COMPOSITION AND STRUCTURE OF RIPARIAN WOODLANDS IN THREE SUB-WATERSHEDS OF TUTTLE CREEK WATERSHED

by

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Abstract

Spring Creek, Headwaters Robideux Creek, and Snipe Creek are sub-watersheds located within the Big Blue River Watershed, which drains to the Tuttle Creek Reservoir impoundment. This reservoir had a very high monetary investment since the beginning; unfortunately the lifespan for this marvel of engineering is declining rapidly due to high sedimentation rates. One of the programs for slowing the sedimentation process is the removal of highly erodible lands from agricultural production. This thesis work aimed to gather more knowledge on the natural riparian areas, to help the stakeholders of Kansas to improve their riparian woodland management decisions. The objective of the study was to characterize the structure and composition of natural riparian woodlands in three sub-watersheds of the Tuttle Creek Watershed. Data was collected using a representative sample design. Plot dimensions for mature tree data collection were 50ft by 30ft. For regeneration smaller, circular plots were used. Data analysis was completed with SAS 9.3. Results showed that trees per acre (TPA) differed significantly between Spring Creek and Snipe Creek, with Snipe Creek having the highest number of TPA. Quadratic mean diameter (QMD) also differed significantly in these two watersheds, with Spring Creek having the highest quadratic mean diameter. A different set of species was found in each watershed, with American elm (*Ulmus americana*) and hackberry (Celtis occidentalis) being found in high numbers in all areas. Regeneration data showed hackberry to be present in high numbers of both seedlings and saplings. Seedlings exhibited more species diversity than saplings. High economic value species were present in the natural riparian woodlands but in low numbers. Species of moderate economic value were predominant in terms of BA, TPA, and regeneration. Human impact on the riparian areas in the sub-watersheds was noticeable, both from livestock and forest management. Also invasive species were found in the riparian woodlands such as garlic mustard (*Alliaria petiolata*) and stinging nettles (*Urtica diotica*). Riparian areas have a great potential for improvement and management in the three sub-watersheds.

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Dedication

For my Mom Maria Elvia Rosa Barahona Ochoa, who has been my support and my strong-arm, thank you for your advice and for being my cheerleader over the phone, thank you for being who you are… my Mom.

Para mi mami, Maria Elvia Rosa Barahona Ochoa, quien ha estado en este proceso desde el comienzo, quien ha sido la que me ha sostenido y alentado para seguir adelante. Gracias por siempre estar en los buenos y malos momentos, y empujarme cuando no quiero caminar. Gracias por siempre estar allí, gracias por ser quien eres, mi mamá.

Chapter 1 - Introduction

The following paragraphs will guide the reader through a review of the historical accounts in the construction and influence of the Tuttle Creek Reservoir in northeastern Kansas. These paragraphs will also review some of the basic concepts on sedimentation and tree influence on this process. Additionally, this chapter will discuss some of the characteristics of riparian woodlands and the ecosystem functions these areas provide. Furthermore, the area of interest and the objective of the study will be presented.

Historical Review of Tuttle Creek Reservoir

The first official mention of building a reservoir near the mouth of the Big Blue River, between Riley and Pottawatomie counties in Kansas, United States (U.S.) occurred in 1928, for purpose of flood control but also conservation of water (Kansas Historical Society 2013). Plans evolved, adding other purposes to the construction, such as sediment retention, and recreational purposes, but the project did not get funded until, in 1951, a flood heavily damaged most of the communities along the Kansas River. Losses were accounted at more than $725,000,000 plus the secondary losses that occur after a flood of such magnitude (U.S. Army Corps of Engineers 2012).

Construction began in 1955; the multipurpose pool, 1075 feet above sea level, was attained on April 1963. Total cost of construction was $80,051,031. The original design did not take into account specific earthquake evaluations of soil structure, although the probability of an earthquake the size necessary to damage the dam is very small, due to the potential catastrophic consequences, the Corps of Engineers began work to stabilize the base of the dam. The stabilization consisted of 351 underground concrete walls along one mile of the downstream slope of the dam; each wall is 4 feet wide, 45 feet long, and 60 feet deep. Construction was completed in August 2009 at a total cost of $170,000,000 (U.S. Army Corps of Engineers 2012).

Thus the total cost of construction and redesign of Tuttle Creek Reservoir was over $250 million. Unfortunately the ongoing sedimentation is decreasing the ability of the reservoir to serve the initial purposes of flood control, water supply, and recreation (Juracek 2011).

As a result of the previous investments in reservoirs across the U.S. and the problem with high rate of sedimentation in the structures, several actions have been made to lengthen the life

span of these impoundments. One of them is the creation of the Conservation Reserve Program by the United States Department of Agriculture (USDA) with the goal of removing highly erodible land from crop production (Pimentel et al. 1995).

This thesis was developed in support of these programs. This investigation will contribute to the characterization of the natural riparian areas that have remained in Spring Creek, Snipe Creek, and Headwaters Robideux Creek, three sub-watersheds with the Tuttle Creek Reservoir. Additionally, estimation of the areas that need forest management and forest establishment will be given.

Sedimentation and tree effect in soil retention

The United States loses billions of tons of cropland soil each year, and about 60% of this soil is deposited in streams that run into reservoirs or to the ocean (Pimentel et al. 1995). Although sedimentation is a natural process, the problem in agricultural fields is the high rate of soil loss that can occur in the process of production. Pimentel et al. (1995) states that human survival and prosperity depend on adequate supplies of food, land, water, energy, and biodiversity; infertile, poor quality land will not sustain food production at the level required by the growing world population.

In U.S. reservoirs siltation is a considerable concern because the phenomena reduces water storage capacity and electricity production, additionally shortens the lifespan and increases the maintenance costs of impoundments. Agricultural soils that are being deposited into U.S. reservoirs and aquatic systems each year reduce flood-control benefits, clog waterways, and increases operation cost of water treatment facilities (Pimentel et al. 1995).

There are several characteristics that influence soil loss and soil productive capacity, those are: slope of the land, soil composition, presence of soil biota, soil depth, organic matter, water-holding capacity, nutrient level, and extent of vegetative cover all influence the rate of erosion (Pimentel et al. 1995; after U.S.D.A. 1989). Additionally Juracek (2011) found that sediment deposition can originate from four sources: (1) stream channel beds, (2) stream channel banks, (3) surface soil within the basins, and (4) shoreline surrounding the reservoir; although the source of sediment cannot be easily specified.

Several attempts to reduce sediment loads into streams have been implemented across the U.S.; one of the most common is the implementation of best management practices (BMP's),

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among these practices are: no-till, reduced tillage, grassed waterways, filter strips, and cover crops; these help control erosion from agriculture fields. Construction of impoundments and channel stabilization also reduce sedimentation downstream (Juracek and Ziegler 2009).

Additionally establishment and management of riparian forest buffers are also a strategy to reduce sediment loads into streams, as these areas have predominantly trees and shrubs located adjacent to and up-gradient from watercourses or water bodies (USDA-NRCS 2010). The width of the riparian buffer should be big enough to avoid ponding and to catch and cycle significant amounts of nutrients leaching from the agriculture fields. For higher efficacy of agroforestry buffers, contour buffers, and grass barriers should follow the contour lines of the landscape (Schultz et al. 2009).

Channel stabilization, also known as streambank stabilization, can take several forms depending on the severity of the bank erosion, soil characteristics, and the volume of water and velocity flowing through the channel.

Some of the most common methods to stabilize streambanks are riprap, mixtures of vegetation and riprap, geotextiles, and tree plantings (specially willow posts) (Pollen-Bankhead and Simon 2010). Studies have shown that vegetation enhance soil strength due to the spatial density of its roots, additionally it has been proven that most of the reinforcement comes from a relatively small number of large roots, rather than abundant small roots. Furthermore, mixtures of riparian woodlands and grass species had provided the most beneficial outcomes, as these mixtures also have a high potential for improving biodiversity in riparian areas (Simon and Collison 2002).

Streambanks and vegetation

In terms of bank stabilization as Pollen-Bankhead and Simon (2010) suggest, tree plantings with grasses may provide an extra hydrologic reinforcement in the early years of trees growth. The relative importance of tree root effects will change seasonally and over the lifetime of the tree. For example: models show that during winter and spring months root reinforcement remained the most important contributor to streambank stability. In summer months evapotranspiration provides the greatest potential benefit to streambank stability, as drier soil is much more resistant to erosion than wetter soil.

One of the biggest concerns of landowners in terms of tree plantings along streambanks or along the riparian area is undercutting and collapse of trees into the stream; taking away massive amounts of soil attached in the root systems. Moreover streambank retreat impacts floodplain residents, riparian ecosystems, streamside structures (bridges and roads), in addition to water quality impoverishment (Wynn and Mostaghimi 2006; after ASCE 1998). These concerns are explained in several scientific papers that analyze the driving forces that interact in these systems. Simon and Darby (1999) key finding was that the riparian hydrologic effects were as important as the riparian mechanical effects, and can be either beneficial or detrimental, depending on antecedent rainfall. And not as generally considered before by Coppin and Richards (1990), that riparian vegetation was generally a mechanical aid of streambank stabilization neglecting the hydrologic effects. Simon and Collison (2002) divided the impact of vegetation in two stages, mechanical and hydrologic effects; and within these subdivided by stabilizing and destabilizing effects. As an explanation of these effects Simon and Darby (1999) pointed out that streambank retreat occurs by a combination of hydraulic-induced bank-toe erosion and streambank mass failure. Afterwards, stream collapse occurs when the driving forces (stress) exceed the resisting forces (strength).

Streambank failure generally occurs during the winter or early spring months when temperate zone deciduous vegetation is dormant with little leafy canopy. In addition, rainfall and other forms of precipitation are often higher during these seasons and evapotranspiration does not have a significant impact on soil moisture until mid-spring (Simon and Collison 2002; after Dingman 1994). All these characteristic combined make these areas more prone to destabilization and further failure. These factors can be especially prevalent in Kansas with highly variable precipitation and vegetation having these characteristics.

Overhanging vegetation can have both beneficial and detrimental effects. Trees leaning out over a stream can stress their root system from the leverage. As roots are undercut, the entire tree can fall into the stream. Some of the benefits that riparian woodlands provides is shade and dropping leaves and twigs that are part of the food chain of aquatic life.

The benefits and disadvantages in hydrological effects of vegetation, are complex because the balance between rainfall interception, infiltration, and actual rates of evapotranspiration will change throughout the year as the climatic conditions; antecedent soil

moisture conditions, and the stage in the yearly growth cycle of vegetation changes will also have an impact on the effect of vegetation along the stream (Simon and Collison 2002).

There is no doubt that vegetation plays an important role in regulating soil moisture and temperature regimes; and also that the impact of riparian vegetation on streambank erosion will depend on how susceptible a soil is to erosion, depending on the soils inherent structure and composition. Some of the factors driving soil erosion in temperate climates are the cycling of freeze-thaw and also desiccation. As examples of these cycles it can be mentioned that woody vegetation may provide the best protection against loss of soil strength for desiccation; as for silty soils (prone to needle-ice formation), a dense ground cover may provide a better protection than deciduous woody vegetation (Wynn and Mostaghimi 2006).

Nilaweera and Nutalaya (1999) studies showed that the main stabilization mechanisms such as soil reinforcement; soil arching and buttressing; and root anchoring depend on tree root strength and distribution within the soil. Furthermore, they found that longer roots of smaller diameter are likely to result in higher root tensile strength and improve pull out resistance.

A study by Abernethy and Rutherfurd (2001) investigated root effect in bank stabilization and showed that root slip resistance varies within the length, branching pattern, tortuosity of the roots, and the nature of the material in which they are growing. They also found that tree roots usually penetrate several meters into the soil, and their tortuous path through the soil typically provides good anchorage.

Furthermore Geyer et al. (1997) documented that the lateral erosion of riverbanks due to the flood of 1993 (a 500-year event), varied greatly by the type of vegetation present within 100 feet of the channel. Kansas River banks that had crop field cover lost an average of 150 feet, and grass covered banks lost an average of 78 feet from this one flooding event. However, if just a single row of trees was present, the bank accumulated sediment, and gained 4 feet. If the dominant land-cover type was forest, then the bank gained 10 feet. This flood attenuation effect is likely due to standing trees reducing water velocity, thus reducing the energy available for erosion and allowing deposition of suspended materials. They also surmised that greater rooting depth, larger and stronger roots and perhaps greater rooting density also stabilize the soil mantle (Geyer et al. 1997).

Some important information that can be emphasized from these studies is that there are many factors that can improve or decrease streambank stabilization effectiveness. Thus when

implementing a plan for bank stabilization all these factors should be analyzed and taken in account for the best of outcomes. Moreover as is stated by Molles et al. (1998) it is essential to combine studies of ecosystem functional responses with community and population studies.

Riparian forest characteristics

A riparian zone is defined as a terrestrial area, other than a coastal area, of variable width adjacent to and influenced by a perennial or intermittent body of water. The riparian zone contributes organic matter to the river or stream and may be influenced by periodic surface or subsurface water. It also provide a functional linkage between terrestrial and aquatic ecosystems through coarse and fine organic matter input, bank stability, water temperature regulation, sediment and nutrient flow regulation, maintenance of wildlife habitat, and limiting nonpoint pollution source (Helms 1998).

Something that a riparian forest can reveal to the community and foresters working in the area is the spatial and temporal variation of flood events due to the resetting of the successional cycle and establishment of pioneer species that occur after a flood event (Shafroth et al. 2002; after Salo et al. 1986; and Stromberg 1998).

Additionally as is presented by Hupp and Rinaldi (2007) the existence of given species of vegetation on a particular land form has the potential to provide information about the hydrogeomorphic conditions of the area. This information can be gathered due to the distributional pattern in vegetation that can be limited by the tolerance of species for specific disturbance regimes (as flood events) or stress (as drought), and consequently by tolerance for biotic interactions. This is also related to temperate fluvial systems where water is the most proximal control on the distributional pattern of perennial riparian vegetation.

Riparian ecosystems have been recognized as a critically functional dominant component of a terrestrial landscape (Sunil et al. 2010; after Tabacchi et al. 1998), but they are also one of the most sensitive to human influence and potentially threatened ecosystems (Sunil et al. 2010; after Gopal 1988). However, riparian areas are often recognized to be potentially the most productive area for crops due to soil quality and available moisture. With this in mind it has to be acknowledged that riparian ecosystems are spatially and temporally dynamic; and also they are shaped by fluvial and upland geomorphic processes (Auble et al. 1994). Disturbances and stress regimes may influence the species composition of plant communities in riparian areas (Shafroth

et al. 2002). Therefore, occasional flooding and excessively wet soil in riparian areas may reduce the actual realized crop production.

Other benefits attributed to riparian areas are effectiveness in modifying scour, erosion, and improvement of environmental quality (Simon and Collison 2002; after Thornes 1990; and Simon and Darby 1999). These ecosystems are also associated with a mixture of heterogeneous plant species (usually native to the area) that improve water quality; give protection against soil erosion; and supply natural habitat for wildlife by Yang (2007); after LWRRDC (1999); and Dunn (2002) providing a biological linkages between terrestrial and aquatic environments and supporting many vertebrate species (Gregory et al. 1991; after Brinson 1981).

Although riparian areas are such an important ecosystem, they are poorly understood because many streams have been mildly to severely affect by human disturbances such as gravel mining and channelization operations (Hupp and Rinaldi 2007; after Hupp 1992). As Molles et al. (1998) explain the widespread modification of river and riparian ecosystems creates an urgent need to better understand the ecological effects of isolating riparian ecosystems from rivers and to develop methods to restore better management in these threatened ecosystems.

For a riparian area to have a proper functioning condition (PFC) there should be adequate vegetation, landform, and large woody debris present to dissipate stream energy associated with high flow events (USDI 1998). Thereby reducing erosion and improving water quality; filtering sediment, capture bedload, and aid floodplain development; improve flood-water retention and ground water recharge; develop root masses that stabilize streambanks against cutting action; develop diverse ponding and channel characteristics to provide diverse habitat and support greater biodiversity. The functioning condition class is a result of interaction among geology, soil, water, and vegetation (USDI 1998).

Riparian areas have their own unique attributes from site to site. Even for similar areas, human influence may have introduced components that have changed the area's capability and potential, therefore, each area should be analyzed against its own capability and potential (Barret et al. 1998, USDI 1998).

As Helms (1998) emphasizes the management of riparian areas is commonly constrained or modified to retain particular ecosystem values and functions; and the term is used in management plans, legislation, regulation, and government policy in which riparian area width is variably defined.

Area of interest

The area of interest for this study is Snipe Creek, Spring Creek, and Headwaters Robideux Creek, sub-watersheds that drain into the Tuttle Creek Reservoir. One of the major concerns is that the impoundment is filling with sediment, thus decreasing the ability of the reservoir to serve several purposes including flood control (this being the main reason why the impoundment was built), water supply, and recreation (Juracek 2011). These sub-watersheds were selected by the Tuttle Creek Watershed Restoration and Protection Strategy (WRAPS) group because these sub-watersheds have highly erodible soils prone to high rates of sedimentation. In addition, the Tuttle Creek Reservoir Watershed has been identified within the Kansas Forest Resource Assessment and Strategy (KFRAS) as high priority area in terms of potential forest benefits to water quality and quantity (Atchison et al. 2011).

As Juracek (2011) states the sediment trapping efficiency for Tuttle Creek Reservoir was estimated to be 98%. Interestingly enough he also found that silt and clay content in the bottom sediment of Tuttle Creek was also 98% or greater.

Efforts are being made to reduce erosion in crop fields; one of these efforts is the Conservation Reserve Program (CRP). CRP is a program that pays a rental fee to a farmer that agrees to remove environmentally sensitive land from agricultural production and plant species that will improve environmental health and quality (FSA 2014). Best management practices that the CRP encourages are: buffers for wildlife habitat, wetland buffers, riparian buffers, wetland restoration, filter strips, grass waterways, shelter belts, living snow fences, contour grass strips, salt tolerant vegetation, and shallow water areas for wildlife.

Objective of the study

The objective of the study was to characterize the structure and composition of natural riparian woodlands of three sub-watersheds within the Tuttle Creek Watershed.

These three sub-watersheds are denoted with 12 digits as HUC 12's. This denomination is given by the U.S. Geological Survey (USGS) as the subdivision of smaller hydrologic units which are classified into four levels: regions, sub-regions, accounting units, and cataloging units. The hydrologic units are arranged or nested within each other, from the largest geographic area (regions) to the smallest geographic area (cataloging units). Each unit is identified by a unique hydrologic unit code (HUC) (USGS 2013).

This study documents the vegetation composition and structure of the existing natural riparian areas in three of the sub-watersheds; this contribution will help stakeholders to implement the most effective vegetation plantings (in terms of economic benefits for the land owners, and plant suitability for the sites) in areas that are in need of establishment and management in the sub-watersheds.

This characterization will help as a tool for stakeholders as the Kansas Forest Service, and the WRAPS shared leadership team implement management and reestablishment plans in the areas of the sub-watersheds in need of these actions. Moreover, this research will also validate the method to document woodland vegetation in the State of Kansas previously used in the Delaware River Watershed by Maradiaga Rodriguez (2012).

As part of the data collection and analysis obtained for these three watersheds, basal area, trees per acre, tree height, canopy class and cover, quadratic mean diameter, and forest regeneration data was gathered. Additionally, qualitative notes as forest management activity, invasive species, livestock use, non-woody understory, and second active channel width (2ACW) land use were documented.

Furthermore to the data analysis, a classification of the economic value of the species was determined. The general purpose of this classification was to give a supplementary benefit to the landowners that want to actively manage their riparian areas.

Chapter 2 - Materials and Methods

The following chapter will focus on the materials and methods used for collecting data and assessing riparian woodlands of three sub-watersheds within the Tuttle Creek Watershed. Data was collected in Spring Creek, Snipe Creek, and Headwaters Robideux Creek, with 15 plots in each sub-watershed, resulting in a total of 45 plots.

Riparian forest extent was determined using Geographic Information System 10.1 (ArcGIS 10.1, Appendix B) by the Kansas Forest Service. Aerial photographs and Natural Resources Conservation Service (NRCS) soils maps were used to assess areas of interest in the sub-watersheds. Areas where data was collected met the requirements for tree and shrub soil suitability, and forest width for areas in need of protection. On-the-ground data collection was assessed to complement the GIS database that will provide assistance to stakeholders working with landowners in the watershed.

Sample Design

Sites for data collection were selected using a representative sample design. With help of the GIS tool, aerial photographs and NRCS soils maps were merged, and then visually assessed areas in need of protection were determined, and then randomly selected for on-the-ground data collection. After the random selection, contact with the landowners of these locations was made to request access to their properties. The reason only areas in need of protection were assessed was the objective to evaluate the species composition and structure of natural riparian woodlands in the selected sub-watersheds.

Active Channel Width, Forest Width, and Plot Locations

Snipe Creek, Spring Creek, and Headwaters Robideux Creek had incised and heavily human-modified stream channels; for these conditions the active channel width (ACW) was estimated at the average one year bankfull height that is denoted by the first line of perennial vegetation present on the stream bank closest to the water line (Figure 2.1). To precisely measure this distance across the stream channel a LaserAce^TM 1000 Rangerfinder manufactured by Trimble® (Sunnyvale, California) was used.

Forest width (FW) was measured perpendicular from the top of the streambank to the forest edge. The measurement was taken with a reel mounted fiberglass tape when the FW was less than 100ft.

Figure 2.1 Measurement of stream active channel width

Plots were set up from the top of the streambank with a transect line perpendicular to the stream course. Every plot location was recorded with a global position system coordinate using a Garmin® eTrex® 20 (Olathe, Kansas).

Data Collection

The first step to collect data in the field was to contact the landowners who had riparian woodlands and secure their permission to walk through their properties and collect data. Field measurements were taken in representative riparian woodlands at several locations across a property. No plant material was collected, only measurements and qualitative notes were gathered.

The sites had to meet several requirements to be selected, with one of the most important requirements being the presence of Natural Resources Conservation Service (NRCS) soil suitability Group 1 and 2 soils adjacent to the stream. Group 1 and 2 soils are classified by the

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NRCS as suitable for planting trees and shrubs (Hart 2007). Another requirement was to have a forest width of at least 50ft measuring from the top of the streambank transversally to the forest edge.

Population of interest

Several riparian and conservation guidelines indicate that a properly functioning riparian area will have a healthy natural plant community which extends at least two bankfull widths on each side of the stream, and it is generally contiguous throughout the property (NRCS 2009). For this study the length of the plots was maintained with a minimum 50ft although some of the stream's ACW were smaller than 50ft. This standard plot size was applied due to the need for a substantial area to characterize the vegetation. Additionally as Maradiaga Rodriguez (2012) points out it provides a consistent plot size within similar reaches.

All of these standards were adapted from earlier efforts to identify proper functioning condition (PFC) riparian areas (USDI 1998). Additionally the Stream Visual Assessment Protocol version 2 (SVAP2) was also adapted to this study (USDA-NRCS 2009).

Overstory trees: plot size, shape, and number

Elzinga (1998) standardized a sampling design for vegetation measuring. This method involved rectangular plots that facilitated measurement of plant material due to shape and size of the plot. For mature tree vegetation a rectangular plot of 50ft long by 30ft wide was used. The total area was $1500ft^2$; except for three plots in Spring Creek where an ACW of 75ft was documented, so the plot size change to 75ft x 30ft with a total area of $2250ft^2$ per plot. Each plot was marked from the top of the streambank, above where the ACW was measured, with a transect line of 50ft or 75ft delineated with a reel mounted fiberglass tape perpendicular to the stream course. Then 15ft was measured on each side of the transect line, giving a total width of 30ft (Figure 2.5). A total of 45 plots were located in 3 sub-watersheds, 15 per sub-watershed (Figure 2.2 – 2.4). Data collected in each plot was recorded in a field work sheet (Appendix A) and afterwards was entered in a Microsoft Excel 2010 spread sheet.

Tree species

Identification of tree species was achieved by visual examination of several parts of the tree. Among those parts were bark color, texture, and structure; leaves structure and arrangement; fruits or seeds, twigs, and branch arrangement (Maradiaga Rodriguez 2012).

Tree height

Mature tree height was measured with a clinometer PM-5 manufactured by Suunto. The method used to take the height measurement was via triangulation; first the person taking the measurement walked a distance of 66ft from the base of the tree. Then the clinometer was pointed to the base and top of the tree; the reading of the numbers on the right side of the clinometer was added or subtracted depending on the position of the tree base relative to the eye of the person reading the numbers. If the person's eye was above the tree base the numbers are added; if the tree was in an upslope position and the tree base has a positive value then that number was subtracted from the reading from the top of the tree. Only the tallest one or two trees were actually measured in each plot. Ocular appraisal was used to estimate the height of other trees in the plot.

Diameter at breast height (DBH)

The DBH is a measurement used commonly in forestry. Diameter at breast height is taken in tree stands to determine tree growth, wood volume, yield, and forest potential. This measurement is taken at a standard height of 4.5ft on the uphill side of the tree (Helms 1998). DBH was measured with a diameter tape (d-tape). Only trees with a DBH $\geq$ 5 inches were measured.

Canopy class

Tree canopy class was determined by visual examination. After recording total height of the tree a classification depending on the relative tree crown height was made. Crown classification was defined as Nyland (1996) suggest:

a) Dominant: trees with large and well-developed crowns that extent above the general layer. These crowns intercept sunlight from top and all the sides of the upper branches.

b) Codominant: trees with medium size crown well-developed. These crowns intercept sunlight along top of the tree and tip of side branches.

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c) Intermediate: trees with narrow and short size crowns. These crowns intercept direct sunlight only at a limited area on top of the tree and none at the sides.

d) Overtopped: trees with small crown, often lopsided, flat-topped, and sparse. These crowns remain under the main canopy area and covered by branches of taller trees. No sunlight strikes directly to any part of the crown.

Riparian Forest Analysis Area

Spring Creek Watershed
Marshall County, Kansas

0   1   2 Miles

- Sample Site Locations
- Riparian Forest Potential/Capability
- 2ACW Riparian Buffer
- Spring Creek HUC12 Boundary

Sources:
Marshall County, Kansas LiDAR 2010
USDA NRCS Soils Survey Geographic Database (SSURGO)
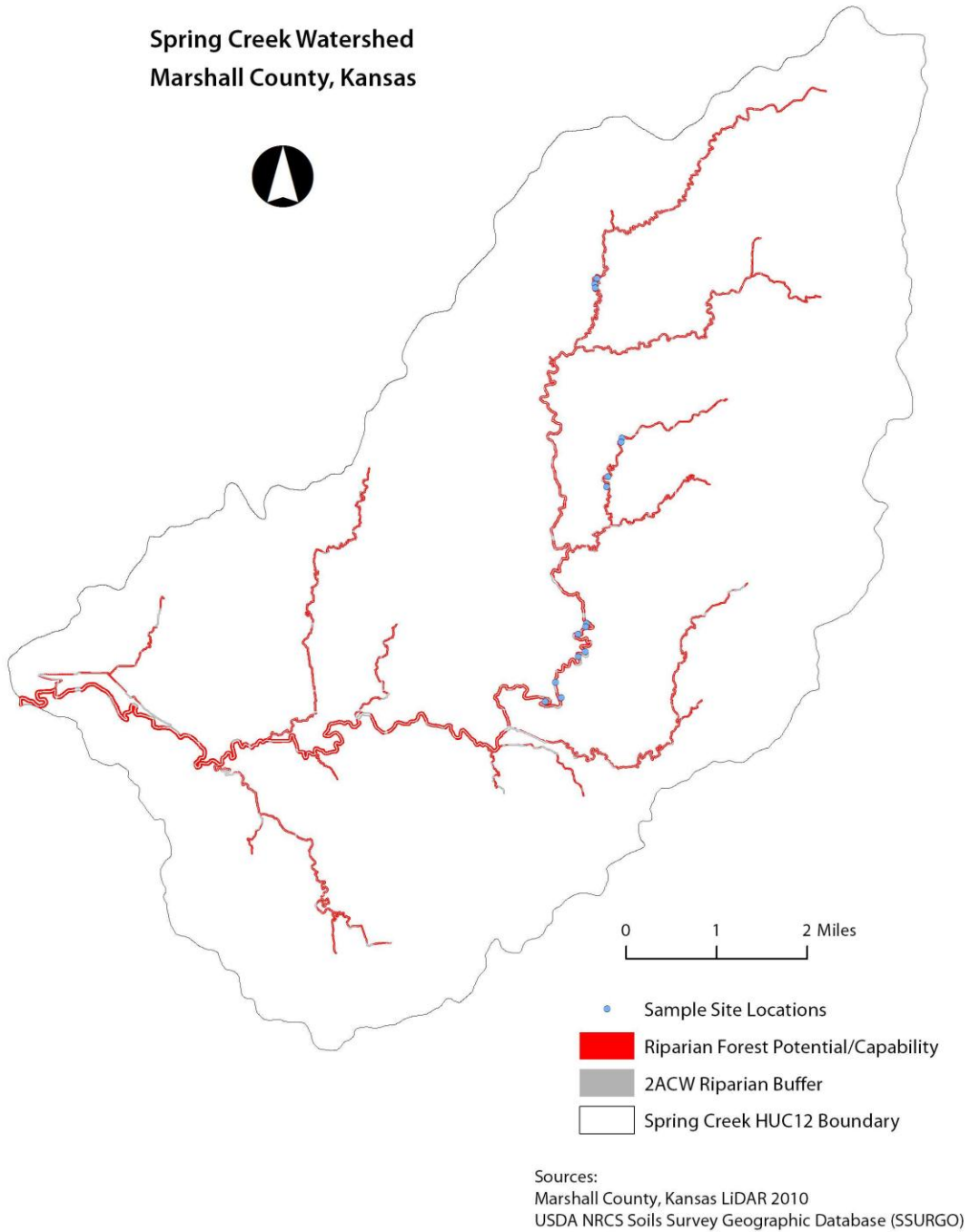
Figure 2.2 Plot location on the riparian areas in Spring Creek

Riparian Forest Analysis Area

Headwaters Robideux Creek Watershed
Marshall County, Kansas

Sample Site Locations

Riparian Forest Potential/Capability

2ACW Riparian Buffer

Headwaters Robideux Creek HUC12 Boundary

Sources:
Marshall County, Kansas LiDAR 2010
USDA NRCS Soils Survey Geographic Database (SSURGO)

0   1   2 Miles
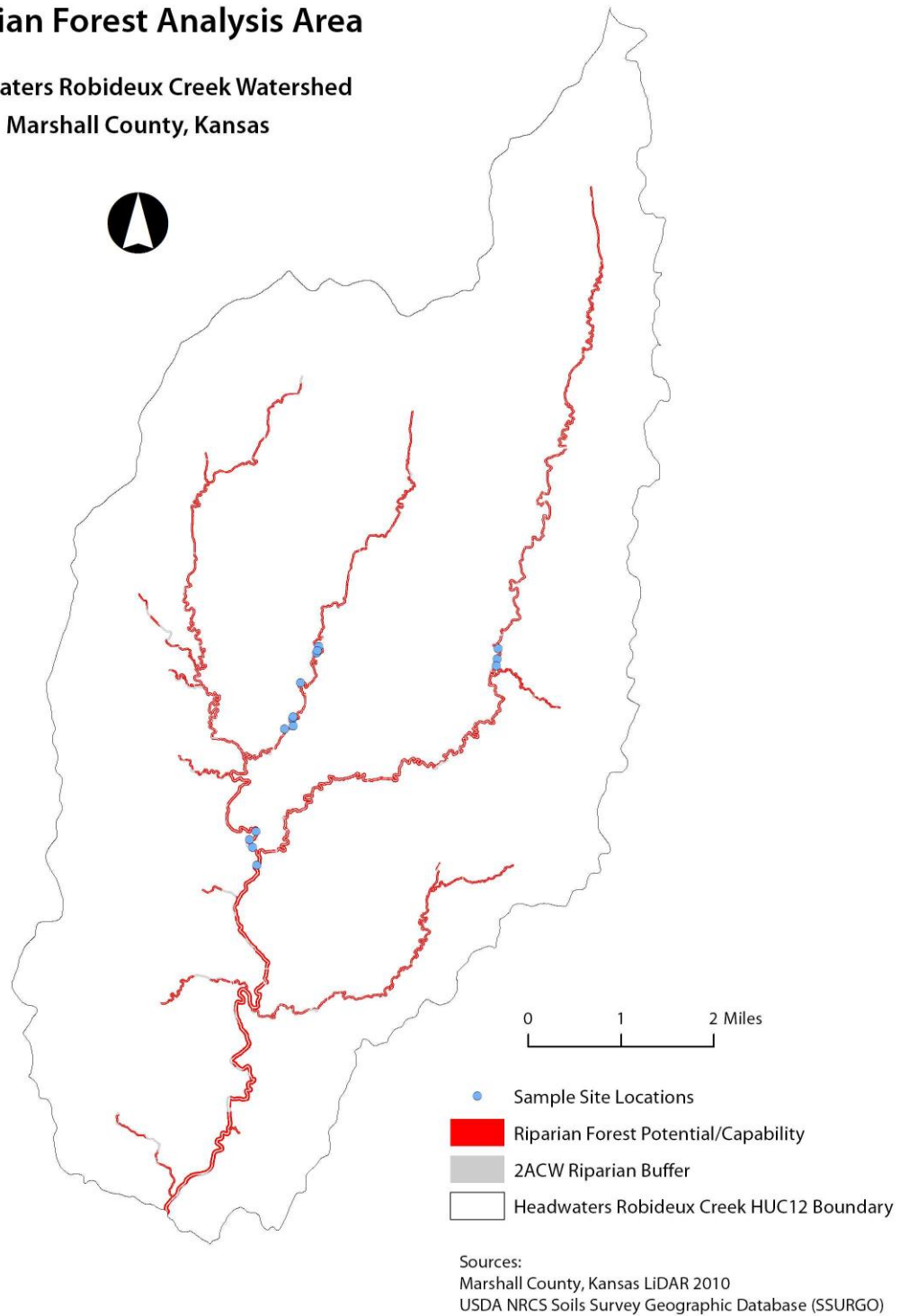
Figure 2.3 Plot location on the riparian areas in Headwaters Robideux Creek
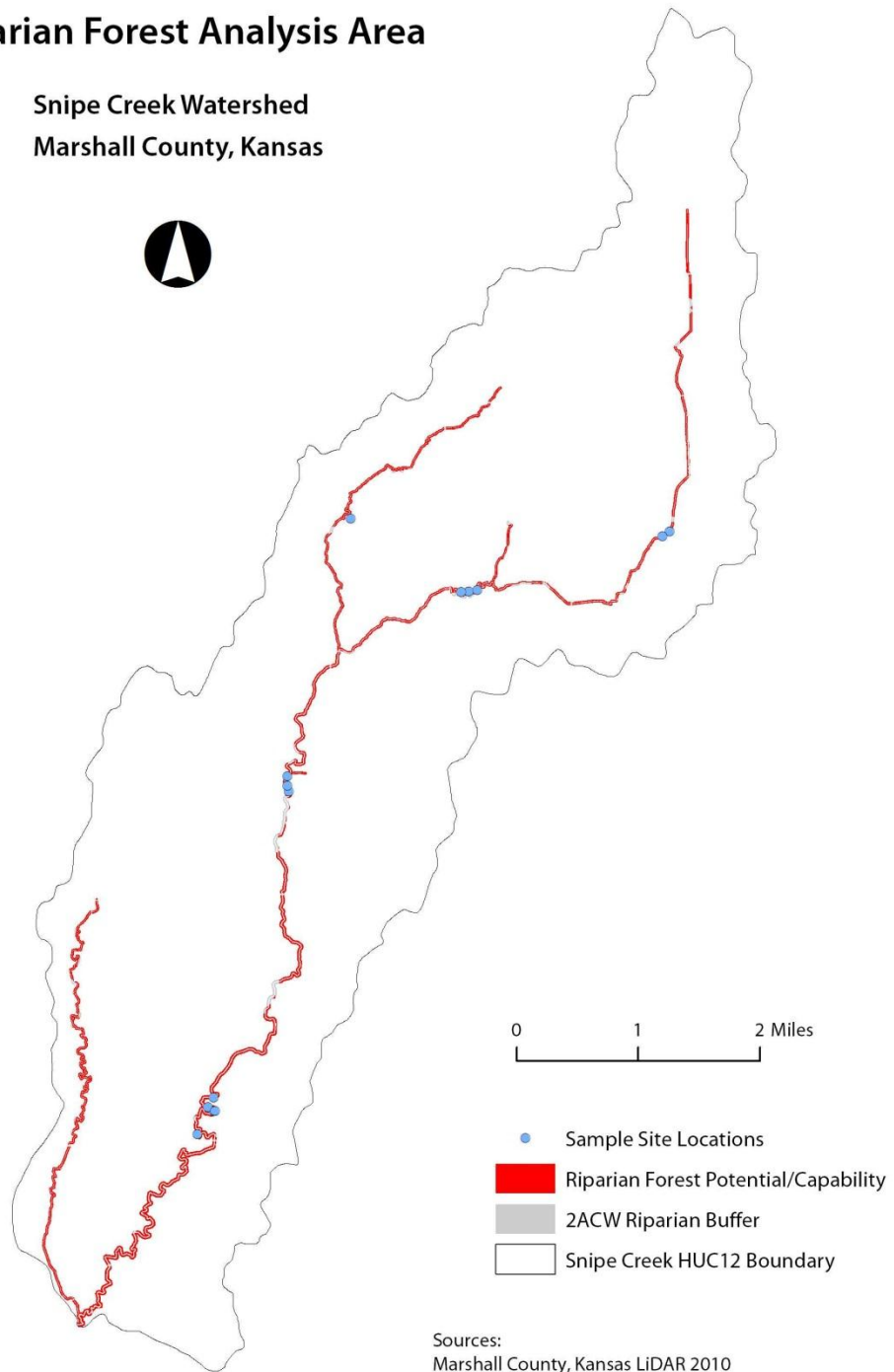
Figure 2.4 Plot location in the riparian areas of Snipe Creek

Seedlings and Saplings: plot size, shape, and number

A different plot size and shape was used to measure tree regeneration. The idea of changing size and shape of the plots was due to the large amount of seedlings and saplings that could be found in a small area. Circular plots were used with a radius of 5.3ft and a total area of 88.247ft^2 per plot; which allowed a plot to be easily delineated with a center point pin, and a length of rope for the radius.

Four plots were assessed within the general rectangular plot with two circular plots taken on each side of the transect line. Locations of two plots were selected from a statistical random number table, and the other two plots were mirror locations from the first draw (Figure 2.5). When selecting the numbers from the random table, the first number determined the position along the transect line, the second number determined the perpendicular position from the transect line to the edge of the plot.

A stratified sample was taken for the regeneration plots, one plot was selected from the random table to be located between 5ft and 25ft and the mirror plot was located in the same number combination in the other side of the transect line; then the other plot was located between 30ft and 45ft and the same procedure was made to locate the mirror plot in the second half of the transect line. Once the sample point was obtained the circular plot was marked and all the seedlings (woody vegetation <1 inch diameter at breast height) and saplings (woody vegetation of ≥ 1 inch and < 5 inches diameter at breast height) were recorded (Maradiaga Rodriguez 2012). This same methodology was applied by Maradiaga Rodriguez (2012), with the addition of the two mirror plot locations.
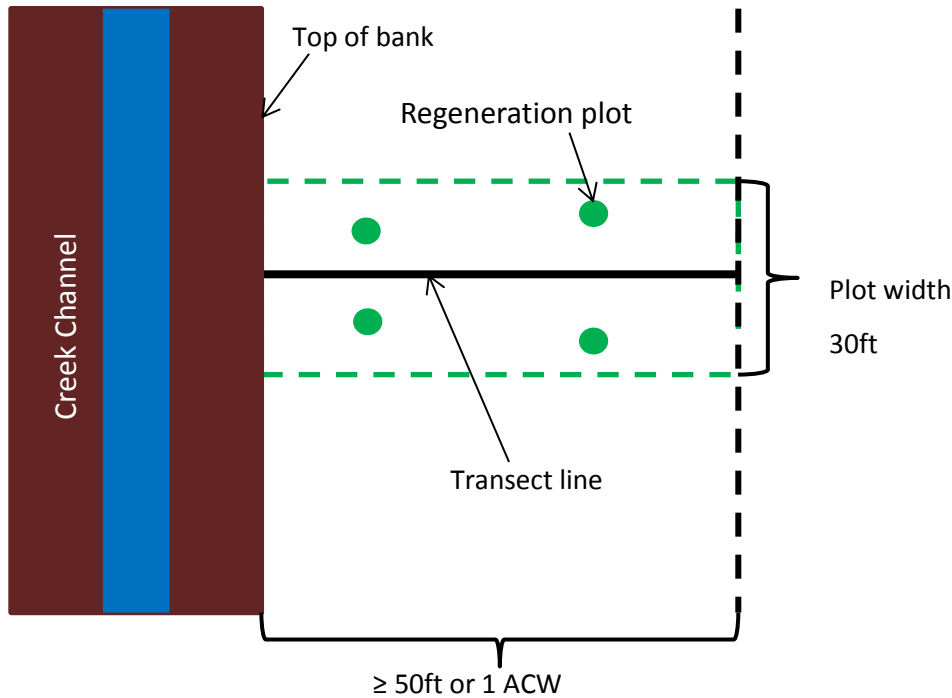
Figure 2.5 Plan view of plot design

Qualitative notes

In addition to the woody trees data collection, notes on evidence of activity in the surrounding area were recorded. If cattle use was obvious, or woodland management or harvest was evident, these observations were recorded. Also the predominant composition of the understory (shrubs, grasses) was recorded, along with notes on the relative density. The presence of invasive species such as garlic mustard and brome was also denoted. The area where these notes were recorded delimited the riparian forest from the top of the streambank for a width of two ACW, or at least 100ft. The predominant land use (cropland, grass, or forest) of the second active channel width was also recorded.

Data Analysis Procedures

Several steps were followed to process the data collected in the field. The first was to enter the data onto Excel spread sheet file.

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

Basal area as a definition is the cross-sectional area of a single stem, including the bark, measured at breast height (Helms 1998). Calculation of the basal area follows the formula computed by Avery (1994):

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

$$BA(ft^2) = 0.005454 dbh^2$$

Where: BA = is the basal area of the tree in square feet; dbh = is diameter at breast height; π = is the mathematical constant 3.1416. This calculation was done for every tree in the plot. Afterwards the total BA by species was calculated, adding the BA of the same species of tree in the plot. Then an expansion factor was used to determine the basal area per acre. This expansion factor was according to the plot size. The size of the plots was at least 1500ft^2, and with 43,560ft^2 in an acre, then:

$$Expansion\ factor = \frac{43,560 ft^2}{1500 ft^2} = 29.04$$

Spring Creek assessment had one of the streams that had an ACW of 75ft so this measurement had to be treated differently in the calculation of the expansion factor, as the total area of the plot was 2250ft^2, then:

$$Expansion\ factor = \frac{43,560 ft^2}{2250 ft^2} = 19.36$$

So, the total basal area per species per plot was multiplied by the expansion factor to calculate the basal area of each species per acre. This computation was done to provide consistent terminology with other forestry studies.

Quadratic mean diameter as Curtis and Marshall (2000) described is the measure of average tree diameter conventionally used in forestry, rather than arithmetic mean diameter. The QMD gives greater weight to larger trees and is equal to, or greater than the arithmetic mean. As a definition the QMD is the diameter of the tree of average BA.

The QMD is calculated by:

$$QMD = \sqrt{\frac{B}{(k * n)}}$$

Where: QMD = is the quadratic mean diameter in inches; B = is the basal area per plot per species; k = is the constant that depends on the measurement units used (in this case 0.005454 because the basal area was measured in square feet); and n = is the corresponding number of trees per species per plot.

Trees per acre

Number of trees per acre (TPA) was calculated by multiplying the number of trees per species per plot by the expansion factor. This expansion factor was the same as the one used in calculating BA per acre.

Regeneration per acre

Regeneration per acre was calculated in several steps. The first step was to add the seedlings per species of the four plots; then an average of the seedlings for the four plots was calculated. The mean number of tree seedlings by species was multiplied by an expansion factor to obtain the seedlings per acre per species. In this case the expansion factor was calculated as follows:

$$Expansion\ factor = \frac{43{,}560 ft^2}{88.247 ft^2} = 493.61$$

For sapling regeneration the same procedures were used to calculate the number of saplings per species per acre. After the calculation of the number of seedlings and saplings per acre per species, the total number of seedlings was obtained by adding the number of seedlings per species for the plot and this same calculation was done for sapling regeneration. Similar to in the BA, this computation was done to report data in a form consistent with other forestry studies.

Height of trees and crown classification

Although height of the tree is a separate estimate as well as crown classification, they are related to each other. So for this study an average of heights by crown classification was calculated.

Economic Classification

This categorization was based on the market value for timber of the tree species. This piece of information was important to document since it may be necessary to provide an incentive to carry out strategies for establishment and management plans of the riparian areas. This categorization was used by Maradiaga Rodriguez (2012) in the Delaware River Watershed study. Group 1 was composed of the high value species such as black walnut and bur oak; Group 2 was composed of the medium value species: green ash, hackberry, and bitternut hickory; finally Group 3 was composed of species of low economic value: American elm, buckeye, honey locust, Kentucky coffee tree, mulberry, Osage orange, eastern redcedar, and boxelder.

Statistical analysis

The data was evaluated and analyzed for statistical significance with the Statistical Analysis System SAS 9.3 (SAS Institute, Inc. Cary, NC, USA).

Data for TPA, BA per acre, and QMD had a normal distribution; therefore a General Linear Model (GLM) was used; additionally a pairwise comparison analysis of the watersheds with a Tukey adjustment was applied. Regeneration data (seedling and sapling) counts had a Poisson distribution; therefore a General Mixed Model (GLIMMIX), Poisson distribution, and logarithmic link function were used; also a pairwise comparison with Tukey-Kramer adjustment to the data was applied. The GLIMMIX procedure was also used for the analysis of the economic group classification. The GLIMMIX analysis was applied to the plot based data set without calculating the expansion per acre factor. Applying expansion factor to data sets with numerous observed zeroes resulted in an exaggeration of the data variability and thus an inability to provide statistical separation of means.

Lin (2003) did a recollection of methods for analyzing tree stands. One of the methods used in forestry was the Poisson distribution to analyze data that has several characteristics; such as discrete outcomes ($x = 0, 1, 2, 3 \dots \infty$), infrequent events (saplings); among others. Also de Vries (1986) determined that natural regeneration can be described by the Poisson distribution.

Chapter 3 - Results and Discussion

Basal area (BA) per acre was not significantly different ($P < 0.05$) among watersheds. Trees per acre (TPA) was significantly different with $P = 0.0031$. The pairwise comparisons analysis of the watersheds showed there was a significant difference between Spring Creek and Snipe Creek with a $P = 0.0023$ (Figure 3.1).
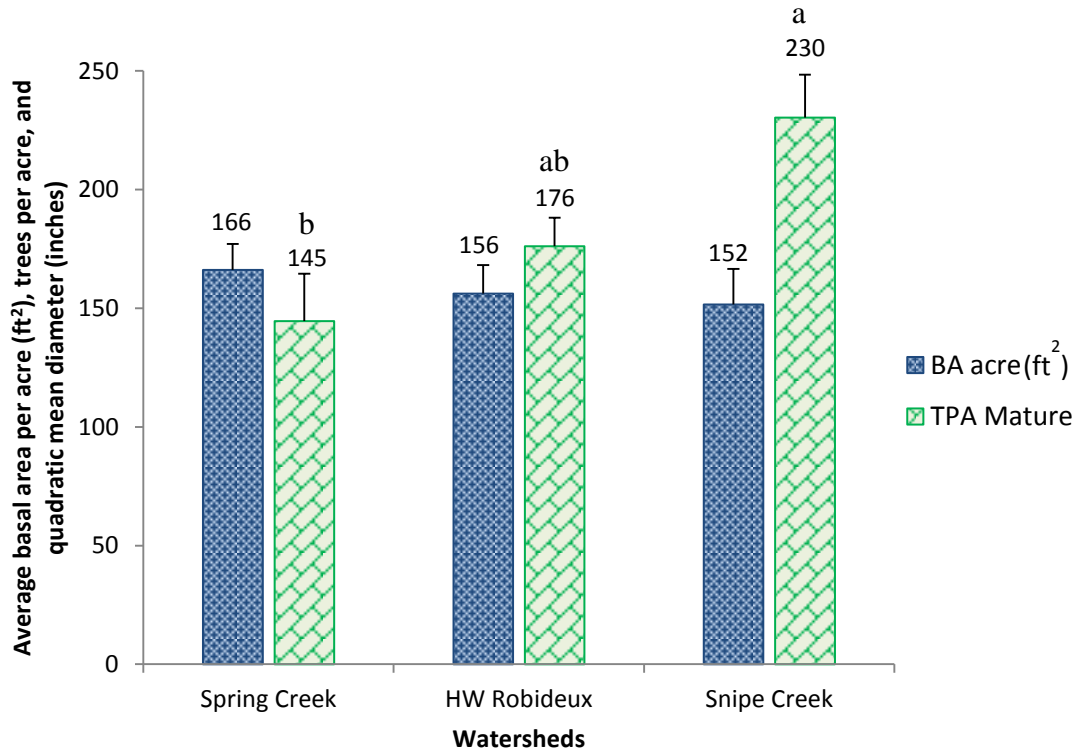
Figure 3.1 Comparison of basal area per acre and trees per acre in the three sub-watersheds.

Different letters represent significant differences with $P < 0.05$

As could be noticed in Figure 3.1 Spring Creek differed from the other two sub-watersheds with higher BA and fewer TPA. This indicates that the trees present in Spring Creek are on average bigger in diameter. The implication for the sub-watershed is the opportunity to harvest. In the contrary Snipe Creek showed a higher number of TPA with the smallest BA per acre, denoting that the diameter of the trees in the sub-watershed was small. Therefore it can be

implied that the management opportunities for this sub-watershed is. For example: thinning of the unwanted species with a replanting of other species could be done, which will increase diversity and future harvest opportunities.

Quadratic mean diameter (QMD) was significantly different with P = 0.0019; the pairwise comparisons with Tukey adjustment showed a significant difference between Spring Creek and Snipe Creek with a P = 0.0013. The general height of the canopy also showed significant difference with P = 0.0172; the pairwise comparisons with Tukey adjustment showed that Spring Creek and Snipe Creek were significant different with P = 0.0147 (Figure 3.2).
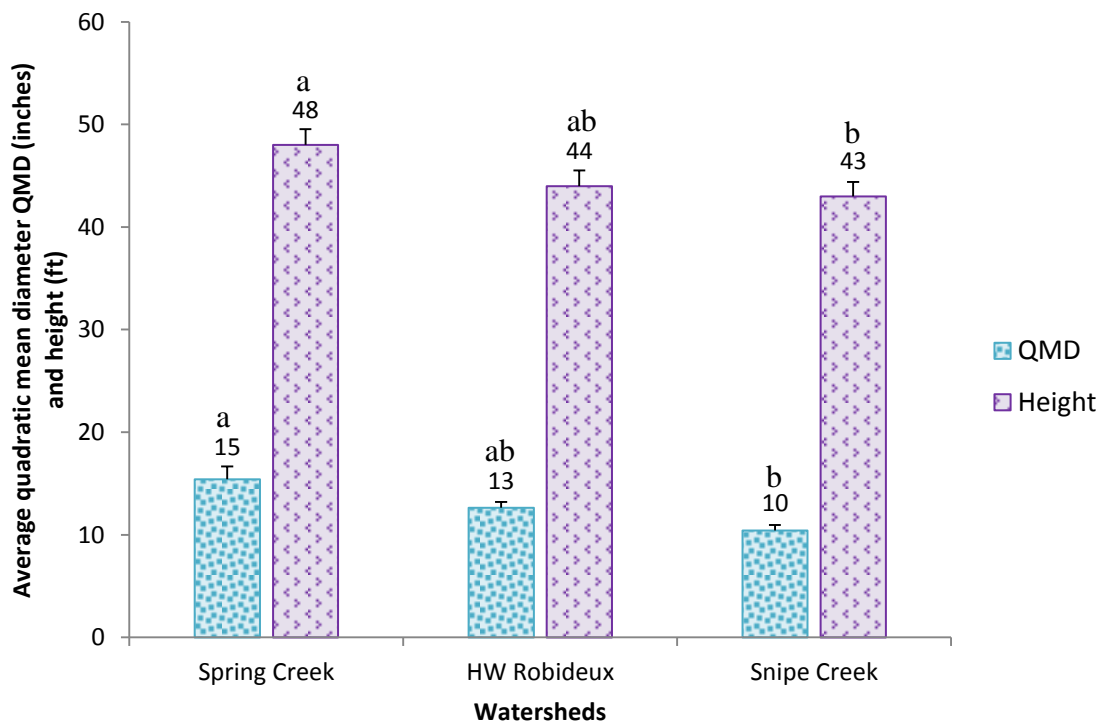
Figure 3.2 Comparison of quadratic mean diameter and tree height in the three sub-watersheds.

Different letters represent significant difference with P < 0.05

Spring Creek in Figure 3.2 showed higher average QMD. This result is consistent with the higher BA/TPA ratio found in the sub-watershed. Snipe Creek results for QMD was the smallest, also accordance with the smallest BA/TPA ratio.

Height showed the same trend as QMD. Spring Creek had the greatest height and Snipe Creek had the smallest height. The Headwaters Robideux Creek had intermediate values for BA per acre, TPA, QMD, and height.

Seedling and sapling numbers per plot were not significantly different with p-values of 0.3481 and 0.9515 respectively. Also the pairwise comparisons with Tukey-Kramer adjustment showed p-values higher than 0.05.

Composition of the three watersheds in terms of tree species was diverse (Table 3.1). The Spring Creek highest BA per acre species was bur oak (*Quercus macrocarpa*) with 38ft^2, followed very closely by black walnut (*Juglans nigra*) with 37ft^2. It was noticeable that Spring Creek also had the highest BA per acre compared with Headwaters Robideux and Snipe Creeks, but it also had the most uniformity in BA for the three most common species ranging from 32ft^2 hackberry (*Celtis occidentalis*) for up to 38ft^2 bur oak. The highest BA per acre species in Headwaters Robideux Creek was black walnut with 62ft^2, followed by honey locust (*Gleditsia triacanthos*) with 24ft^2. In Snipe Creek the highest BA was hackberry with 69ft^2, followed by green ash (*Fraxinus pennsylvanica*) with 24ft^2. Black walnut was found one of the top 3 species for BA in each watershed.

Table 3.1 Riparian woodland basal area composition by sub-watershed.

Spring Creek		Headwaters Robideux		Snipe Creek	
Species	**BA acre (ft^2)**	**Species**	**BA acre (ft^2)**	**Species**	**BA acre (ft^2)**
Bur oak	38	Black walnut	62	Hackberry	69
Black walnut	37	Honey locust	24	Green ash	24
Hackberry	32	Hackberry	22	Black walnut	16
American elm	31	American elm	20	American elm	14
Honey locust	18	Green ash	9	Honey locust	9
Green ash	6	Bitternut hickory	9	Mulberry	9
Boxelder	3	Buckeye	3	K. coffee	7
K. coffee	1	Mulberry	3	Osage orange	3
		Osage orange	3	Bur oak	1
		E. redcedar	1	Buckeye	< 1

The overstory had a total of 10 species in Headwaters Robideux Creek and Snipe Creek. Spring Creek only had 8 overstory species recorded. Black walnut (*Juglans nigra*) was the

predominant species in Spring Creek with 36 trees per acre (TPA) followed by American elm (*Ulmus americana*) with 31 TPA. In Headwaters Robideux Creek the predominant species was black walnut with 62 TPA followed by American elm with 31 TPA. In Snipe Creek the predominant species was hackberry (*Celtis occidentalis*) with 108 TPA. Species as eastern redcedar (*Juniperus virginiana*), osage orange (*Maclura pomifera*), and Kentucky coffee tree (*Gymnocladus dioicus*) were present in the watersheds but in small numbers (Table 3.2).

Table 3.2 Riparian woodland tree species composition by sub-watershed

Spring Creek		Headwaters Robideux		Snipe Creek	
Species	**Avg. TPA**	**Species**	**Avg. TPA**	**Species**	**Avg. TPA**
Black walnut	36	Black walnut	62	Hackberry	108
American elm	31	American elm	31	Green ash	25
Hackberry	28	Honey locust	19	American elm	25
Honey locust	19	Hackberry	17	Mulberry	19
Bur oak	13	Bitternut hickory	12	Honey locust	15
Green ash	8	Mulberry	10	K. coffee	14
Boxelder	7	Buckeye	10	Black walnut	14
K. coffee	3	Green ash	8	Osage orange	6
		E. redcedar	4	Buckeye	2
		Osage orange	4	Bur oak	2

Hackberry (*Celtis occidentalis*) was common in the three sub-watersheds. In BA per acre it was found in the top three species ranging from 69ft^2 to 22ft^2. In TPA the ranges were from 108 to 17. The predominance of the species could be explained due to the tolerance of the plant to shade, especially in the early growing stages (USDA-NRCS 2014). Hackberry is also a plant that produce a berry like fruit that wildlife (especially birds) eat, particularly in the winter months when food is limited (USDA-NRCS 2014). Thus this seed dispersal via the wildlife helps spread the tree species in the riparian woodlands.

The overstory canopy was analyzed according to the height and the canopy crown class. Crown classification was determined with Nyland (1996) methodology, dividing tree crowns depending on the size and sunlight interception area. Figure 3.3 showed the average height and

the tree crown classification that predominated in the three sub-watersheds. Only two dominant trees were documented in the entire data set; one located in Spring Creek, a bur oak with height of 70ft; and another in Snipe Creek, a green ash with height of 83ft. Figure 3.3 showed that the range of heights had little variability within crown classification by sub-watershed, but an obvious trend was present when comparing height by crown classifications. Significant differences were not found within codominant or overtopped classifications. The exception was the intermediate classification that showed significant difference with P = 0.0180; the pairwise comparisons with Tukey-Kramer adjustment showed a significant difference between Snipe Creek and Spring Creek with P = 0.0265
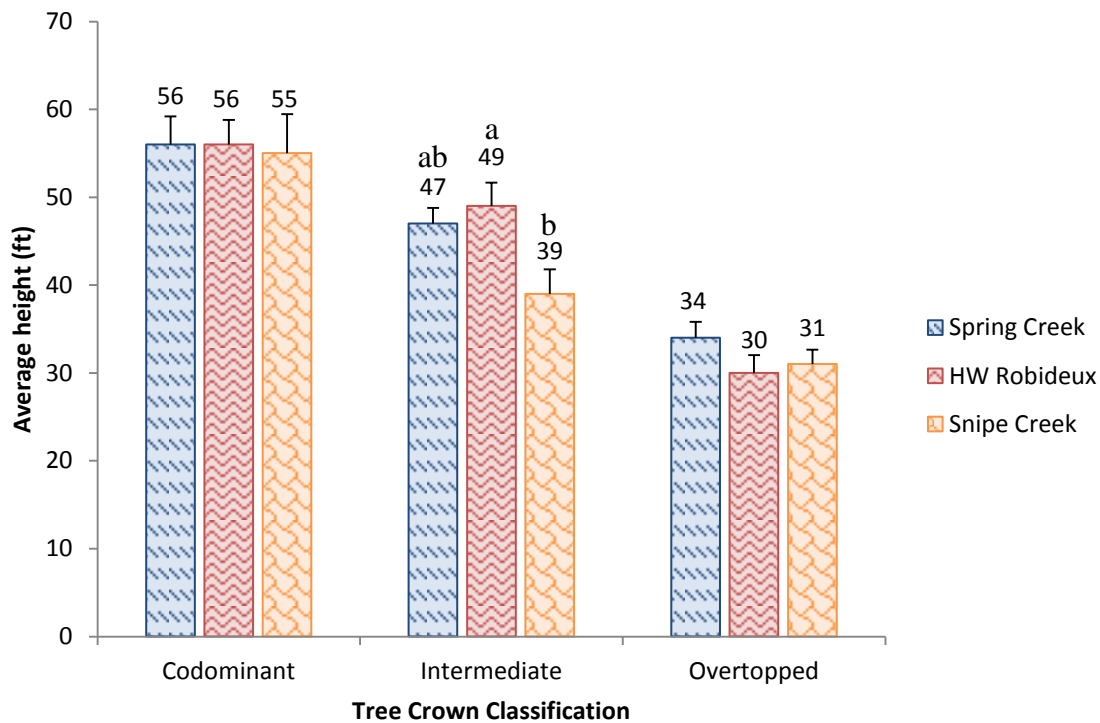
Figure 3.3 Average tree height by crown classification in the three sub-watersheds.
Different letters represent significant difference with P < 0.05

Quadratic mean diameter (QMD) was determined as a standard forestry measurement to report the diameter of the tree with average BA. This analysis was done with the purpose to list

the species from high to low diameter in each sub-watershed. Figure 3.4 shows the differences in diameters and species in every sub-watershed. Note that Spring Creek had the highest QMD, and the tree species with the biggest average diameter was bur oak with 23". Headwaters Robideux Creek highest QMD was green ash with an average 16" diameter. Snipe Creek highest QMD was black walnut with an average 14" diameter.
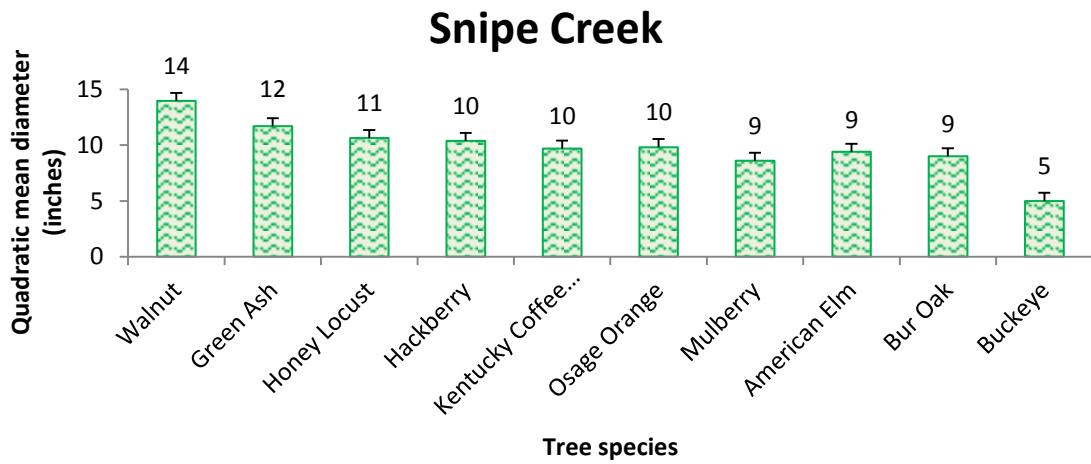
Spring Creek

Headwaters Robideux Creek

Snipe Creek
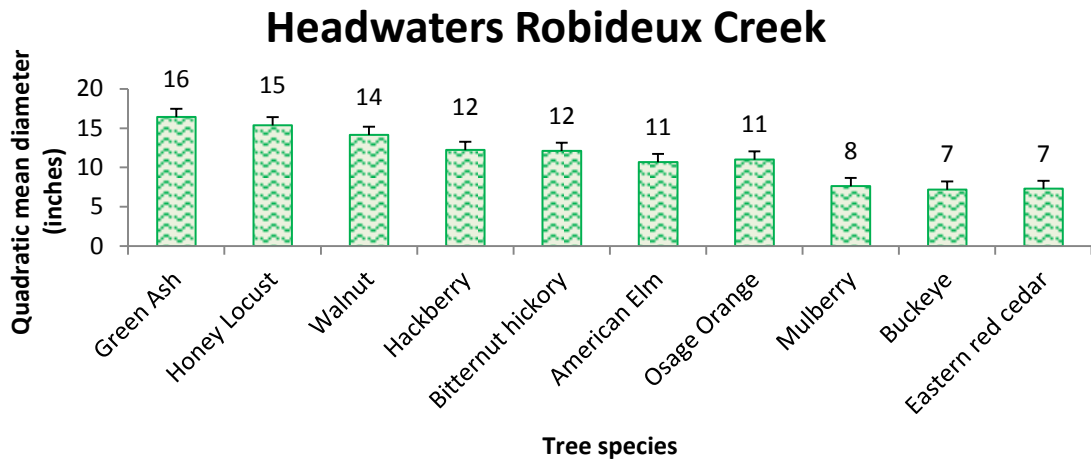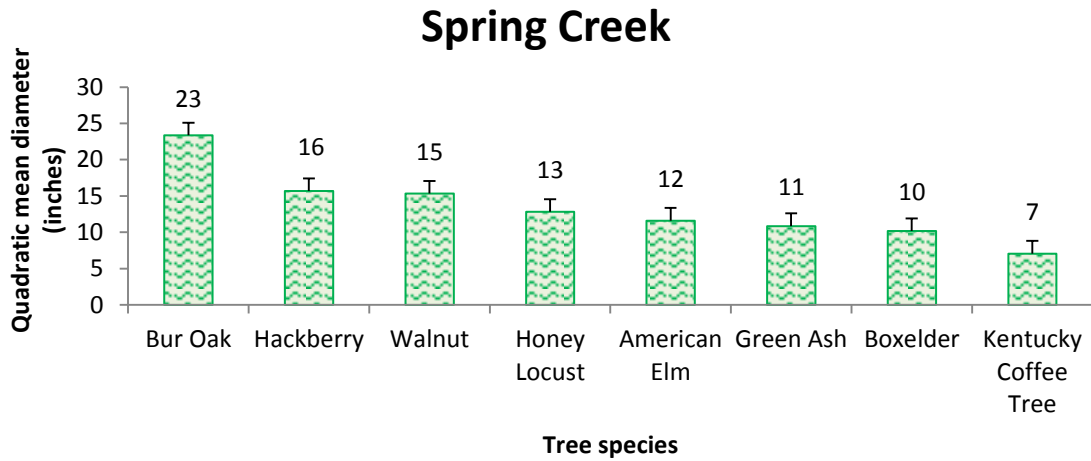
Figure 3.4 Quadratic mean diameter (QMD) display by each sub-watershed.

Tree distribution by species in each watershed

Basal area in figure 3.5 represents the percentage of area that is occupied by each tree species. The "Other" category in the pie charts depicted the sum of the species that were recorded in the watersheds but had less than 5% representation. In Spring Creek the highest percentage tree species was bur oak (*Quercus macrocarpa*) accounting for 23% of the BA; followed by black walnut (*Juglans nigra*) with 22%. The Other category was composed of green ash (*Fraxinus pennsylvanica*) with 3%, boxelder (*Acer negundo*) with 2%, and Kentucky coffee tree (*Gymnocladus dioicus*) with 1%.

In Headwaters Robideux Creek the highest percentage of BA was accounted by black walnut (*Juglans nigra*) with 40%; followed by honey locust (*Gleditsia triacanthos*) with 15%. The Other category for this watershed was composed of buckeye (*Aesculus glabra*), mulberry (*Morus rubra*), and osage orange (*Maclura pomifera*) with 2%, each, and eastern redcedar (*Juniperus virginiana*) with 0.2%.

The Snipe Creek highest BA species was hackberry (*Celtis occidentalis*) with 45%; followed by green ash (*Fraxinus pennsylvanica*) with 16%. The Other category for this watershed was composed by Osage orange (*Maclura pomifera*) with 2%, bur oak (*Quercus macrocarpa*) with 1%, and buckeye (*Aesculus glabra*) with 0.2%.

Spring Creek

Other 6%
American elm 19%
Bur oak 23%
Hackberry 19%
Honey locust 11%
Black walnut 22%

Headwaters Robideux Creek

Other 6%
American elm 13%
Green ash 6%
Hackberry 14%
Bitternut hickory 6%
Honey locust 15%
Black walnut 40%

Snipe Creek

Other 3%
Black walnut 10%
American elm 9%
Green ash 16%
Mulberry 6%
Kentucky coffee tree 5%
Honey locust 6%
Hackberry 45%
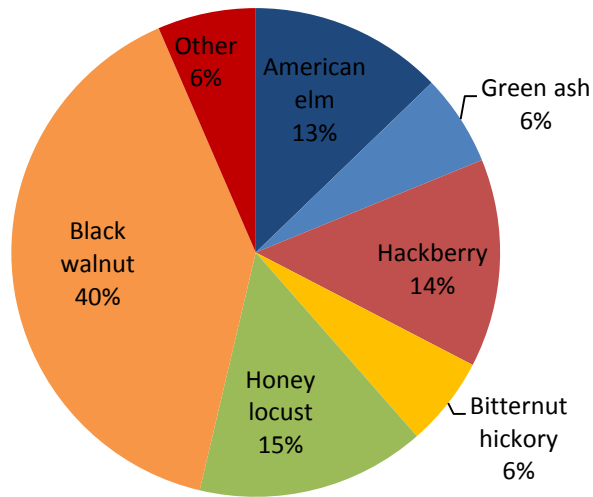
Figure 3.5 Percentage of BA per species present in each sub-watershed.

31

Mature trees per acre by species

Figure 3.6 presents the percentage (%) of each tree species calculated from trees per acre (TPA) data for each sub-watershed. The "Other" category in the pie charts depicted the sum of the species that were recorded in the watersheds but had less than 5% representation. In Spring Creek highest TPA species percentage was black walnut (*Juglans nigra*) with 25%; followed very closely by American elm (*Ulmus americana*) with 21%, and hackberry (*Celtis occidentalis*) with 20%. This watershed did not have the "Other" category because the only tree species that was less than 5% was Kentucky coffee tree (*Gymnocladus dioicus*) with 2%.

In Headwaters Robideux Creek the most common tree species was also black walnut (*Juglans nigra*) with 35%; followed by American elm (*Ulmus americana*) with 18%. The Other category was composed by green ash (*Fraxinus pennsylvanica*) with 4%, eastern redcedar (*Juniperus virginiana*), and osage orange (*Maclura pomifera*) with 2% each.

In Snipe Creek the most common tree species was hackberry (*Celtis occidentalis*) with 47%; followed by American elm (*Ulmus americana*) with 11% and green ash (*Fraxinus pennsylvanica*) with 11% as well. The Other category was composed of Osage orange (*Maclura pomifera*) with 2%, buckeye (*Aesculus glabra*), and bur oak (*Quercus macrocarpa*) with 1%, each.
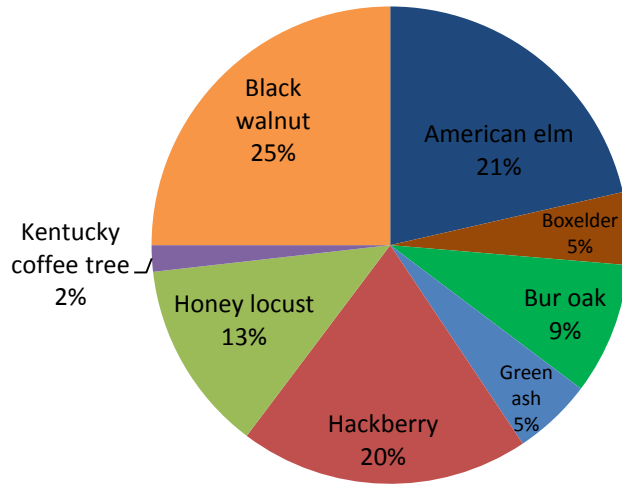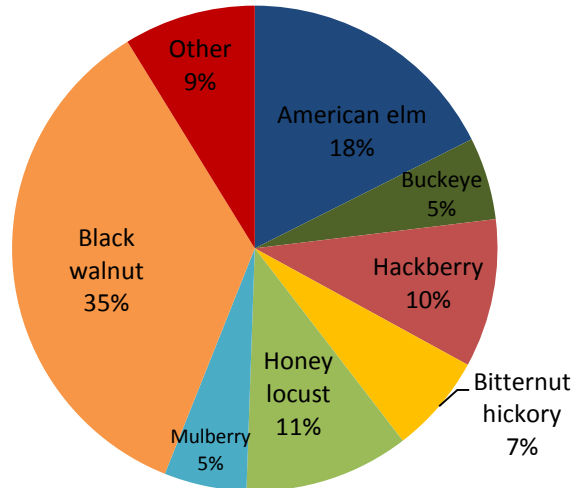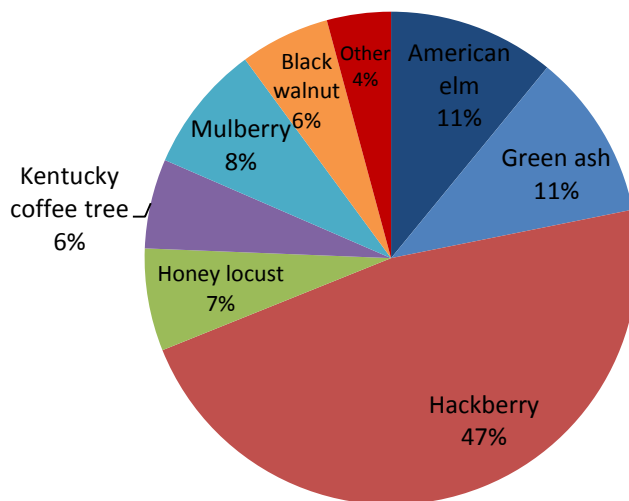
Figure 3.6 Percentage distribution of trees per acre (TPA) per species in each sub-watershed.

Black walnut (*Juglans nigra*) was very prevalent in Headwaters Robideux Creek in both BA and TPA data. Note also that Headwaters Robideux Creek had a moderate QMD of 14" for black walnut. This implies an opportunity for a thinning to be done on the properties, to release the walnut from competition, and to let the healthiest black walnut grow more quickly into sawlog and veneer size classes to produce a significant income in the future.

In Spring Creek the approach should be different. The results showed that the species with predominance in BA and the greatest QMD (23 inches) is bur oak (*Quercus macrocarpa*). This implies that it is the species with highest current potential for harvest. The implication of this set of data for landowners in the sub-watershed is that they can harvest the biggest diameter bur oaks, bringing substantial revenue. Also these actions will improve the conditions for black walnut to develop at a higher rate.

In Snipe Creek a third approach may be advantageous. The amount of hackberry (*Celtis occidentalis*) present in Snipe Creek is more than double that of the other two sub-watersheds in both BA and TPA. Black walnut has the highest QMD. This provides an insight that some of the hackberry should be removed to improve the growing conditions for walnut to grow faster and provide the landowners higher revenue in the future. Underplanting of bur oak would also add another valuable species to the mixture.

Regeneration per acre by species

Regeneration for this study was recorded by seedlings and saplings of each woody species. Seedlings were accounted as specimens of less than one inch in diameter at breast height (dbh); one-year-old seedlings less than one foot tall were also included. Saplings were trees with greater than one inch dbh but less than five inches dbh. The "Other" category in the pie charts depicted the sum of the species that were recorded in the sub-watersheds but had less than 5% representation.

Collection of data for these three sub-watersheds was from May to July 2013. This could have influence the amount of small seedlings found for the sub-watersheds.

Table 3.3 presented the frequency of occurrence of regeneration in the 45 plots assessed for the study. Spring Creek had the lowest percentage of sapling occurrences of the three sub-

watersheds; Snipe Creek had the highest. Seedlings percentages were equal in Spring Creek and Headwaters Robideux Creek. Occurrence of both seedlings and saplings in the plots was less than 50% in all the sub-watersheds, with Spring Creek having the lowest number of plots with both types of regeneration.

Table 3.3 Percentage of overstory plots per sub-watershed with regeneration

	Spring Creek	Headwaters Robideux	Snipe Creek
Plots		%	
Plots that had seedlings	100	100	80
Plots that had saplings	33	47	53
Plots with both seedlings and saplings	33	47	47

Seedlings

Figure 3.7 presents the percentage of seedlings by species in each of the sub-watersheds studied. Spring Creek seedlings were composed mostly of hackberry (*Celtis occidentalis*) with 82%; followed by honey locust (*Gleditsia triacanthos*) with 9% and green ash (*Fraxinus pennsylvanica*) with 5%. The Other category was composed by American elm (*Ulmus americana*), Kentucky coffee tree (*Gymnocladus dioicus*), bur oak (*Quercus macrocarpa*), and black walnut (*Juglans nigra*) with 1% each; bitternut hickory (*Carya cordiformis*) and, mulberry (*Morus rubra*) with 0.3%, each; and boxelder (*Acer negundo*) with 0.2%. It also should be noted that 5% of the hackberry and 36% of the honey locust found were small seedlings, perhaps current year germinants.

Headwaters Robideux Creek seedling composition was mainly hackberry (*Celtis occidentalis*) with 68%, followed by buckeye (*Aesculus glabra*) with 12%, and green ash (*Fraxinus pennsylvanica*) with 8%. The Other category was composed by American elm (*Ulmus americana*) and honey locust (*Gleditsia triacanthos*) with 4%, each; eastern redcedar (*Juniperus virginiana*) with 2%, mulberry (*Morus rubra*) with 1%, black walnut (*Juglans nigra*) with 0.3%, bur oak (*Quercus macrocarpa*) and osage orange (*Maclura pomifera*) with 0.2% each. It should be noted that 40% of the hackberry and 17% of the honey locust found were small seedlings, perhaps current year germinants.

Snipe Creek seedling composition was mainly hackberry (*Celtis occidentalis*) with 62%; followed by American elm (*Ulmus americana*) with 22%, and honey locust (*Gleditsia triacanthos*) with 10%. Other category was composed by buckeye (*Aesculus glabra*) with 3%, bur oak (*Quercus macrocarpa*), black walnut (*Juglans nigra*), and green ash (*Fraxinus pennsylvanica*) with 1% each; Kentucky coffee tree (*Gymnocladus dioicus*) with 0.1%. Note that 18% of the hackberry and 86% of the honey locust found were small seedlings, perhaps current year germinants.

Saplings

Figure 3.8 presents the percentage of saplings per species in each watershed. The frequency of saplings and diversity of species were low in Spring Creek, the highest percentage was hackberry (*Celtis occidentalis*) with 70%, then boxelder (*Acer negundo*) with 20%, and finally honey locust (*Gleditsia triacanthos*) with 10%.

Headwater Robideux Creek sapling composition was led by buckeye (*Aesculus glabra*) with 42%; followed by black walnut (*Juglans nigra*) and hackberry (*Celtis occidentalis*) each with 17%. Also eastern redcedar (*Juniperus virginiana*) was present with 16% and American elm (*Ulmus americana*) with 8%.

Snipe Creek sapling composition was led by buckeye (*Aesculus glabra*) with 39%; followed closely by hackberry (*Celtis occidentalis*) with 38%. American elm (*Ulmus americana*) was also documented with 15% and Kentucky coffee tree (*Gymnocladus dioicus*) with 8%.
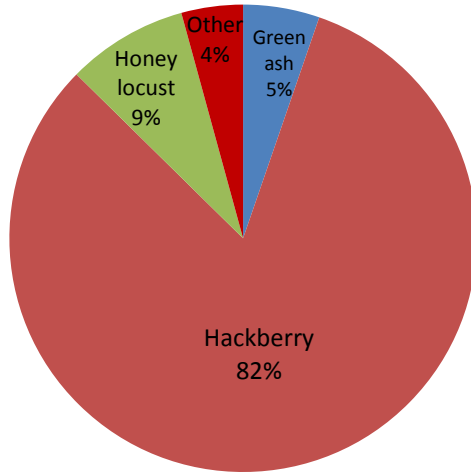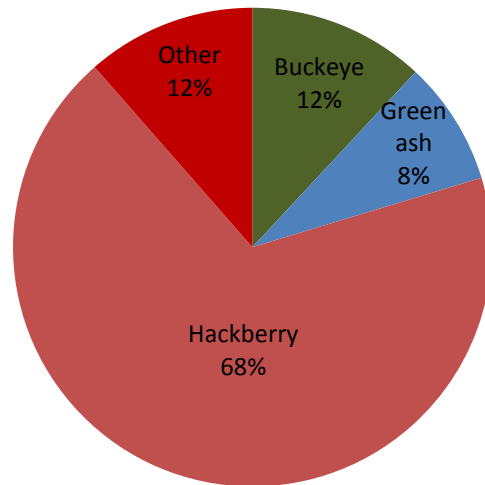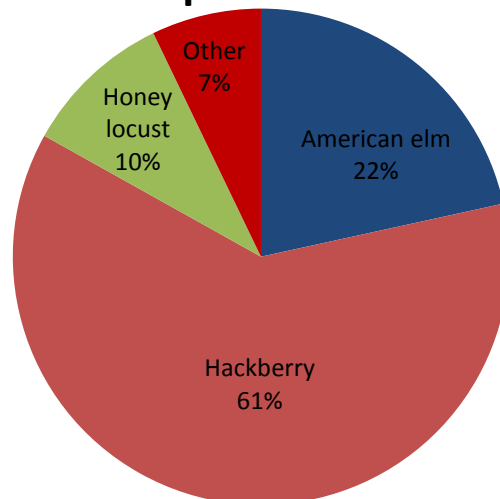
Figure 3.7 Percentage seedlings in each sub-watershed.
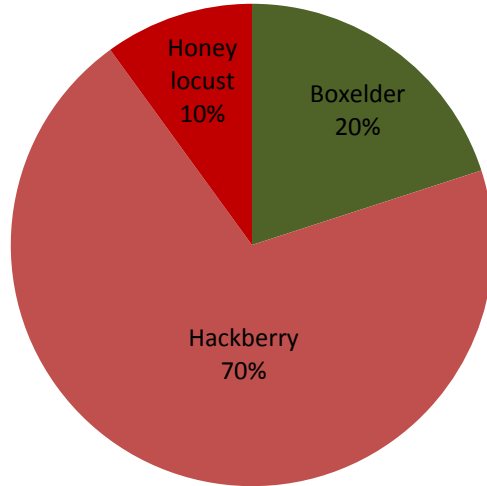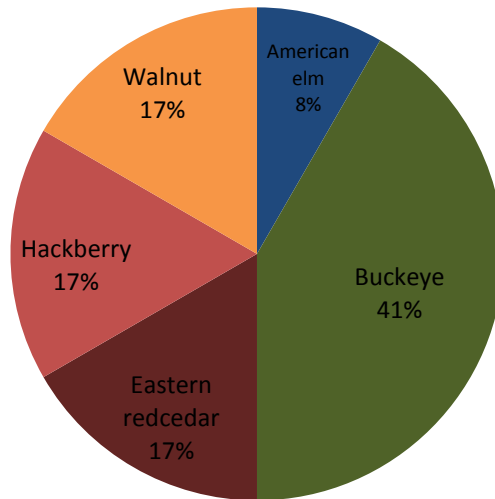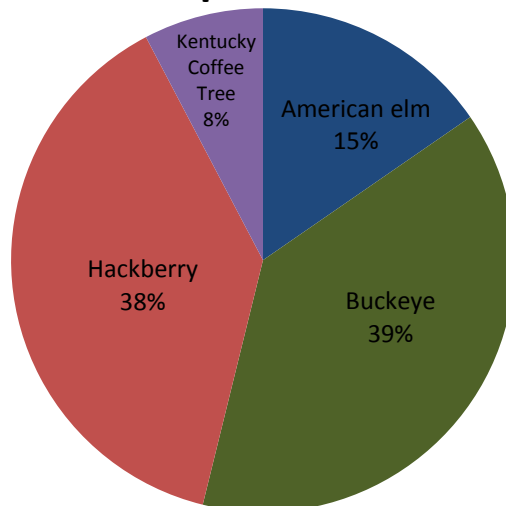
Figure 3.8 Percentage saplings in each sub-watershed.

Economic Value Categorization of Riparian Woodlands

The species data was also classified into economic value groups. This categorization was based on the marketable timber value of the species found in the three sub-watersheds. This data is reported on a per plot basis without using the per acre expansion factor, applying expansion factor resulted in an exaggeration of the variability and thus an inability to provide statistical separation of means.

Figure 3.9 shows for Group 1 basal area (BA) per plot was greater in Spring Creek and Headwaters Robideux Creek than in Snipe Creek. The pairwise comparisons with Tukey-Kramer adjustment for Group 1 showed that Snipe Creek was significantly different from Spring Creek with $P = 0.0004$ and from Headwaters Robideux Creek with $P = 0.0039$.

With respect to Group 2 the pairwise comparisons with Tukey-Kramer adjustment showed that again Snipe Creek was significantly different from Spring Creek with $P = 0.0171$ and from Headwaters Robideux Creek with $P = 0.0079$. Although in this case Snipe Creek had a higher BA per plot than Spring Creek and Headwaters Robideux Creek.

For Group 3 there was no significant difference within the group or among the watersheds. Note that a similar trend could be observed with both Group 1 and 3 species, with Spring Creek leading the BA per plot followed by Headwaters Robideux Creek and finally Snipe Creek
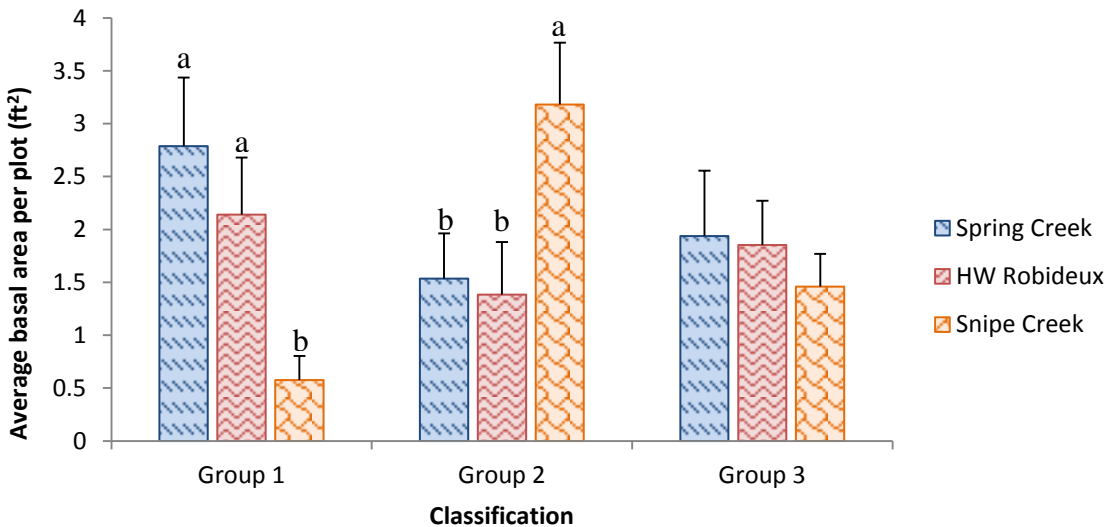
Figure 3.9 Average basal area per plot by group classification in the three sub-watersheds.
 Different letters represent significant difference with $P < 0.05$

Results of BA per Group classification are also consistent with the other data sets as BA per watershed and QMD. Spring Creek showed the highest BA per plot in Group 1, and the highest QMD for this sub-watershed was bur oak (*Quercus macrocarpa*) that is one of the trees with higher timber value.

Headwaters Robideux Creek also shows a high BA per plot in Group 1, this is consistent again with the BA per sub-watershed, where black walnut (*Juglans nigra*) was the highest tree present in Robideux. Black walnut belongs also to the high timber value thus classifying in Group 1.

Snipe Creek shows to be the highest in Group 2, this also is consistent with the BA per species in the sub-watersheds, where Snipe Creek had 45% occupied by hackberry (*Celtis occidentalis*); this species has a moderate timber value therefore belongs to Group 2.

Figure 3.10 shows that Group 1 trees per plot were greater in Headwaters Robideux Creek and Spring Creek than in Snipe Creek. The pairwise comparisons with Tukey-Kramer adjustment showed that in Group 1 Headwaters Robideux Creek was significantly different than Snipe Creek with $P = 0.0031$ and Snipe Creek was significantly less than Spring Creek with $P = 0.0116$.

With respect to Group 2, the pairwise comparisons with Tukey-Kramer adjustment showed that Snipe Creek also had a significant difference with respect to Spring Creek and Headwaters Robideux Creek with $P < 0.0001$ each. In this case Snipe Creek was the sub-watershed with the highest amount of trees per plot.

For Group 3 there was no significant difference within the group or among the watersheds.

The results by classification of economic value also are consistent with the distribution of tree species in the sub-watersheds. Group 1 shows that Spring Creek has slightly less amount of trees than Headwaters Robideux Creek; this also can be noted in the distribution of species, where Spring Creek has bur oak (*Quercus macrocarpa*) and black walnut (*Juglans nigra*) but the percentage of these two species combined are one percentage point less than the black walnut in Headwater Robideux Creek.

Group 2 show a different trend, Snipe Creek presents a higher amount of trees per plot than Headwaters Robideux Creek and Spring Creek. These results are also consistent with the percentage of hackberry (*Celtis occidentalis*) found in Snipe Creek. Hackberry is a moderate timber value species.
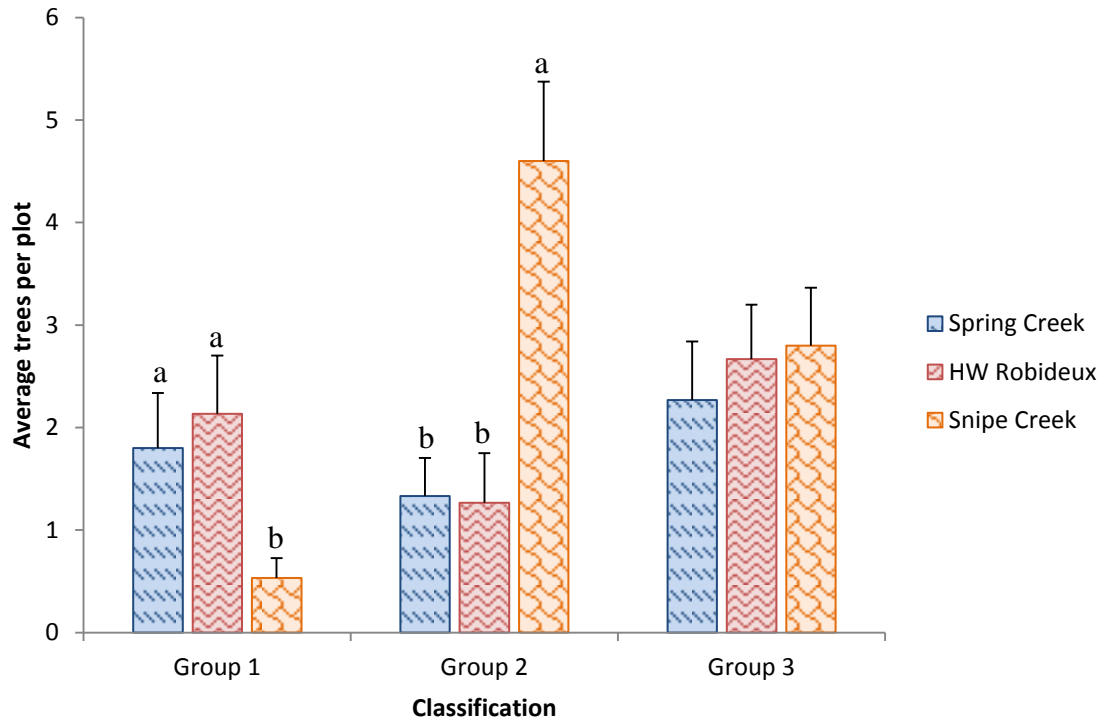
Figure 3.10 Average number of trees per plot by group classification in the three sub-
Different letters represent significant difference with P < 0.05

Analysis for regeneration by group was achieved by combining seedlings and saplings per group class in each sub-watershed. Figure 3.11 showed that Group 1 and 2 did not present a significant difference. Group 3 presented a different trend, the pairwise comparisons with Tukey-Kramer adjustment showed that Snipe Creek had more regeneration of low economic value than Spring Creek with a P < 0.0001. The comparison between Snipe Creek and Headwaters Robideux Creek also showed a significant difference between this two sub-watersheds with a P = 0.0262. Again Snipe Creek had the highest in amount of low economic value regeneration compared with Headwaters Robideux Creek.
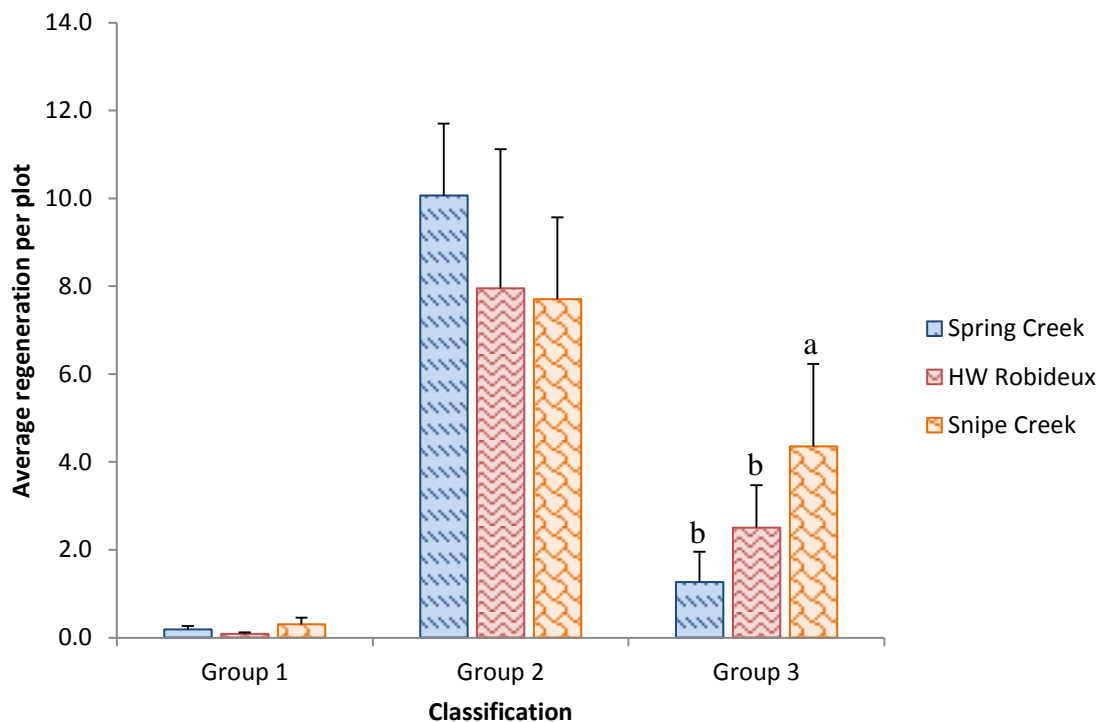
Figure 3.11 Average regeneration per plot by group classification in the three sub-watersheds.

Different letters represent significant difference with $P < 0.05$

From the results of regeneration by economic value group, it should be noted there is a lack of regeneration in Group 1 for all the three sub-watersheds. It also shows the massive amount of regeneration in Group 2 (primarily hackberry), and a considerable amount of regeneration in Group 3. These results showed an opportunity for management of regeneration in all the sub-watersheds.

Qualitative data

Human intervention in the riparian woodlands was evident in the three sub-watersheds assessed. Table 3.4 presented the frequency in which livestock and forest management was encountered in the assessed riparian forest sites. In 53% of the assessed plots in Snipe Creek evidence of livestock use was found; whereas Spring Creek had no evidence of cattle use. Evidence of plots with forest management was observed in all three sub-watersheds. Spring Creek had 27% with forest management; however 20% of the total 27% was old management (depicted by very old stumps). Headwaters Robideux Creek had 47% of forest management, where 27% of the total 47% was old management. Snipe Creek had 47% of forest management, where 33% of the total 47% was old management. The rest of the management was recent evidence of harvest, apparently mostly for firewood.

The second active channel width characterization was classified depending on the presence of forest, grass, or crop land. Headwaters Robideux Creek was the only sub-watershed with 100% riparian forest coverage in the second ACW. On the other hand Snipe Creek only had 53% of the second ACW covered by forest. Grassland coverage was present only in Snipe Creek, in the 2ACW, adjacent to the riparian forest plots.

Table 3.4 Human intervention in the riparian woodlands

| Sub-watersheds | Total Plots | Plots with | | 2nd Active Channel Width | | |
| | | Livestock | Management | Forest | Grass | Crop |
		%		%		
Spring Creek	15	0	27	93	0	7
Headwaters Robideux	15	47	47	100	0	0
Snipe Creek	15	53	47	53	20	27

The most common species of understory found in the plots were gooseberry (*Ribes rotundifolium Michx.*), buckbrush (*Symphoricarpos orbiculatus*), and garlic mustard (*Alliaria petiolata*), which is considered an invasive species, along several kinds of grasses, and stinging nettles (*Urtica dioica*). Table 3.5 presented the percentages of plots in which these understory species were found. Grasses are the most common understory species found with an incidence of 67% of the plots in Spring Creek and Headwaters Robideux Creek. Garlic mustard also prevails

in Spring Creek with 67% incidence and in Headwaters Robideux Creek with 47%. Snipe Creek did not have any plots where garlic mustard was noted.

Table 3.5 Understory species

Sub-watershed	Common understory species				
	Gooseberry	Grass	Buckbrush	Garlic mustard	Nettles
	%				
Spring Creek	7	67	40	67	33
Headwaters Robideux	13	67	53	47	7
Snipe Creek	27	53	47	0	13

Areas assessed were sites well established riparian forest with a mature tree stand. These areas had canopy coverage which average between 95% and 97%. This percentage is an indication of lack of large canopy gaps in the assessed areas.

Other qualitative notes were taken during the data collection; the following observations were only rarely made: beaver damage in the trees, incidence of Dutch Elm Disease (DED), if there were other species of mature trees in the second ACW, or if there was abundant woody debris in the area, and if there were evidence of ice damage or recent floods.

GIS Sub-watersheds Analysis

This analysis was made by the Kansas Forest Service (KFS). ArcGIS software and LiDAR data sets were used to classify riparian areas into functioning classes (Figure 3.12 - 3.14). As denoted in Table 3.6 Spring Creek has the highest percentage of well-established forest, with a 61% of the sub-watershed categorized as forest in need of protection; this sub-watershed also had the lowest area classified as needing management or establishment (Figure 3.12). Headwaters Robideux Creek had a higher need for forest management and establishment with 41% and 2% respectively (Figure 3.13). Snipe Creek had the highest percentages for forest establishment and management with 4% and 48% respectively (Figure 3.14).

Table 3.6 Percentage of riparian forest functioning condition classes

Sub-watershed	Forest in need of		
	Establishment	**Management**	**Protection**
	%		
Spring Creek	2	37	61
Headwaters Robideux	2	41	57
Snipe Creek	4	48	48

Results for Spring Creek, Headwaters Robideux Creek, and Snipe Creek in terms of woodland coverage may be heavily exaggerated. A study by Maradiaga Rodriguez (2012) found that Centralia, Banner, and Atchison watersheds were heavily agricultural dominated. Centralia presented 80% in cropland; Atchison presented 75.6% in cropland; and Banner being the exception had only 12.5% in cropland, but 75.6% in grassland. These three watersheds (Centralia, Banner, and Atchison) are located east of Spring Creek, Snipe Creek, and Headwaters Robideux Creek. It was expected that land cover and usage is similar across the region.

For this thesis study the specification by sub-watershed of land use and coverage could not be obtained, but a study lead by Juracek and Mau (2002; after U.S. Geological Survey 2000) found that land cover for the Big Blue River Basin is mostly agricultural, with cropland accounting for about 66% of the basin. Grassland and pastures account for 29%; woodland cover for 3% and urban land use for 1%. The Juracek study categorized the entire watershed, not just the riparian areas. The LiDAR data sets were analyzed in a way that may have overestimated the

amount of woody coverage in the riparian areas, something that did not happen in the Maradiaga Rodriguez (2012) study.

Improvement in managing the LiDAR data sets, and a better approach to the estimation of the riparian functioning condition should be examined.

Riparian Forest Functioning Condition Class

Spring Creek Watershed
Marshall County, Kansas

0   1   2 Miles

■ Forest In Need of Establishment
■ Forest In Need of Management
■ Forest In Need of Protection
□ Spring Creek HUC12 Boundary

Sources:
Marshall County, Kansas LiDAR 2010
USDA NRCS Soils Survey Geographic Database (SSURGO)
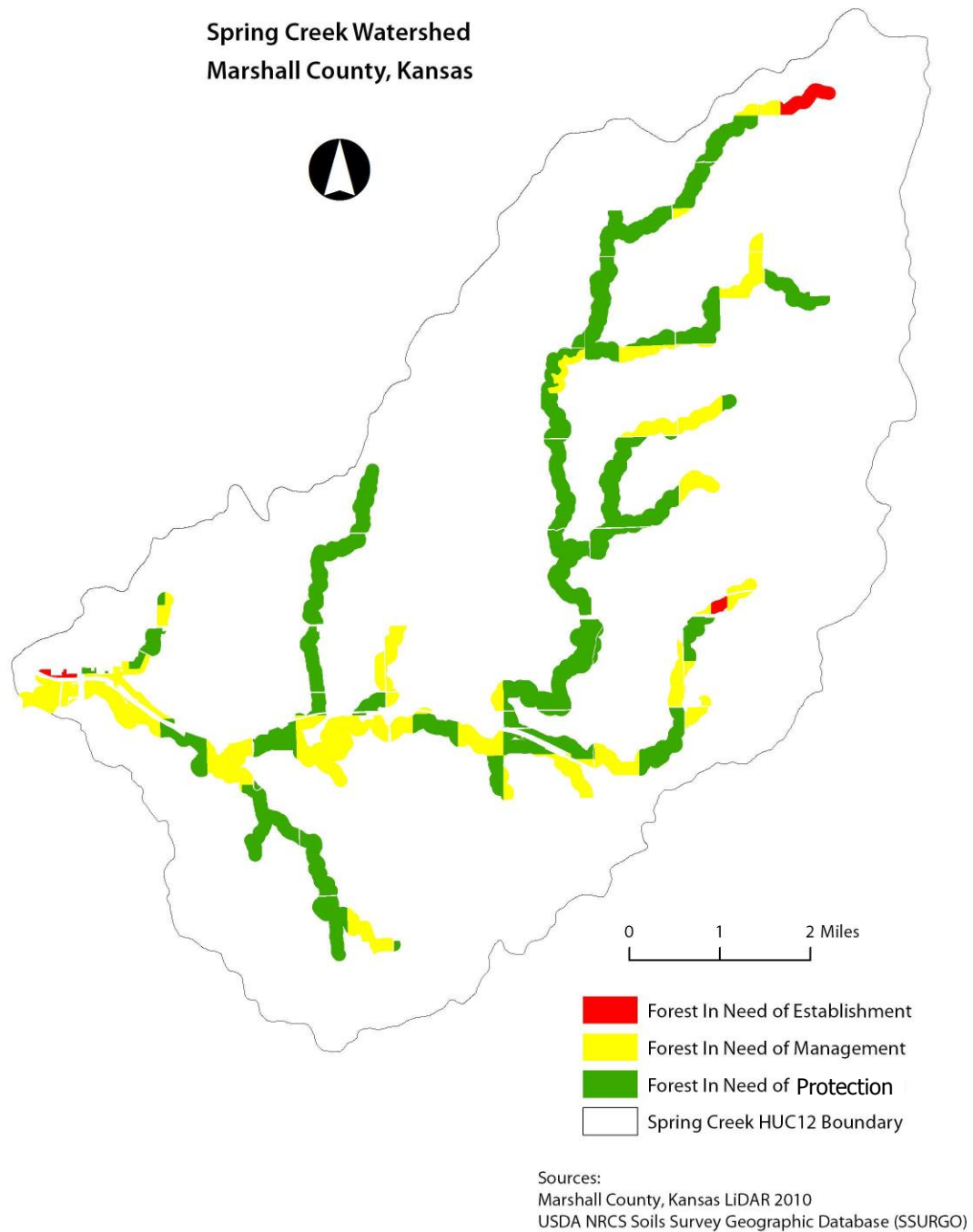
Figure 3.12 Cartographic exaggeration of riparian forest categories in Spring Creek
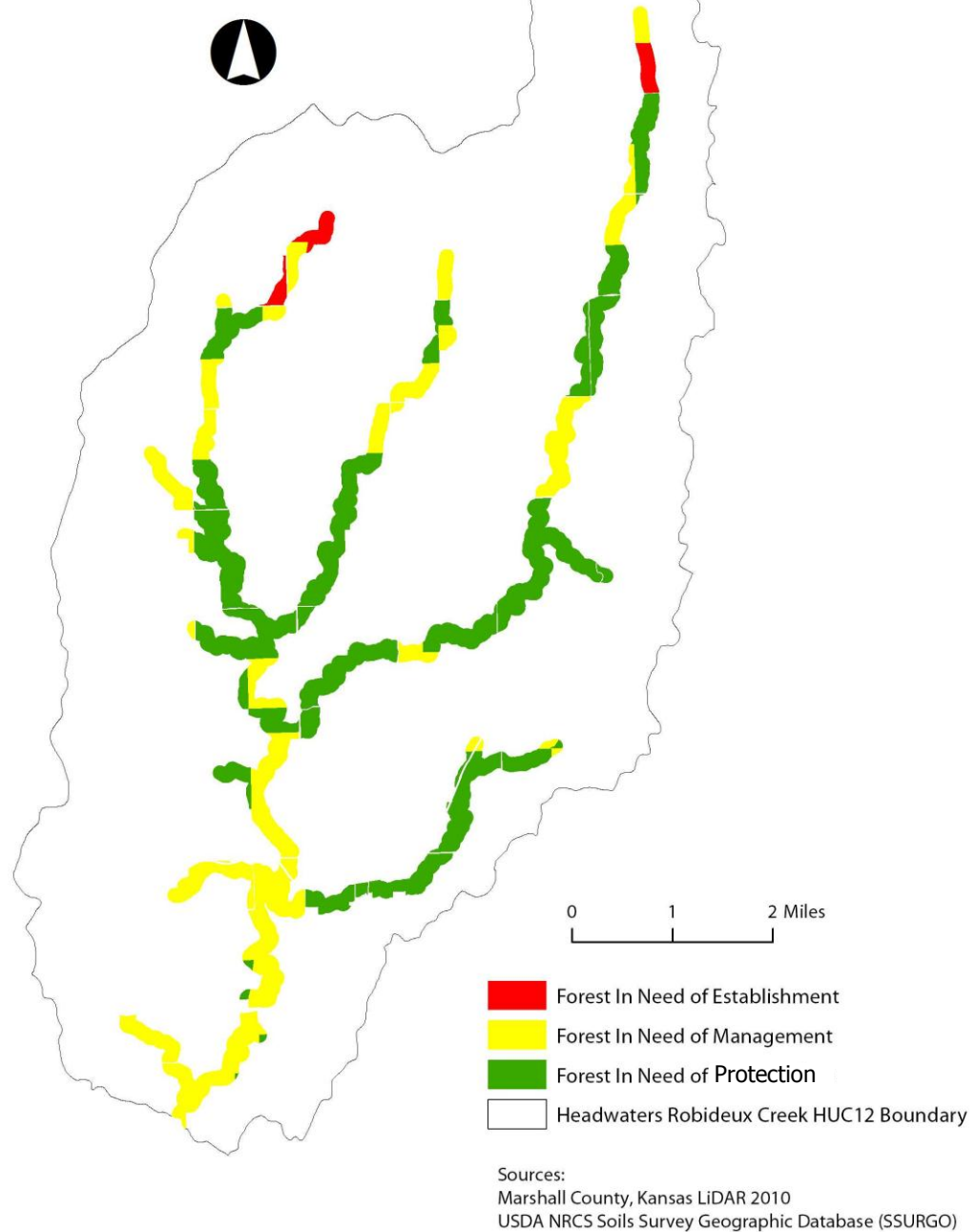
Figure 3.13 Cartographic exaggeration of riparian forest categories in Headwaters Robideux Creek

Riparian Forest Functioning Condition Class

Snipe Creek Watershed

Marshall County, Kansas
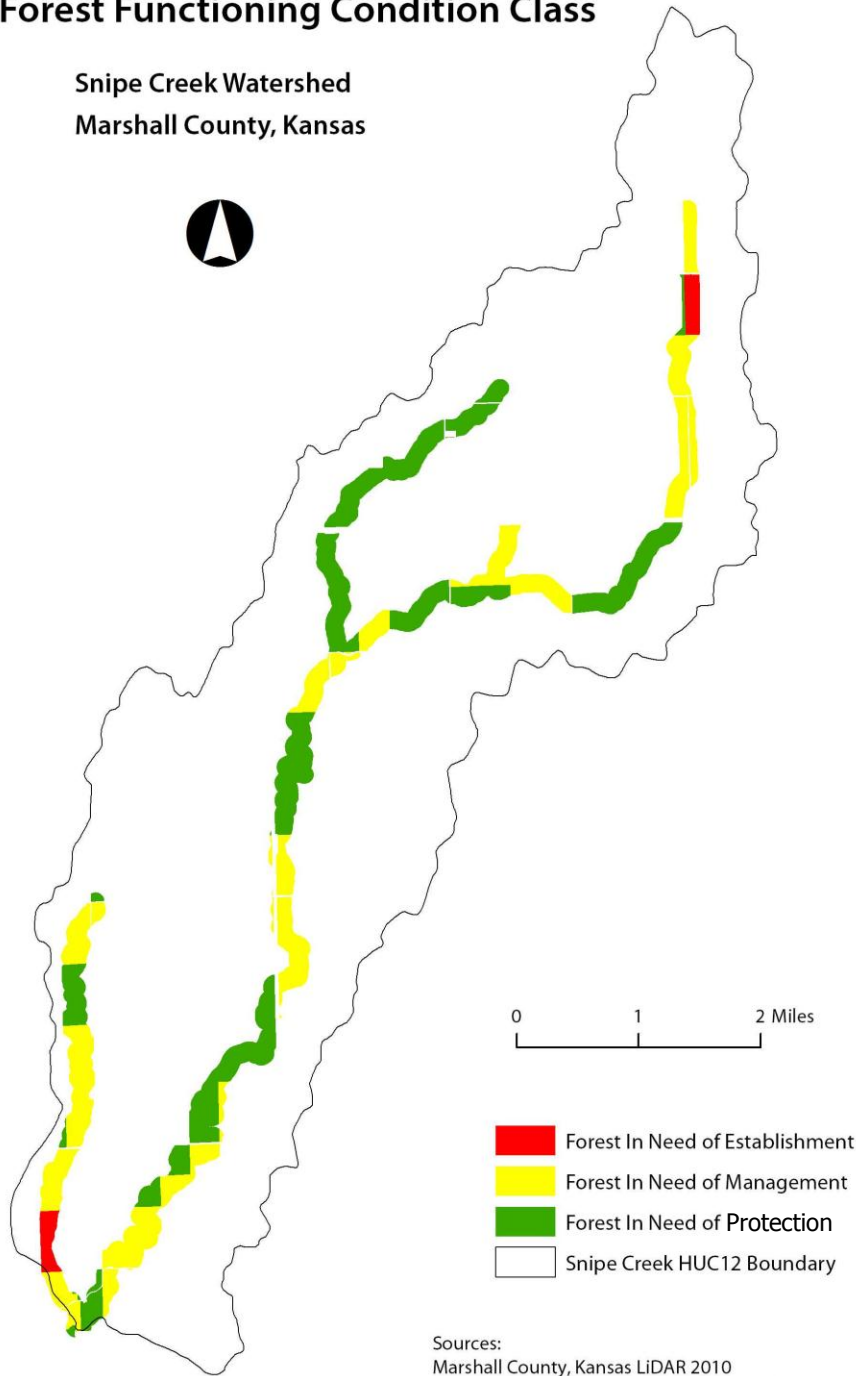
0   1   2 Miles

■ Forest In Need of Establishment

■ Forest In Need of Management

■ Forest In Need of Protection

□ Snipe Creek HUC12 Boundary

Sources:
Marshall County, Kansas LiDAR 2010
USDA NRCS Soils Survey Geographic Database (SSURGO)

Figure 3.14 Cartographic exaggeration of riparian forest categories in Snipe Creek

Chapter 4 - Conclusions and Recommendations

Structure of the riparian woodlands along the three sub-watersheds was fairly similar to each other; in terms of basal area coverage no differences were found.

As for trees per acre, some differences were found among the sub-watersheds; this difference may be triggered by human intervention in the riparian areas. Also the quadratic mean diameter (harvest potential) showed that Spring Creek had higher opportunities for harvest than Snipe Creek.

Composition gave an interesting picture of what could be more beneficial for the landowners to harvest, for example in Spring Creek, bur oak (*Quercus macrocarpa*) was the tree species with higher quadratic mean diameter, this tree is also classified as a high value tree in the market; thus providing a good opportunity to manage these trees and take advantage of the marketability of the species. The draw back in this sub-watershed is that the sapling presence is really low and the species presence in terms of saplings account are not the most desired ones, with hackberry (*Celtis occidentalis*) being the most common regeneration species present in the area, followed by boxelder (*Acer negundo*) and honey locust (*Gleditsia triacanthos*).

Snipe Creek with quadratic mean diameter smaller than the other two sub-watersheds had black walnut (*Juglans nigra*) as the highest diameter tree, but there were not many walnuts in the sub-watershed. If competition is removed from around these trees it could generate a really high potential for future harvest and earning a significant income. Note that regeneration in the area should be managed to improve diversity and productivity in the riparian woodlands.

Headwaters Robideux Creek had an interesting composition in terms of TPA and BA. It was found that this sub-watershed had high amounts of of black walnut (*Juglans nigra*) as both TPA and BA. This means a good opportunity to manage the riparian woodlands, with removal of competing lower value species, to promote faster growth of black walnut into commercially valuable sizes.

Additionally, in terms of species composition it can be noted that hackberry (*Celtis occidentalis*) is the predominant species, present in every classification with considerable percentages. This could be due to the species capacity of tolerate shade in early stages of their development and also to the wildlife (especially birds) that eat the berry like fruit and help with spreading the seeds (USDA-NRCS 2014). Note that black walnut (*Juglans nigra*) which has a

high economic value is also present at some level in the mature riparian woodlands of each sub-watershed, although usually at a lower percentage than hackberry (*Celtis occidentalis*). There is a lack of walnut regeneration across the watersheds. This could be due to the intolerance of the species to shade (USDA-NRCS 2014). Note that the areas of interest of the study were well established riparian woodlands, this means that the canopy cover was higher than 95% making inhospitable conditions to species that are intolerant to shade.

In terms of the economic group classification, Group 1 species had less presence in all the stand parameters (BA, TPA, and regeneration). This could be taken as an opportunity to improve this aspect of the riparian woodlands in these three sub-watersheds. Although it has to be acknowledged that the species present in Groups 2 and 3, while they do not have a high economic value, they do possess ecological values; being part of the food chain for many bird species and other wildlife that dwell in the riparian woodlands.

Human intervention in the sub-watersheds was evident as harvesting activity, and cattle usage of the riparian woodlands. As for the second active channel width only Snipe Creek showed substantial agronomic activity (47% for grass and crop uses combined). The second active channel width was in forest at the majority of the sites in all watersheds.

For a riparian area to achieve a proper functioning condition (PFC) it should contain an appropriate vegetation, landform, and large woody debris which help to dissipate stream energy during a high flood event (USDI 1998). Appropriate vegetation is defined by USDI (1998) as a diversity of plant species that could maintain wildlife, both aquatic and terrestrial. Note that the riparian areas in Spring Creek, Headwaters Robideux Creek, and Snipe Creek could be improved. Diversification in terms of tree species could be one of the first steps to upgrade the woodlands. The areas that should be approached first should be areas that had no vegetation along the streambank.

Furthermore data analysis of the understory species, beside the woody regeneration, showed a diverse range of species. Among them, invasive species as garlic mustard and stinging nettles were found. Also species as gooseberries, buckbrush, and some winter grasses were found in the riparian woodlands.

Results for Spring Creek, Headwaters Robideux Creek, and Snipe Creek in terms of woodland coverage may be heavily exaggerated. A study by Maradiaga Rodriguez (2012) found

that in three sub-watersheds close to the area assessed, the riparian zone was agriculturally dominated.

For this thesis study the specification by sub-watershed of land use and coverage could not be obtained, but a study lead by Juracek and Mau (2002; after U.S. Geological Survey 2000) found that land cover for the Big Blue River Basin is mostly agricultural; Spring Creek, Headwaters Robideux Creek and Snipe Creek are part of this basin; with cropland accounting for about 66% of the basin. Grassland and pastures account for 29%; woodland cover for 3% and urban land use for 1%. Thus the LiDAR data sets may have overestimated the amount of mature riparian forest coverage in the watersheds. Improvement in managing the LiDAR data sets, and a better approach to the estimation of the riparian functioning conditions should be examined in the future.

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Appendix A - Field work data sheet

Site		Bank		Plot		Plot dim:	
date		BAF		BAF Tree		F. Wdth:	
ACW		Plot type		GPS (bank)			
				GPS (plot end)			

Species	DBH (in)	Ht (ft)	Canopy class	Notes:

General notes 1st ACW:

General notes 2nd ACW:

Regen plot 1			Regen Plot 1 mirror		
Species	Class	Notes	species	class	notes

Regen plot 2			Regen plot 2 mirror		
Species	Class	Notes	species	class	notes

Canopy Coverage	
Yes:	No:

Appendix B - GIS Methodology for Riparian Forest Assessment in Tuttle Creek Watershed

1. To get ACW:
   a. Create flow accumulation raster from LiDAR data using ArcGIS hydrology toolset
   b. Each cell value equals drainage area in m^2, need to convert to mi^2—multiply area in m^2 by 3.86102e-7 to calculate drainage area in mi^2.
   c. Select out flow accumulation cells > 1 mi^2 using extract by attributes tool
   d. Convert raster to point
   e. Add field "ACW" (active channel width) and calculate field based on SC regional curve:

$$ACW_{ft} = 10.5616 * DA_{mi^2}^{0.3851}$$

   f. Multiply this by 1.33 to get bank width and add 2*ACW to 0.5*bank width to get buffer distance (make sure to convert units to meters if necessary!)
   g. Buffer by the 2ACW field
   h. Buffer again by the bank width field
   i. Erase bank width buffer from 2ACW buffer
   j. For Spring River and other streams with drainage areas beyond the HUC12 of interest, ACW needs to be measured by hand because of complexity of integrating upstream drainage area
   k. Merge and dissolve "custom" Spring River and flow accumulation-derived 2ACW buffers
2. (Not Applicable to Tuttle) To get woodland cover using leaf-off LiDAR data:
   a. Use ArcScan to buffer leaf-off LiDAR data to a distance of 20m for each pixel greater than 3.96m (13 feet) to create an overestimate of woodland cover (Dilate with value of 20). Convert to vector, select GRIDCODE = 1, and clip NAIP by this shape.
   b. Use "Extract by Attributes" tool to extract NAIP-derived NDVI values greater than 0.45, which seemed to be a breaking point where the NDVI pixels represented woodland cover
3. To get woodland cover using leaf-on LiDAR data:
   a. Create bare earth and first return rasters from LAS files
   b. Subtract bare earth raster from first return raster
   c. Reclassify resulting raster so pixels > 3.96 meters (13 feet) have a value of one, and pixels < 3.96 have a value of zero
   d. Using ArcScan, dilate 5 pixels and close 8. This seems to give good results generally, but feel free to experiment with different values

     e.   Convert to vector and select out where GRIDCODE = 1 to produce a woodland feature class

4. To get percent cover within 2ACW buffer width per parcel:
    a.   Intersect parcels with 2ACW buffer (**ACW2_parcels_intersect**)
    b.   Clip resulting layer by suitable soils (NRCS SSURGO Conservation Tree and Shrub suitability classes 1 and 2) (**ACW2_parcels_intersect_soils_clip**)
    c.   Dissolve by parcel ID field (**ACW2_parcels_intersect_soils_clip_dissolve**)
    d.   Add a new field – "suitable_acres", calculate geometry in acres
    e.   Intersect this layer with the woodland cover layer created in step 2 (**ACW2_suitable_woodland_intersect**),
    f.   Dissolve this (check PID and suitable acres as the dissolve fields) (**ACW2_suitable_woodland_intersect_PID_acres_dissolve**)
    g.   Add a new field – "wooded_acres", calculate geometry in acres
    h.   Add a new field – "percent_cover", use field calculator to divide wooded acres field by suitable acres field, which yields percent cover
    i.   Join this layer to the original parcels layer using the parcel ID field as the join field (**parcels_with_percent_cover**)
    j.   Search for parcels that fulfil the soil suitability requirements, but that don't have any tree cover. Manually digitize these parcels and enter something like "0.01" to indicate absence of tree cover
    k.   Symbolize the parcels by cover t

This methodology was facilitated by David Burchfield former GIS specialist in the Kansas Forest Service.