (*Quercus macrocarpa*) was predominant. Fewer black (*Quercus velutina*), chinkapin (*Quercus muehlenbergii*), and northern red oak (*Quercus rubra*) were recorded. In the Atchison County Lake watershed, honeylocust had the highest BA per acre, with 28% of the total, bur oak in the Banner Creek Lake watershed with 22%, and cottonwood (*Populus deltoides*) in Centralia City Lake watershed 42% (Figure 4.4). In the Atchison County Lake watershed, honeylocust, walnut, and bur oak accounted for more than 50% the BA. Meanwhile in the Banner Creek Lake watershed, bur, black, and chinkapin oak, hackberry, and walnut accounted for more than 50% the BA of the trees. Unlike the other two watersheds, Centralia City Lake watershed's BA was mainly comprised of cottonwood and honeylocust, totaling 74%.

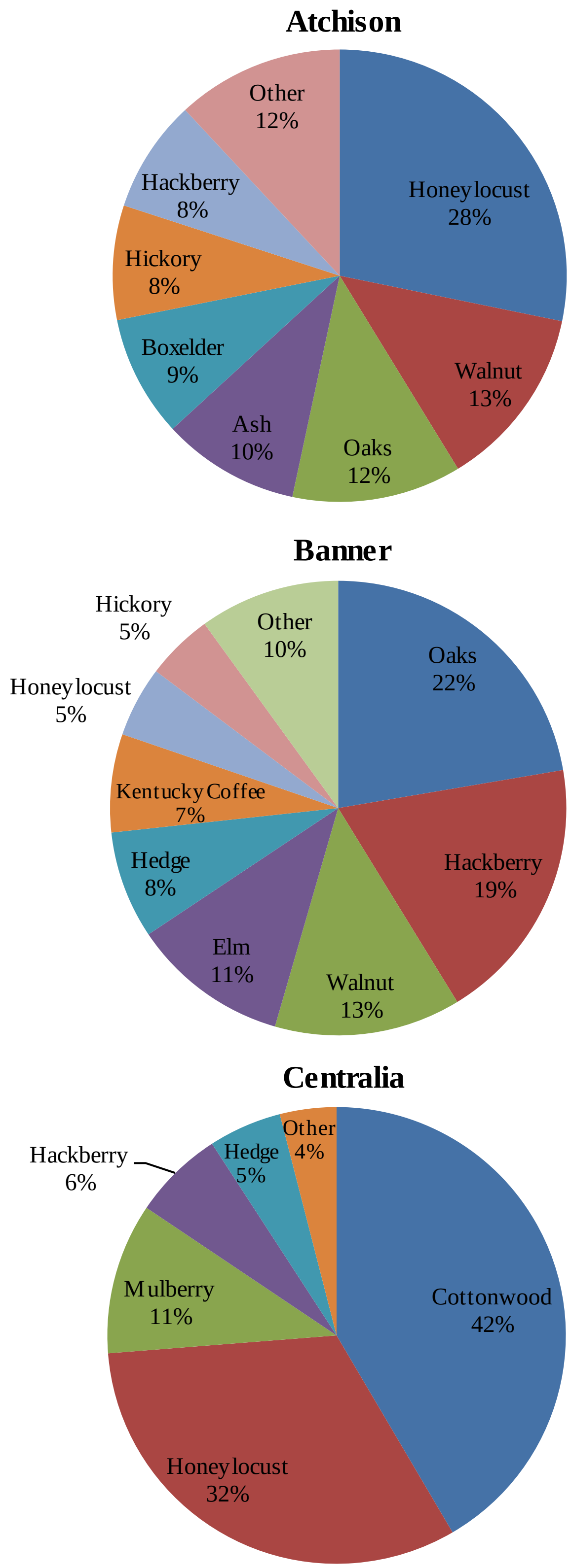

Figure 4.4 Comparison of the riparian forest basal area (BA) composition as a percentage of the total in each watershed.

In all three riparian woodlands, the dominant seedling regeneration was hackberry which was especially high in the Centralia City Lake watershed at 90% (Figure 4.5). Hackberry and ash (*Fraxinus americana* and *Fraxinus pennsylvanica*) accounted for 50% of seedling regeneration in the Atchison County Lake watershed. Within the Banner Creek Lake watershed, the two species with the highest seedling regeneration were hackberry and two species of hickory (*Carya cordiformis* and *Carya tomentosa*), which together accounted for 53% of the total. Hackberry was common in the overstory of all three watersheds, and is quite shade tolerant, so the high amounts of hackberry seedling regeneration was expected.

In addition, hackberry also dominated the sapling regeneration in the riparian woodlands of Atchison County Lake and Centralia City Lake watersheds while bitternut hickory (*Carya cordiformis*) was the prevailing species in the Banner Creek Lake watershed (Figure 4.6). Only 3 species of saplings were found in the Centralia City Lake watershed; the lack of diversity in the overstory is even more pronounced in the understory.

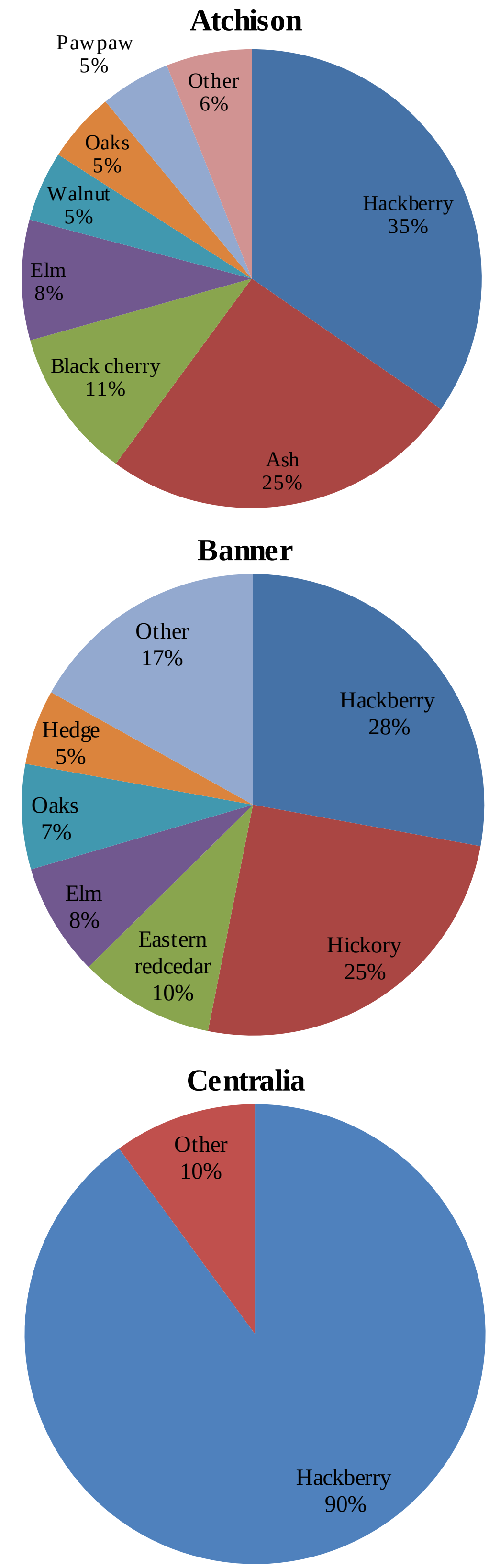

Figure 4.5 Comparison of the seedling regeneration between and within watersheds.

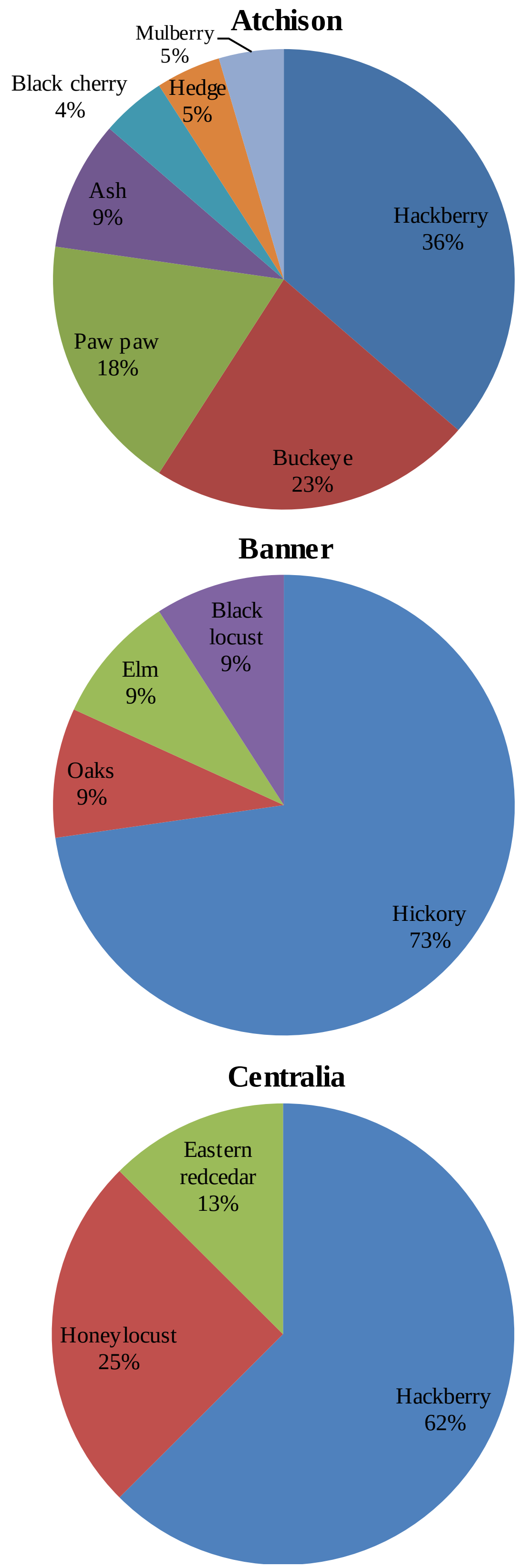

Figure 4.6 Comparison of the sapling regeneration between and within watersheds.

Categorization of Overstory Species by Timber Harvest Potential

Tree species composition was important from a commercial point of view for the watersheds. Therefore, in consultation with the Kansas Forest Service district forester (Bruton, personal communication, July 26, 2012) the species found in the watersheds were categorized based on the timber harvest value: Group 1 (high value) was composed of all oaks and walnut; Group 2 (moderate value) was composed of ash, black cherry, cottonwood, hackberry, hickory, and silver maple; Group 3 (low value) comprised all other species.

All the Groups showed significant difference in BA among the three watersheds at P-value < 0.05. Banner Creek Lake watershed had significantly higher average basal area (BA) of Group 1 species than Centralia City Lake watershed. However, in Group 2, BA per acre in the Centralia City Lake watershed was significantly higher than Atchison County and Banner Creek Lake watersheds. Of the three watersheds, Centralia City Lake watershed had the most variation among the three groups (Figure 4.7).

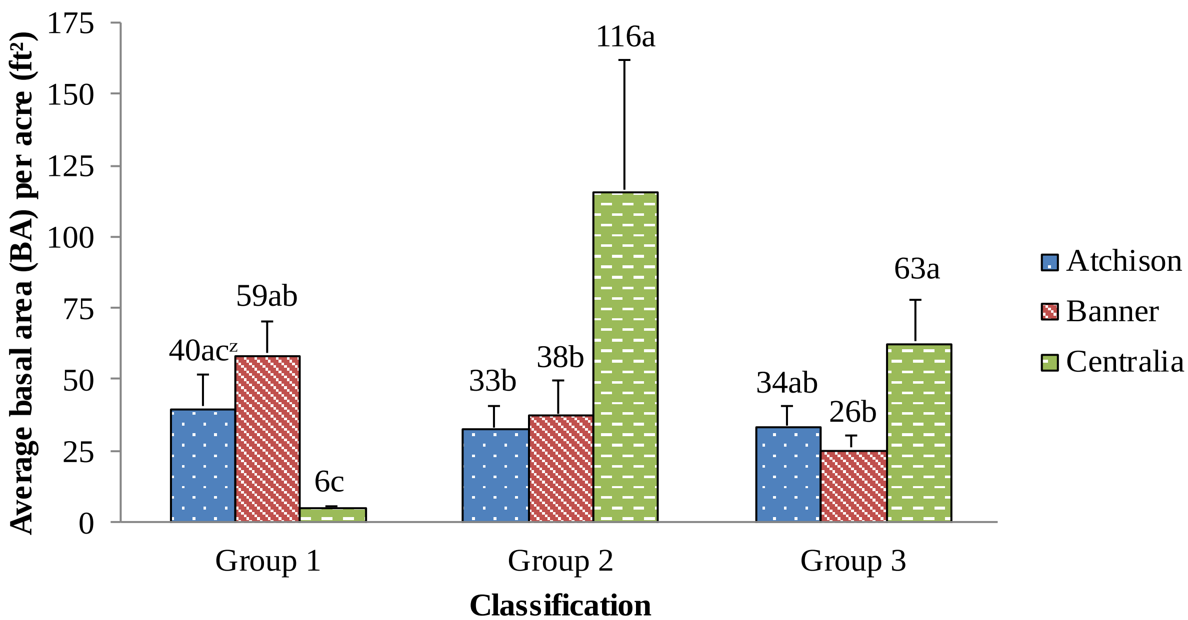

Figure 4.7 Overstory basal area (BA) in ft² per acre by species group.

[z] Means followed with the same letter within group are not significantly different (P < 0.05).

Note: data had a gamma distribution and a generalized linear model with a gamma link function was used. In addition, a Tukey-Kramer adjustment was used for the multiple comparison procedure.

No significant difference in TPA among the three watersheds was found at P-value < 0.05. However, visual observation in figure 4.8 showed some trends in the three groups. Most of the TPA of high value species was found in the Atchison County Lake watershed. Species in Group 1 represented over 35% of the TPA found there, but in the Banner Creek and Centralia City Lake watersheds Group 1 represented less than 25%. In general, the overstory vegetation is dominated by moderate and low value species such as hackberry, honeylocust, and elm.

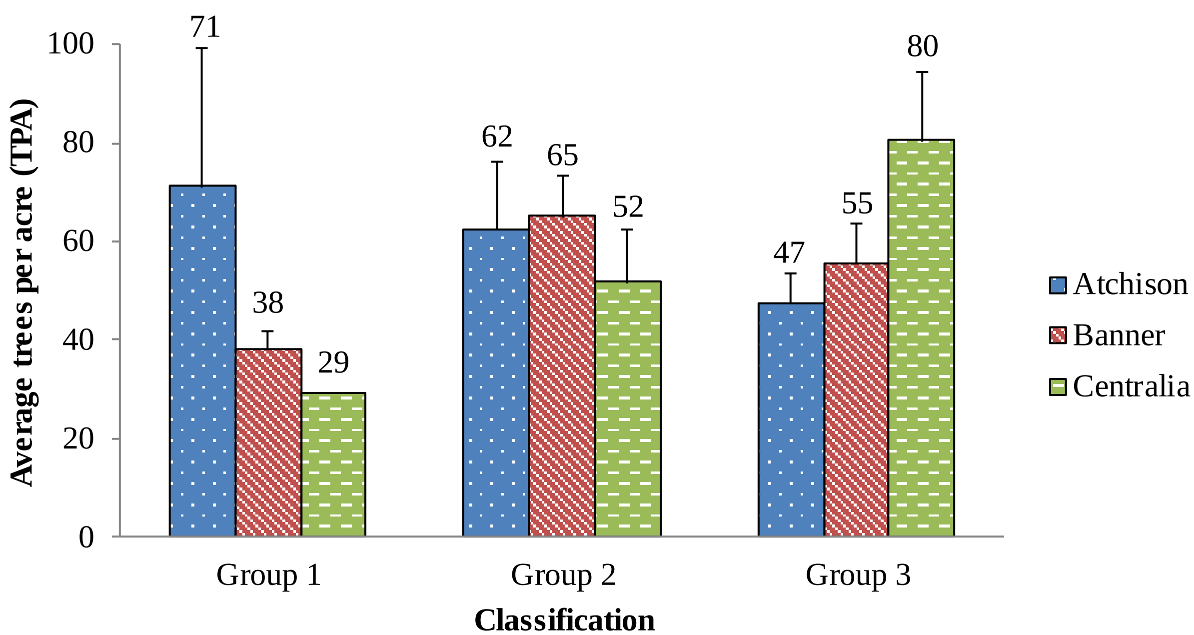

Figure 4.8 Overstory trees per acre (TPA) by species group.

Categorization of Regeneration Species by Timber Harvest Potential

In all three watersheds, regeneration was primarily seedlings. A high number of seedlings (> 3000 seedlings/acre) and saplings (> 400 saplings/acre) were found in Atchison County Lake watershed. As well as in the overstory trees, the regeneration in those watersheds is dominated by moderate value species such as hackberry and hickory. No significant difference was found in any of the Groups at P-value < 0.05 when both seedling and sapling regeneration were combined. However, there were some trends on the data. Visual observation revealed that most of the regeneration was found in the Group 2 species (Figure 4.9) due to high number of hackberry.

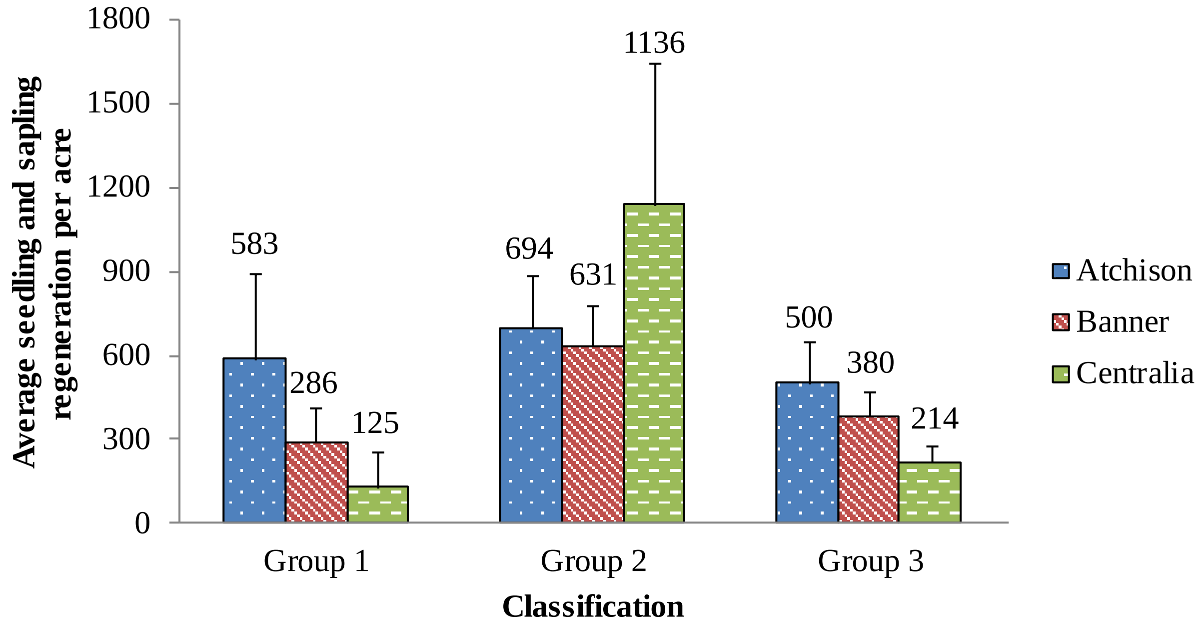

Figure 4.9 Seedling and sapling regeneration per acre by species group.

Banner Creek Lake watershed had seedling regeneration found on 92% of the plots (Table 4.3). However, the Atchison County Lake watershed had the most sapling regeneration, with about 50% of the plots having saplings present.

Table 4.3 Percentage of plots per watershed with seedling and sapling regeneration.

	Atchison	Banner	Centralia
Plots		**%**	
Plots that had seedlings	92	94	79
Plots that had saplings	50	22	29
Plots with both seedlings and saplings	42	22	21

Qualitative Data

Considering sedimentation rates, Banner exhibits a surprisingly high rate, despite having a grassland-dominated watershed. Observations made during the riparian forest assessment indicated that Banner also had the highest incidence of grazed riparian woodlands, with 72% of the tracts surveyed showing evidence of cattle use, whereas Atchison only had cattle using 25% of the tracts visited (Table 4.4). The only riparian woodland sites assessed were the ones that were classified as "In need of protection" with GIS data indicating that a well-established stand of trees was present in the riparian zone. To reduce the impact of cattle use in the riparian area, perhaps riparian fencing, hardened stream access points, and alternative water sources should be promoted in the watershed.

In the three watersheds, threats to forest health and streambank stability were commonly observed during field riparian assessments, including excessive livestock use, ice storm damage, and lack of sustainable forest management. In the Atchison County Lake watershed, 92% of the plots had a second active channel width (ACW) occupied by forest, while the remaining 8% were cropped. In the Banner Creek Lake watershed, however, fewer plots were in forest (72%), but 28% were in grass. The distribution of land use in the second ACW in the Centralia City Lake watershed was higher for forest (64%), followed by grass (29%) and crops (7%).

Table 4.4 Qualitative data.

		% Plots with		2nd. Active Channel Width (ACW)		
Watershed	**Total Plots**	**Livestock**	**Management ¶**	**Forest ¶**	**Grass ¶**	**Crop ¶**
					%	
Atchison	12	25b[z]	25	92	0	8
Banner	18	72a	11	72	28	0
Centralia	14	21b	0	64	29	7

[z] Means followed with the same letter within a column are not significantly different ($P < 0.05$).

¶ No significant differences among watersheds.

Chapter 5 - Conclusions and Recommendations

Due to the differing extent and composition of riparian woodlands in the three study watersheds, customized approaches could be used to promote improved riparian area management, to reduce sedimentation. Centralia City Lake watershed had the highest amount of over-mature stands of cottonwood. Harvesting of the declining large cottonwoods should be promoted concurrently with the establishment of a more diverse, valuable and longer-lived mixture of species.

Atchison County Lake and Banner Creek Lake watersheds have substantial amounts of the more valuable oak and walnut timber, with Atchison County Lake watershed BA of 25% and Banner Creek Lake watershed BA of 35% in these Group1 species. The management and economic value of these species should be highlighted. Thinning and crop tree release, to allow the oaks and walnuts to grow more quickly following the removal of competing species, would be an excellent practice to promote. With the oaks showing a QMD of 18-19 inches, they are close to reaching maturity, while the walnuts are in the slightly smaller size class, with a QMD of 10 inches in Atchison County Lake watershed, and 14 inches in Banner Creek Lake watershed, which would respond well to a release from competition (Smith 1986). Demonstration sites should be established with a willing landowner in each watershed, to show how these treatments are conducted, and data collected to document the effect.

The dominate species of tree seedlings recorded in all three watersheds was hackberry, which raises some concerns. Hackberry is very shade tolerant, and high numbers of seedlings can build up over time. Unfortunately, hackberry is a moderate-value species. Education and management should seek to reduce the prevalence of hackberry in the understory following harvest, and the promotion of a more diverse species mixture when planting. Species with higher values for timber and wildlife include bur and northern red oak, black walnut, silver maple, hickory, and black cherry.

Future research should be focused on increasing the adoption and success of riparian forestry practices, such as forest buffers, within Eastern Kansas. Increased success of riparian plantings will lead to increased adoption of these practices. Therefore, research into site preparation, planting, and maintenance techniques is recommended.

Because lower-value timber species dominated both the forest canopy as well as forest regeneration within study watersheds, research into market development and alternative uses for these species is recommended. Revenue from the removal/harvest of lower-value species would increase revenue generated from forest management, thus increasing incentives for watershed landowners to actively manage their woodland.

Finally, quantifying the ability of various types of riparian vegetation to stabilize streambanks is recommended. This may assist in quantifying watershed-scale sediment load reductions resulting from the implementation of riparian forest buffers.

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Appendix A - Description of Materials and Methods

Instruments utilized in the process of data collection

a) b)

Figure A.1 a) LaserAce™ 1000 Rangefinder used to measure the active channel width (ACW) and b) GPS map 76CSx used to record the location of each plot studied.

Resource: a) Trimble manufacturer 1978, and b) Garmin manufacturer 2007

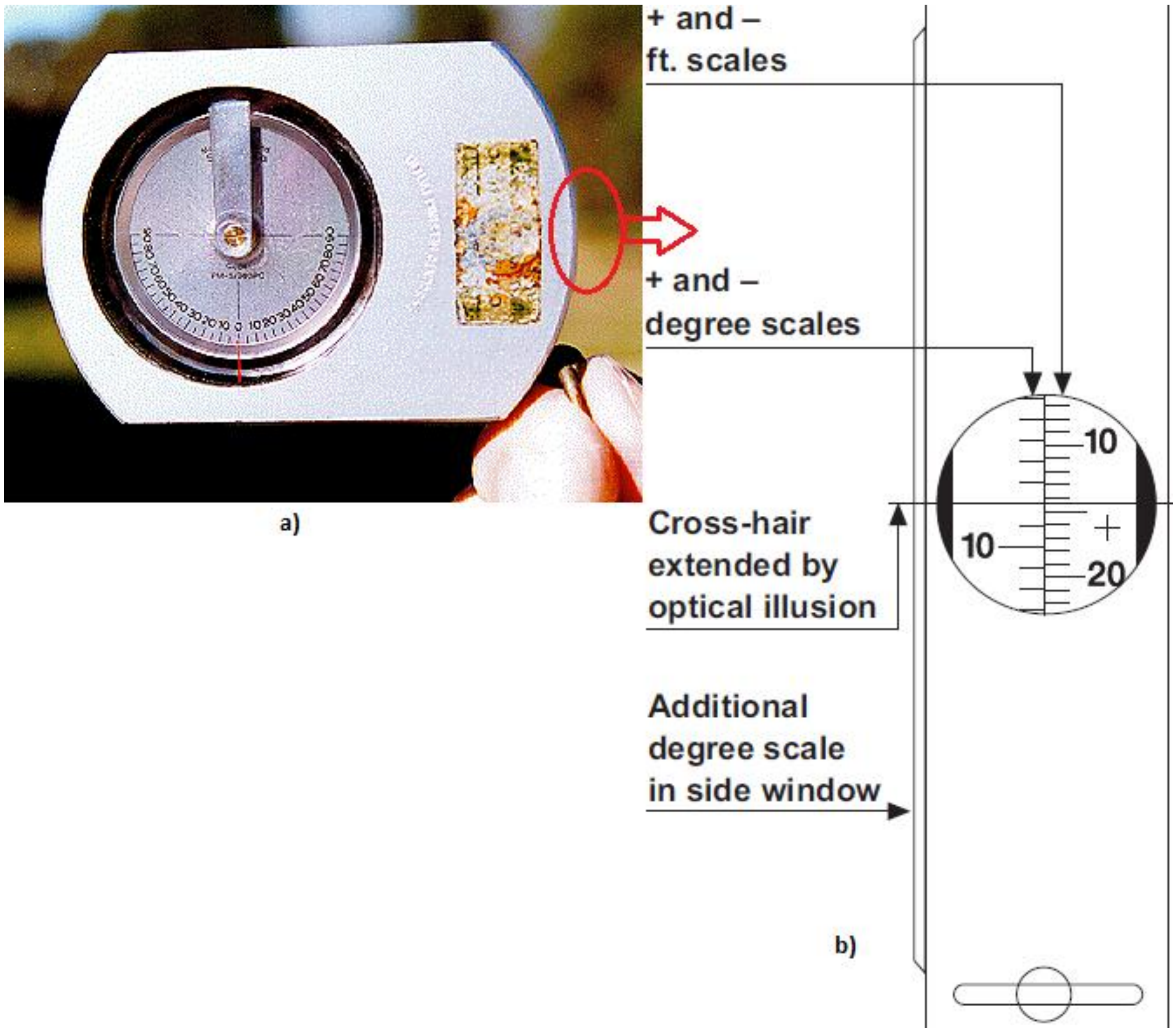

Figure A.2 Suunto Clinometer used to measure tree height.

Source: a) Brack 2001 and b) Suunto 1936

Figure A.3 Equipment used in data collection: a) Reel fiberglass tape, b) Chaining pins, c) Ropes, d) Diameter tape, e) GRS densitometer, f) Sheet holder, g) Pencil.

Source: Forestry Suppliers Inc. 1952

Table A.1 Worksheet used in data collection.

Site:	**Bank:**		**Plot:**	**Plot dim:**
Date:	**BAF:**		**BAF Tree #**	**F. Width:**
ACW:	**Plot Type: Standard**		**GPS:**	
Species	**dbh (in)**	**Ht (ft.)**	**Canopy Class**	**Notes**
General Notes 1st ACW:				
General Notes 2nd ACW:				

Figures showing the process of data collection

Figure A.4 Measuring the active channel width (ACW) using the LaserAce™ instrument.

Figure A.5 Measuring trees that fell into the plot area.

Figure A.6 Measuring the diameter at breast height (dbh) with a diameter tape instrument.

Figure A.7 Assessing saplings and seedlings regeneration.

Appendix B - Supplemental Information

Table B.1 Average seedling regeneration per acre by species in the three watersheds.

Atchison		Banner		Centralia	
Species	**Avg. TPA (seed)**	**Species**	**Avg. TPA (seed)**	**Species**	**Avg. TPA (seed)**
Hackberry	1021	Hackberry	736	Hackberry	1679
Ash	750	Hickory	667	Elm	54
Black cherry	313	E. redcedar	250	Honeylocust	36
Elm	250	Elm	208	Mulberry	36
Walnut	146	Oaks	194	Walnut	18
Oaks	146	Hedge	139	Silver maple	18
Paw paw	146	K. coffee	111	Hedge	18
Buckeye	104	Red Bud	83	Boxelder	18
Mulberry	42	Catalpa	56		
Honeylocust	42	Buckeye	42		
		Sycamore	42		
		Boxelder	42		
		Ash	28		
		Walnut	14		
		Black locust	14		

Table B.2 Average sapling regeneration per acre by species in the three watersheds.

Atchison		Banner		Centralia	
Species	**Avg. TPA (sap)**	**Species**	**Avg. TPA (sap)**	**Species**	**Avg. TPA (sap)**
Hackberry	167	Hickory	111	Hackberry	89
Buckeye	104	Oaks	14	Honeylocust	36
Paw paw	83	Elm	14	E. redcedar	18
Ash	42	Black locust	14		
Black cherry	21				
Hedge	21				
Mulberry	21				