REGIONAL PATTERNS OF PRESETTLEMENT FORESTS IN THE BOSTON MOUNTAINS OF NORTHWEST ARKANSAS

A Thesis presented to the Faculty of the Graduate School
University of Missouri – Columbia

In Partial Fulfillment of the Requirements of the Degree

Master of Arts

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May 2006

The undersigned, appointed by the Dean of The Graduate School, have examined the thesis entitled

REGIONAL PATTERNS OF PRESETTLEMENT FORESTS IN THE BOSTON MOUNTAINS OF NORTHWEST ARKANSAS

Presented by Dustin J. Hulting

a candidate for the degree of Master of Arts of Geography

and herby certify that in their opinion it is worthy of acceptance

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This thesis is dedicated in memory of Dr. Alan Woolf.

ACKNOWLEDGEMENTS

I cannot thank my wife enough for helping me get through this thesis as well my entire graduate school career. Jessica, your love and support never ceases to amaze me. I also want to thank my family for supporting me countless times and in so many ways.

Of course I'd like to extend my deepest gratitude to Dr. Mark Cowell for being such a wonderful mentor. I also thank him for opening my eyes to the truly fascinating nature of forests. I'd also like to thank Jim Harlan for all his help and patience. I also greatly appreciate the support and guidance given to me by Dr. Michael Urban. I'd also like to thank Dr. David Larsen for being on my committee. I can't forget to thank Tim Ponce and Joe Clark for helping digitize the survey records and taking care while doing so.

Above all, I want to thank my Lord and Savior, Jesus Christ. Without his strength and love, completing this thesis would never have been possible.

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ABSTRACT

Mixed mesophytic forests typically contain the highest tree species diversity within the deciduous forest biome of eastern North America. While these diverse forests are primarily found in the Appalachian Highlands, strikingly similar forests are noted as occurring in protected slopes and coves within the Boston Mountains of northwestern Arkansas (Braun 1950, Thompson 1977). Over the last thirty years, ecologists have placed increased importance on understanding the natural state of ecosystems as well as the processes that shaped them (Noss and Cooperrider 1994). This project uses General Land Office survey records predating extensive European settlement to reconstruct regional vegetation patterns. Survey records were digitized into a Geographic Information Systems database in order to interpolate land cover and forest types as well as map tree species distributions within the study area. These patterns were then analyzed to identify how environmental factors influenced the structure and composition of vegetation within the Boston Mountains. The results of this project show that woodlands and closed canopy forests dominated the landscape, comprising 42.8% and 35.6% of the total landcover. Analysis also shows that tree species' distributions were strongly influenced by the rugged topography found in the study area. These influences were also seen in the composition and distribution of forest types within the area. While the forests of the Boston Mountains were dominated by regionally typical oak and hickory species, results show the presence of a mixed mesophytic forest type. This species association was found in the most rugged and protected portions of the study area and displayed many traits commonly found in southern Appalachian mixed mesophytic forests.

CHAPTER 1
INTRODUCTION

The Mixed Mesophytic forest region is considered to be the heart of the Deciduous Forest Biome and contains the most complex and species-rich forests in all of eastern North America. Located primarily in the central and southern portions of the Appalachian Highlands, this forest region identifies where the mixed mesophytic tree species association dominates the landscape (Figure 1.1). Mixed mesophytic stands in this region are noted as containing high levels of plant diversity in all strata of the forest with no species exhibiting clear dominance. In the Appalachians, the number of important canopy species in a well developed mixed mesophytic forest can exceed twenty-five, with a number of additional tree species common in the understory (Braun 1950, Leopold, McComb and Muller 1998). In general, these rich forests develop where site conditions include regular precipitation, well-drained, rich soils, intermediate levels of soil moisture and low levels of major natural disturbances such as fire and large blowdowns (Runkle 1996).

While the presence of mixed mesophytic forests in the Appalachians is well documented, the presence of strikingly similar stands in the Boston Mountains of northwestern Arkansas has not been widely studied. The Boston Mountains are the southernmost feature of the greater Ozark Plateau and contain some of the most diverse topography located between the Appalachian and Rocky Mountains. While this mountain range covers a relatively small area and only reaches elevations of around 800 meters, this region contains intriguing vegetation patterns. Moving west from the heart of the Deciduous Forest Biome in the Appalachian Highlands, there is a general reduction

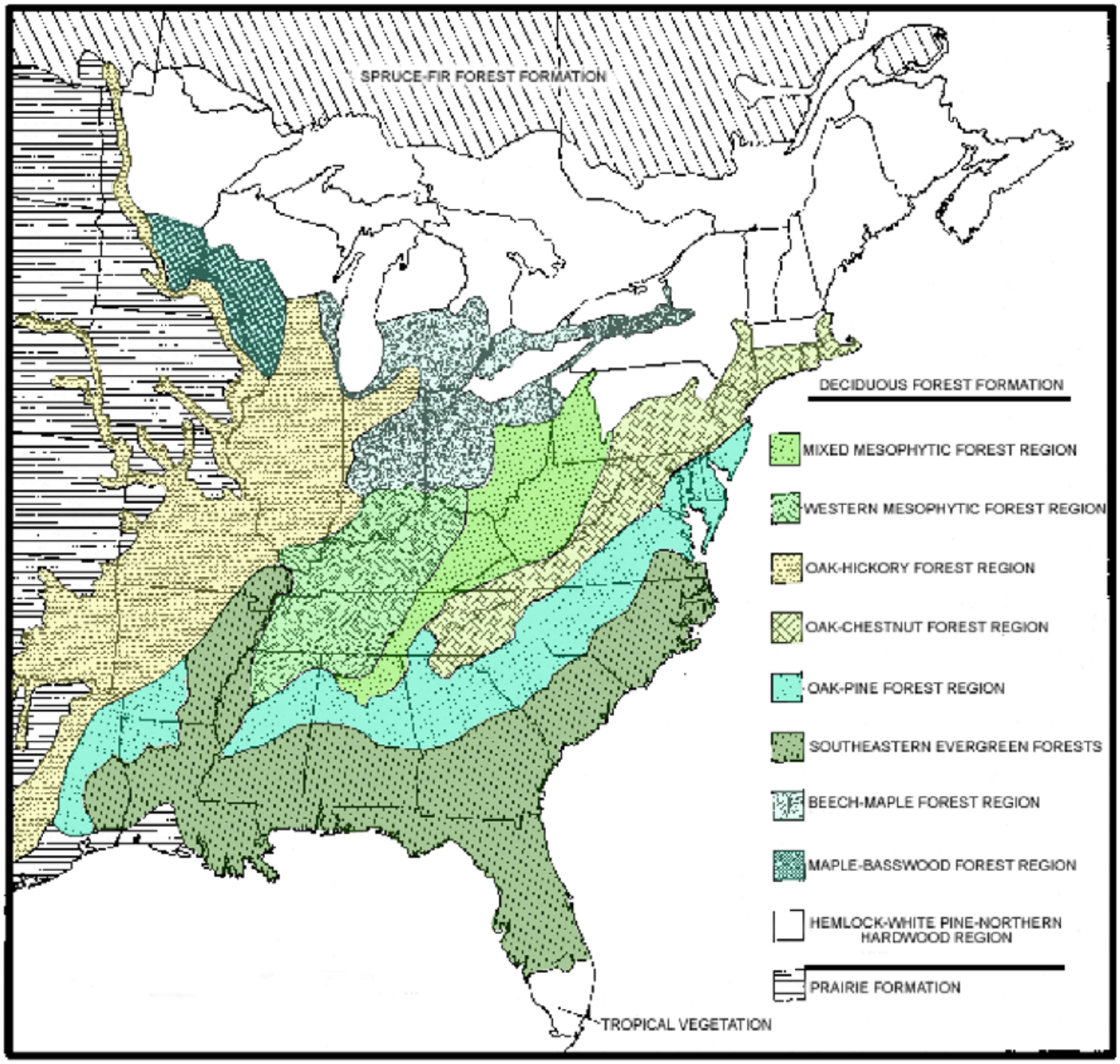


Figure 1.1. Map of potential vegetation types of eastern North America (Map adapted from Braun 1950 as presented in USFS Gen. Tech. Rep. SRS-53, 2002).

in tree species diversity as the humid species-rich forests of the east give way to oak-hickory forests of the Ozarks. Moreover, the western boundary of the Boston Mountains falls where deciduous forests transition to the dry grasslands of the continental interior. These trends underscore the unusual nature of mixed mesophytic forests in this otherwise relative xeric, species-depleted edge of the Deciduous Forest Biome in the Arkansas Ozarks.

While pre-eminent 20th century forest ecologist Lucy Braun noted the composition and significance of the rich forests of the Boston Mountains, relatively little research has sought to better understand the region's forest patterns. Among the studies concerning forests within the Boston Mountains, only a few contain in-depth records as to the composition of mixed mesophytic stands founds in the Arkansas Ozarks. These studies include Braun's (1950) discussion of two locations in Cass and Newton counties, Thompson's (1975, 1977) research focusing on a single valley in Newton County, and Turner's (1935) general descriptions of forest types found in the Boston Mountains.

Thompson's thesis (1975) and accompanying article (1977) describe in considerable detail the composition of different forest types occurring in Lost Valley, located near Ponca in Newton County, Arkansas. Focusing on possibly the same deep valley noted by Braun, this research identified four naturally occurring vegetation types: xeric red cedar glade, upland oak-hickory forest, mixed mesophytic hardwood forest, and the sweetgum-sycamore stream bank community. Thompson also discussed how the climate and geology of the Boston Mountains affects vegetation; as well as the soils associated with the different vegetative communities of Lost Valley.

Turner's (1935) overview of forest types in the Boston Mountains labeled what would be considered mixed mesophytic forests as the Quercus alba-Quercus rubra-Acer rubrum-Acer saccharum-Carya ovata association (Turner 1935, Thompson 1975). Read (1952) analyzed the correlation between surface geology, soil parent type and tree species occurrence on a north facing slope in Koen Experimental Forest located in Newton County, Arkansas. Other studies such as Rice and Penfound (1959) and Risser and Rice (1971) dealt primarily with upland forests throughout Oklahoma, but also contained some information concerning the small portion of the Boston Mountains located in the northeast corner of that state. These studies found that due to differences in topography and site conditions, this small western-most portion of the Boston Mountains generally contains more open woodlands and does not have the diversity of forests located in Arkansas.

To achieve a landscape level analysis of natural forest patterns, General Land Office survey notes for twenty-eight townships were digitized into a Geographic Information Systems database. This survey data was interpolated to answer the three main questions of this study: 1) what was the presettlement landcover of the study area? 2) what were the major tree species associations found throughout the study area? and 3) how are distributions of tree species influenced by the topography of the Boston Mountains? Due to the limited amount of ecological information concerning the Boston Mountains, as well as the significant impacts of logging in the Ozarks over the last 125 years, the findings of this study can be used to understand the region's natural forest patterns and help further explain why mixed mesophytic forests occur in the Arkansas Ozarks.

CHAPTER 2
PROJECT BACKGROUND

The Eastern Deciduous Forest Biome

While species composition at the stand level is primarily determined by site conditions and local seed sources, regional patterns of natural forest development are often due to physiographic and climatic developments over a geologic timescale. Consequently, a basic understanding of the history of eastern North America's Eastern Deciduous Forest Biome is important in explaining how forest regions and species associations have developed. The history of the Deciduous Forest Biome of eastern North America dates back to the establishment of angiosperms as the dominant flora of the world, some 60 to 70 million years ago (Delcourt and Delcourt 1993).

During the late Cretaceous epoch and much of the Tertiary period, the climate of present day North America was characterized by warmer temperatures and increased but seasonal precipitation patterns. These climatic patterns coincide with palynological records showing high levels of genetic radiation among extant floral taxa. The result of these evolutionary and climatic trends was the development of an ancient, rich forest, traditionally termed the “Arcto-Tertiary Geoflora.” During its peak in the Eocene epoch of the Tertiary period, this floral formation spread across much of eastern North America (Braun 1950, Graham 1993). Macrofossil evidence shows that across much of its extent, these ancient forests were composed primarily of tropical taxa; except in the Appalachian and Ozark Highlands where neotropical and paleo-subtropical flora mixed with temperate constituents (Delcourt and Delcourt 1993, Graham 1993). Although no current floral patterns in the world match the richness of this ancient forest, the mixed mesophytic forest type located at the center of the modern day Deciduous Forest Biome contains a somewhat similar mix of temperate and neotropical plant species. While many of the genera that comprise contemporary deciduous forests evolved during the time of the Arcto-Tertiary Geoflora around 65 to 35 million years ago, climatic changes since the last glacial maximum around 18,000 years ago have most affected the contemporary geographic distributions of tree species.

During the height of the Pleistocene glaciation most temperate tree species were displaced to the southeastern coastal regions, and many of the neo- and paleo-tropical plant taxa found in rich Tertiary forests were extirpated from their North American ranges altogether. As the Laurentide ice sheet retreated at the end of the Wisconsinan glacial period, eastern North America's climatic patterns began to resemble contemporary temperature and precipitation regimes (Delcourt and Delcourt 1993, Graham 1993). Tree species migrated in response to these climatic changes, ultimately leading to the development of today’s contemporary forest patterns.

Following the recession of the Laurantide ice sheet and the intensification of the Rocky Mountain rainshadow effect, the interior portions of the continent became warm and dry. These changes generally restricted the once extensive ranges of mesophytic tree species to areas of the eastern United States where cooler, more humid environments remained. In portions of the southern Appalachians, climate patterns and rugged topography combined to allow the persistence of mesophytic species; resulting in the development of the mixed mesophytic forest region (Graham 1993, Leopold, McComb, and Muller 1998). Conversely, the oak-hickory forest region formed in the continental interior where oak and hickory species, better suited to drier conditions, became the dominant tree species (Figure 1.1; Braun 1950, Delcourt 1991).

While oak-hickory forests are best developed in the Ozarks, site conditions found within the Boston Mountains enable the development of diverse forests similar to the mixed mesophytic forests of the southern Appalachian Mountains. Within the Boston Mountains, what Braun (1950) described as relic mixed mesophytic forests can be found in areas where factors such as topography, aspect, and soils combine to form humid microclimates; primarily in coves and on protected north facing slopes (Thompson 1977). In her seminal work, *Deciduous Forests of Eastern North America*, Braun (1950) writes "[t]he Boston Mountains are of particular interest vegetationally, both because of the considerable number of southern and mesophytic Appalachian species occurring there, and because of the relic mixed mesophytic forests of protected slopes of deep ravines."

While the surrounding oak-hickory forests are typically dominated by only six genera, the canopy of a typical mixed mesophytic stand in the Boston Mountains can be composed of species from more than thirteen genera (Braun 1950, Thomson 1977). Braun (1950) also wrote about the peculiar mix of species or what she described as the southern Appalachian character of mixed mesophytic forests found in the Boston Mountains. In these rich forests oak (*Quercus* spp.) and hickory (*Carya* spp.) species typical of the Midwest mingle with tree species found more commonly in forests further east, such as American beech (*Fagus grandifolia*), sweetgum (*Liquidambar styraciflua*), umbrella magnolia (*Magnolia tripetala*), black gum (*Nyssa sylvatica*), American basswood (*Tilia americana*), and sugar maple (*Acer saccharum*). Braun also noted the presence of Ozarkian endemic species such as vernal witchhazel (*Hamamelis vernalis*) and Ozark chinkapin (*Castanea ozarkensis*), as well as what she described as local variations of cucumber magnolia (*Magnolia acuminata* var. *ozarkensis*), and Ohio buckeye (*Aesculus glabra* var. *leucodermi*). The presence of stands containing twenty or more important species, as well as the unique compositional characteristics within the region, serve to highlight the exceptional nature of forests found in the Boston Mountains (Braun 1950, Thomson 1977).

The Environmental Setting of the Boston Mountains

The formation of the Eastern Cordillera, which includes the Appalachian and Interior Highlands, has a complex past that is believed to have begun hundreds of millions of years ago. The Alleghenian orogeny, thought to be the most recent episode of mountain building in the eastern United States, occurred during the late Paleozoic era around 300 million years ago. This mountain building period was initiated by the collision of the tectonic plates that North America and Africa ride on during the formation of the supercontinent Pangaea. As a result of the tremendous tectonic forces, many of the landforms comprising the Eastern Cordillera, including the Blue Ridge and Appalachian Plateau, assumed their current configurations (Shankman and James 2002). Although the precise history of the Eastern Cordillera is not completely understood, it is generally accepted that the Appalachian Highlands, Ozark Plateau and Ouachita Mountains were formed through similar, if not identical orogenic processes (Fenneman 1938, Thornbury 1965, Shankman and James 2002).

It is now believed that the multiple orogenies of the Paleozoic era resulted in a great uplifted landform that stretched from present day New England down the eastern seaboard and over to northern Texas (Shankman and James 2002). Massive erosion over millions of years, including the development of the Mississippi River Valley, separated the prehistoric highlands that spanned much of eastern North America into the discrete features of the Interior Highlands and the Appalachian Highlands (Figure 2.1). Within these landforms, extensive fluvial dissection and differing geology ultimately resulted in the topographically diverse nature of the Appalachian Plateau, Blue Ridge, Ouachita and Boston Mountains (Fenneman 1938, Thornbury 1965).

The Interior Highlands, a physiographic province contained within southern Illinois, southern Missouri, northern Arkansas and eastern Oklahoma, form isolated areas of uplifted topography surrounded by low-lying features (Figure 2.2). This region contains the points of highest elevation and the most rugged topography found between the Appalachian and Rocky Mountains. The Interior Highlands' two major features are the Ozark Plateau in the north and the Ouachita Mountains in the south. It is believed that these landforms were formed during the Paleozoic, around the same time as the Appalachian Highlands to the east (Shankman and James 2002). In addition to their similar geologic histories, the Interior Highlands and the Appalachian Highlands have very similar geomorphic and geologic character. Of particular interest are the similarities between the folded Paleozoic rocks of the Ouachita Mountains and the Ridge and Valley province, as well as the Mississippian and Pennsylvanian rocks found in both the Cumberland Plateau and the Boston Mountains (Thornbury 1965).

The Ozark Plateau is divided into four sections: the St. Francois Mountains, Salem Plateau, Springfield Plateau, and the Boston Mountains; each with its own distinct geology and physiography (Figure 2.2; Thornbury 1965). The Boston Mountains form a range of low-lying mountains with its primary axis oriented east to west. At roughly 320

Figure 2.1. Highlands of the eastern United States.

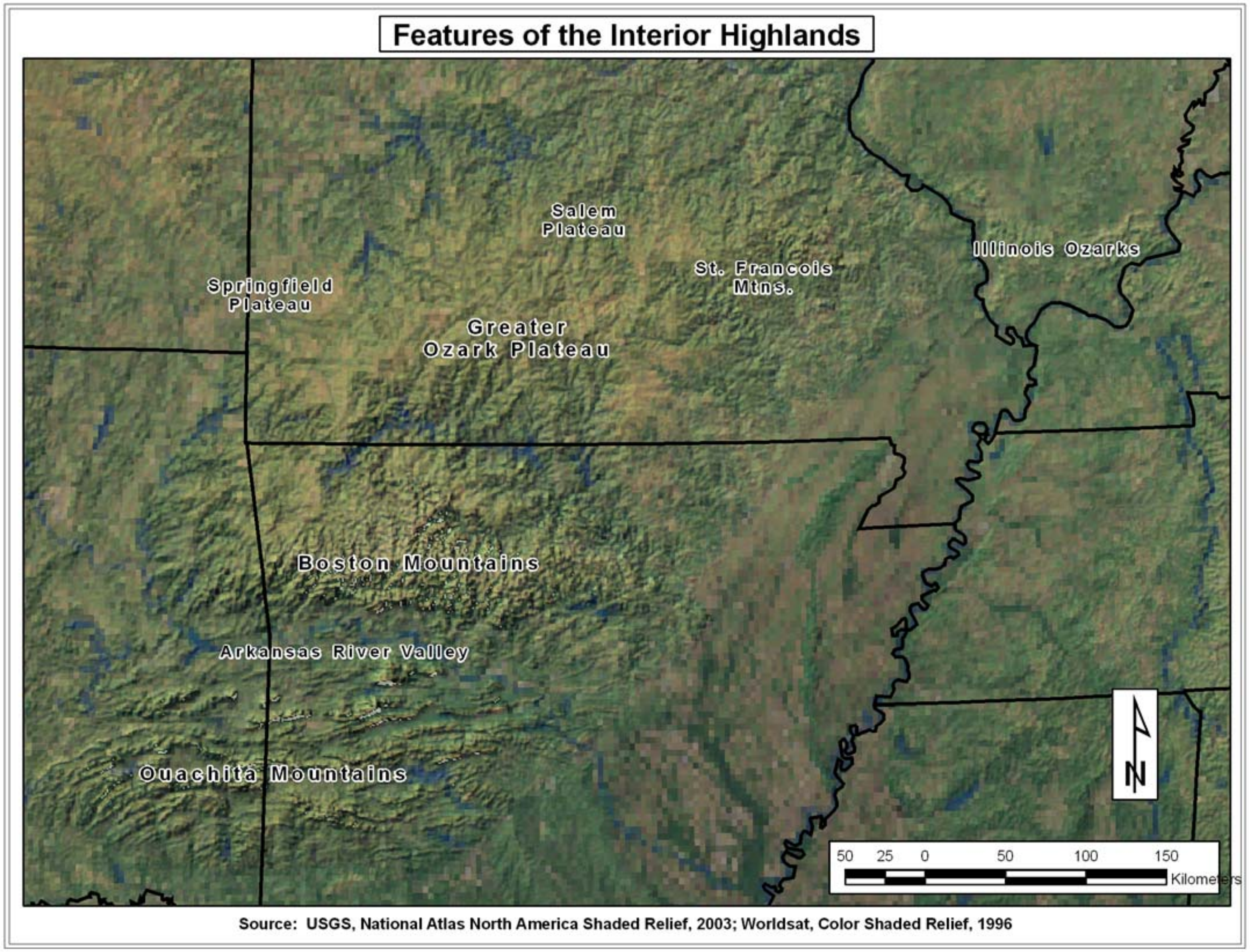


Figure 2.2. Features of the Interior Highlands of the United States.

kilometers long and 55 kilometers wide, these mountains cover roughly 16,500 square kilometers (Fenneman 1938). The Boston Mountains are located primarily in northwestern Arkansas, with a slight extension into northeastern Oklahoma, and are considered the southernmost feature of the greater Ozark Plateau. Elevations in these low mountains reach approximately 790 meters with local relief of 250 meters or more (USFS 1994). A small percentage of the Boston Mountains region consists of open hills and plains. However, the area is primarily characterized by steep, rocky hillslopes, large outcrops of sedimentary rock, and major valleys with depths of 150 to 300 meters (Fenneman 1938, USFS 1994). Due to a high level of fluvial dissection, this rocky landscape is distinctly more rugged than that of the greater Ozark Plateau to the north.

The Boston Mountains fall within the humid temperate climate domain, with a hot continental climate regime. The average growing season is 180 to 205 days long, with average temperatures ranging from 14 to 18°C. Annual precipitation for the area averages 114 to 132 centimeters and is distributed fairly regularly throughout the year, with the highest and lowest amounts of precipitation in the months of May and January respectively (USFS 1994).

The study area for this project includes twenty-eight townships that contain portions of six different Arkansas counties: Boone, Carroll, Franklin, Johnson, Madison and Newton (Figure 2.3). Covering over 2600 km^2, these townships are located at the heart of the Boston Mountains and contain some of the region's most rugged topography. The highest point of elevation, 781 meters, is located within Newton County; the lowest point of elevation, 218 meters, is in Franklin County.

The physiography of the study area was dominated by the primary east-west ridge of the Boston Mountains, with a secondary extension running from the center of the study area to the northeast (Figure 2.3). This northern part of the upper Boston Mountains includes the headwaters and the initial run of the Buffalo River (Figure 2.4). Within the study area, the eastern and southern townships contain the most rugged topography. The northeastern townships contain the flattest topography, with some extending onto the flatter Springfield Plateau found to the north of the Boston Mountains (Figures 2.2 and 2.4).

While Turner (1935), Braun (1950) and Thompson (1975) have documented the composition of diverse forests found in the Boston Mountains during the 20th century, these records offer little insight into the presettlement character of vegetation within this region. Extensive logging beginning in the late 19th century left this region severely denuded and in need of better management. The establishment of the Ozark National Forest in 1909 helped address these concerns by placing much of the Boston Mountains under the management of the United States Forest Service. While the protections afforded these forests have generally grown over the last century, the effects of 150 years of human disturbance still remain (Strausberg and Hough 1997).

Over the past few decades, ecologists have sought to better understand the natural composition and structure of forests, as well as the processes that lead to their development (Noss and Cooperrider 1994). Consequently, GLO survey notes predating widespread European settlement have become an important source of data, due to their unparalleled extent and overall fidelity (Schulte and Mladenoff 2001). These records offer an insight into the original character of the landscape, allowing ecologists to identify how forests can be restored and better managed.

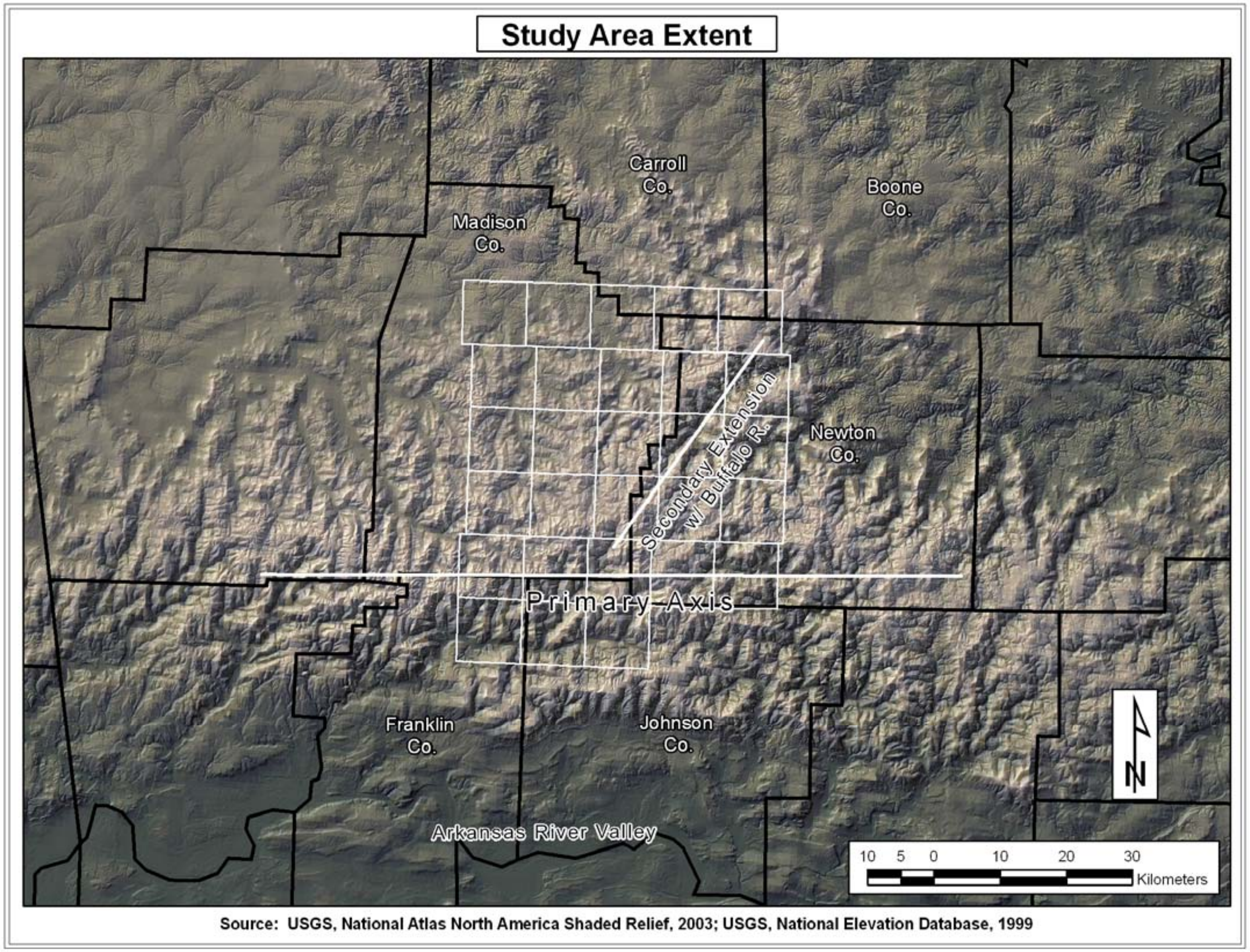


Figure 2.3. Map showing extent of the townships digitized, the counties within the project extent and orientation of major landforms.

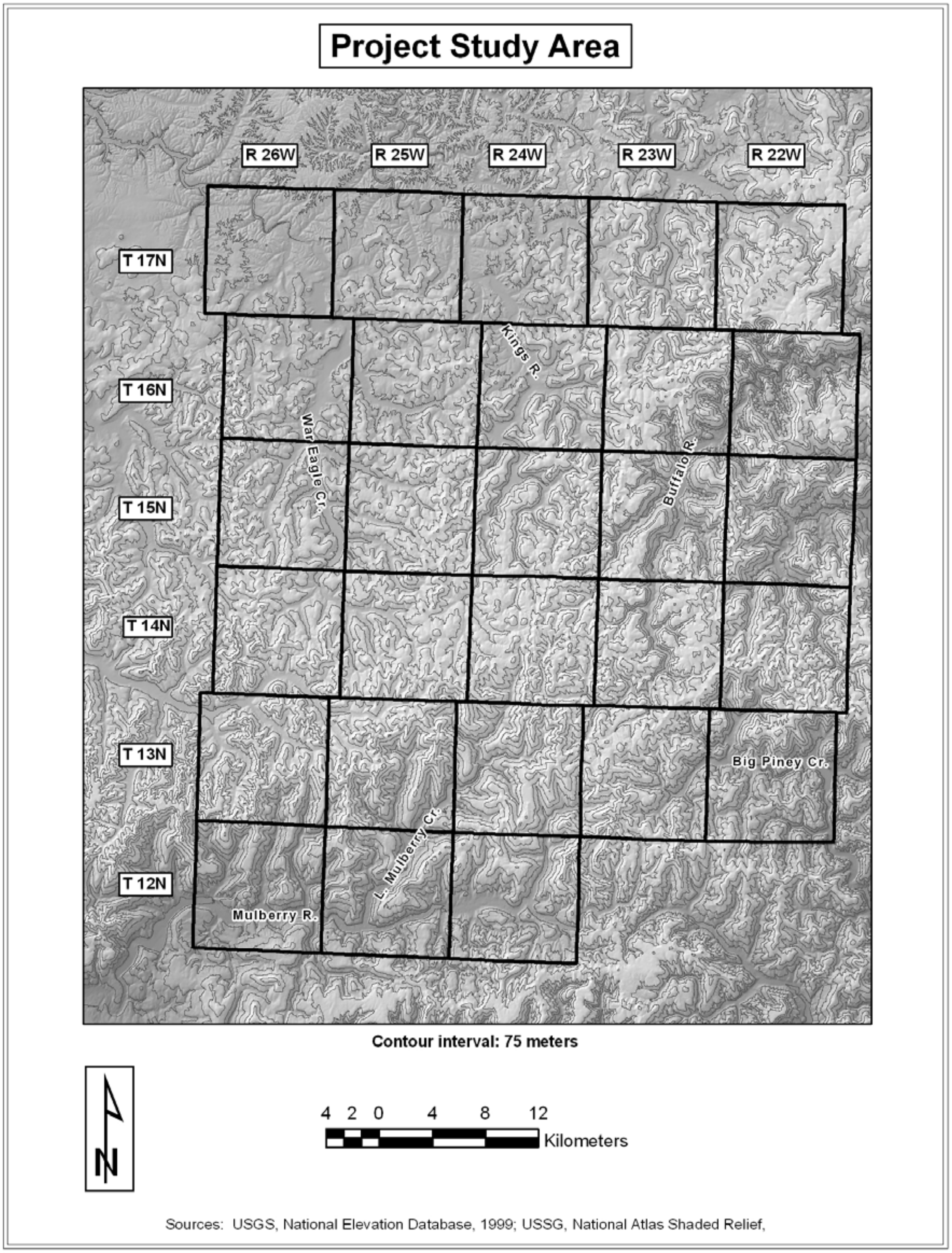


Figure 2.4. Map showing locations of townships containing digitized survey data and major streams within study area.

The Public Land Survey System

For thousands of years people have worked to survey and divide the Earth's surface. From the Babylonian Boundary Stones established over three thousand years ago, to the “rope stretchers” of ancient Egypt, to the Centuriation cadastral surveys of ancient Rome, civilizations have striven to develop more accurate and efficient methods of surveying (Colcord 1976). An early attempt at such a system was the irregular metes and bounds survey method. Brought from Europe and used throughout the American colonies, this system based survey boundaries and land claims on physical features as well as the preferences of those purchasing the land (Carstensen 1976). This survey method soon proved contentious and ineffective, and in 1785 the then young nation of the United States of America adopted a rectangular survey system through the Land Ordinance of 1785. This ordinance established the first widely utilized, government instituted, regular system of surveying in which land was first surveyed into six mile square townships, then further divided into 36 one mile square sections (Figure 2.5). Eventually referred to as the Public Land Survey System (PLSS), this system now covers thirty states and over 1.3 billion acres of public domain lands (Carstensen 1976).

From its establishment, the basis of this system has been the six mile township. The townships themselves are referenced to principle meridians (lines of longitude) and principle baselines (lines of latitude). Townships are numbered in an ascending order north or south from an established base line; likewise they are numbered in ascending order west or east from an established meridian (Carstensen 1976). Each township is then broken into thirty six sections measuring one square mile, which are then further subdivided into half sections, quarter sections and so on. Within a township, the section

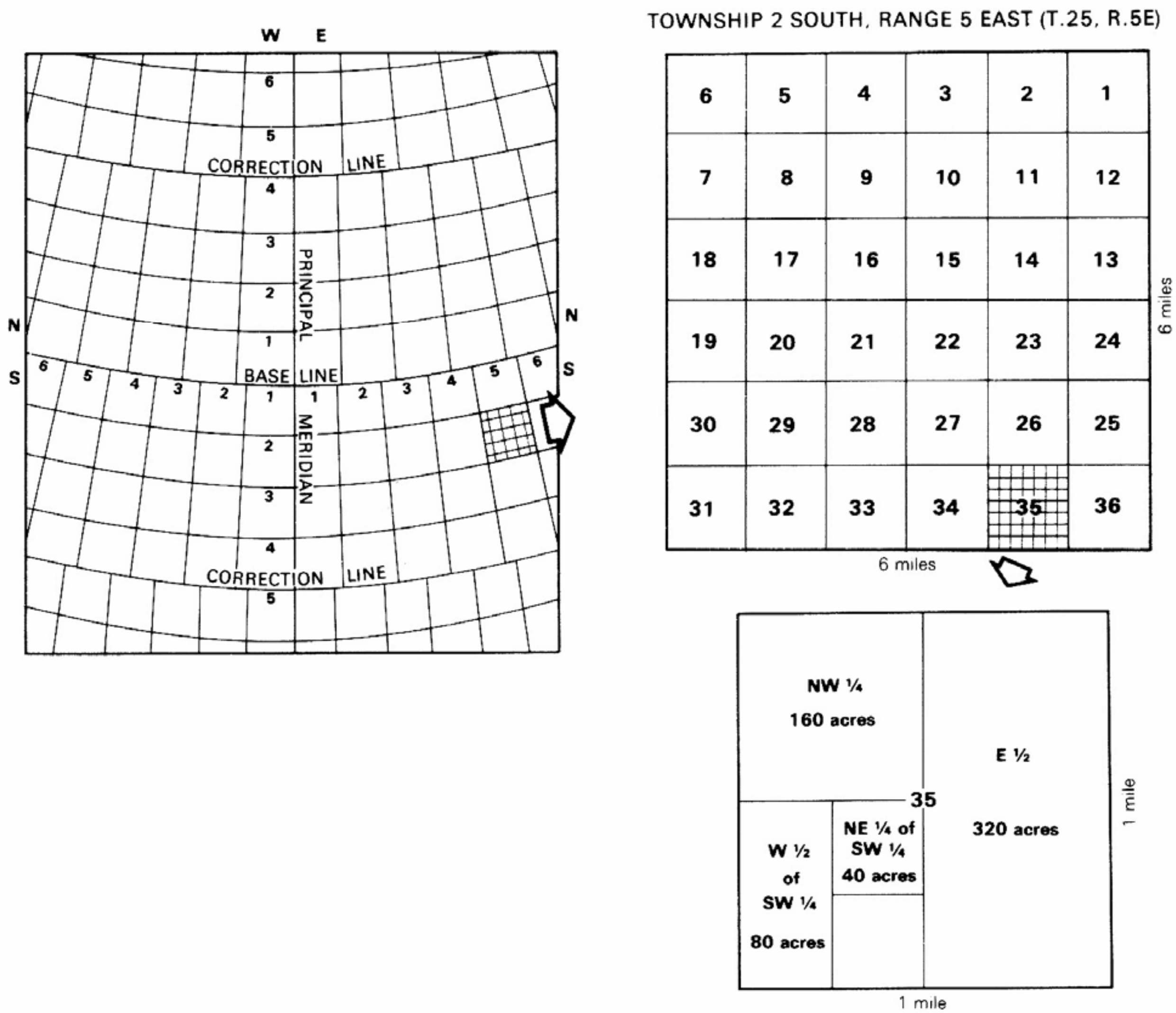


Figure 2.5. The hierarchical structure of the Rectangular Survey System utilized by the General Land Office (Johnson 1976).

in the northeast corner is labeled as Section 1 and the section in the southeast corner is labeled as Section 36 (Figure 2.5). This hierarchical structure allows specific land claims to be effectively located.

Physical surveying of the land was conducted along lines demarcating individual sections. Markers, typically wooden posts, were established every half mile at the corners of each section (corner post) as well as at the midpoint (quarter post) of each section line. At each corner and quarter post, two to four witness or bearing trees were marked, or “blazed”. The species and diameter of each witness tree, as well as the distance and bearing to the corner or quarter post was recorded. Similarly, the species and diameter of trees that fell along or near survey lines were also recorded. In addition to line trees, “[s]urveyors were also instructed to provide descriptions of the ‘face of the country’ along the line, including vegetation (sometimes in order of abundance), transitions between major vegetation types, suitability for cultivation, burned areas, and structures such as cabins and mills” (Stewart 1935, Batek et al. 1999). Meander corners were set where survey lines crossed rivers, bayous or lakes; and when permanent streams were encountered, the direction and speed of the watercourse additionally was also noted. GLO records also indicated where there was evidence, whether word of mouth or physical, of potential resources such as salt licks or lead deposits (Manies and Mladenoff 2000). When all of these available descriptors are used in conjunction, PLSS notes allow for an extensive view of presettlement conditions at a landscape scale.

While the structured and innovative system behind these surveys was clearly important in its success, other factors were important in allowing the plan to proceed efficiently. The low levels of European settlement and paucity of formal land claims in the newly established Public Domain lands were critical in allowing the strict rectangular surveys to be rigidly draped across the land (Johnson 1976). This process of “survey before settlement” allowed settlement to proceed with fewer conflicts. Also important to the success of the Public Land Survey System was the discipline and loyalty demonstrated by those employed by the General Land Office to complete these surveys. While incidences of fraud and surveyor bias have been identified, the vast majority of records are believed to be based on credible work (Dyer 2001, Schulte and Mladenoff 2001).

The Use of PLSS Notes in Presettlement Vegetation Reconstructions

In addition to their spatial extent and fidelity, GLO survey notes are an extremely valuable data source because most of the surveys of the eastern United States were performed not only when there were few existing settlements but also when human impacts on the landscape were relatively low. This was in part due to widespread and dramatic population declines of indigenous peoples throughout eastern North America following initial contact with Europeans in the fifteenth and sixteenth centuries. It is believed that prior to widespread European settlement, centuries of low anthropogenic disturbance resulting from Native American population declines may have mitigated the effects of indigenous people on the land, even in areas of relatively extensive habitation (Denevan 1992, Whitney 1996, Brown 1998, Guyette, Muzika and Dey 2002). Thus, the records contained in Public Land Surveys represent a spatially expansive and relatively intensive data resource characterizing the natural landscape prior to the extensive changes that followed European settlement.

While GLO survey notes are recognized as being valuable and accurate representations of presettlement conditions, it is important to bear in mind when working with GLO records that these surveys were not carried out for ecological purposes, but to facilitate the division and disposal of public lands. As with other common data sources there are considerations when working with survey records, such as appropriate study size and data fidelity, that must be addressed in the scope of the project. Although the method in which GLO survey data was collected makes it inherently geographic and valuable for ecological studies, the relatively low density of data points per township creates complications when interpolating vegetation patterns at the scale of only a few townships.

Manies and Mladenoff (2000) attempted to assess how accurately GLO point data can recreate vegetation patterns. Conducted on a relatively undisturbed landscape, the authors compared patterns from classified aerial photographs to those derived from a recreated GLO field survey. The results indicated that broad scale patterns are accurately depicted in interpolated maps, while localized patterns were potentially lost due to the resolution of the survey data. Similarly, Manies and Mladenoff (2000) concluded that "[p]redictive power appears to be related to the order of vegetative dominance on the landscape." Ultimately, the authors concluded that most of the error in the interpolated vegetation patterns was due to the relatively small study area of 8107 ha or 86% of a survey township, and that vegetation reconstructions at the scale of only a few townships are not valid due to the inherent complexity of vegetation patterns at smaller scales. The authors recommended analyses be conducted at the county level or greater, where the resolution of GLO data and common vegetation reconstruction methods are better suited.

In addition to complications due to data resolution, Manies and Mladenoff considered the effects of survey bias on vegetation predictions (2000). It was concluded that while witness trees may have been selected in a non-random manner, the resulting forest types or associations would not be affected. This research supports the theory that surveyor bias is constrained by the environment, and that the effect of any bias present in the GLO data is insignificant when mapping vegetation patterns at larger scales (Bourdo 1956, Delcourt and Delcourt 1996, and Schulte and Mladenoff 2001).

Although Bourdo (1956) noted that survey notes have been utilized since the early 1900s to examine the general characteristics of presettlement conditions, recent years have seen an increased interest in using GLO survey notes for the basis of ecological studies. The primary reason behind this increased use has been the advent of modern Geographic Information Systems (GIS). These systems have the necessary computing power and software to efficiently transcribe, visualize and manipulate the large amounts of data needed to accurately interpolate vegetative patterns resolved from GLO data.

Numerous studies have utilized survey notes effectively to recreate presettlement landscapes, usually in order to better understand anthropogenic changes over the past 300 years (e.g., Nelson 1997, Batek et al. 1999, Radeloff et al. 1999, Dyer 2001, Cogbill, Burk and Motzkin 2002, Cowell and Jackson 2002). Employing methods similar to those originally developed by Cottom and Curtis (1956), vegetation reconstructions have primarily used point data in the form of line and witness tree records as the basis for interpolation of both the composition and structure of forests. These methods capitalize on the information innate in GLO point data such as species description, stem diameter, stem density (via distance to post measurements) and topologic structure. Although this project did not specifically assess vegetation change due to anthropogenic disturbance, the studies listed above serve as the general basis on which the current project is based. A study of particular relevance to this project was the vegetation reconstruction conducted within the Missouri Ozarks by Batek *et* al. (1999). Many of the interpolation methods utilized in that study were subsequently refined to produce the vegetation reconstructions for this project.

While most presettlement forest reconstructions have concentrated on eastern forests, the Interior Highlands have also been the focus of some research. Much of the debate within this region has concerned forest structure and the effects of natural and anthropogenic disturbances within the Missouri Ozarks. Both survey data and accounts collected by pioneers and early settlers have been used to analyze the presettlement extent of open barrens and the historic condition of the region's woodlands (Beilmann and Brenner 1951, Steyermark 1959, Nigh, Pallardy and Garrett 1985, Schroeder 1981 Batek et al. 1999, Guyette, Muzika and Dey 2002).

Although they are considered a part of the Ozark Plateau, current and historical descriptions support the idea that the forests of the Boston Mountains differ significantly in structure and composition from the forests of the greater Ozarks (Braun 1950, Thompson 1977, Leopold, McComb, and Muller 1998). Foti's (2004) work sheds further light on these differences, by analyzing the extent of forests in the both the greater Ozark Plateau and the Boston Mountains. This study conducted a vegetation reconstruction using GLO records extending across several ecological sections and subsections of the Ozarks found in southern Missouri and northern Arkansas, concluding that the Boston Mountains contained considerably more woodlands and closed canopy forests than the rests of the Ozarks. While that study only used survey data entered along north-to-south transects, this project is intended to provide a more detailed understanding by interpolating regional scale forests patterns using the full resolution of GLO survey data.

CHAPTER 3
METHODS

This project entailed the interpolation of landcover and forest types found in the presettlement landscape of the Boston Mountains using GLO survey records. These interpolated patterns, along with the distributions of important canopy species and taxa, were analyzed for correlation to factors known to influence tree growth and distribution; including slope, aspect and topographic roughness. The insights gained from these analyses were then used to identify how environmental factors within the Boston Mountains have historically enabled the development of a mosaic of oak hickory and mixed mesophytic forests, unique within the greater Ozark Plateau.

Study Area

The twenty-eight townships comprising the study area for this project were chosen because they are located at the center of the Boston Mountains and contain some of the region's most rugged topography (Figure 2.3). A total of twenty-three surveyors recorded townships and section line survey data (Figure 3.2). Survey records for the study area indicated that many of the township boundary lines were surveyed a few years before the interior portions of the townships. In general, boundaries lines were surveyed from the late 1820s to the late 1830s while interior lines were surveyed from the mid 1830s to the late 1840s (Figure 3.3).

Data Entry

Survey records for the entire state of Arkansas were obtained on CD-ROM from

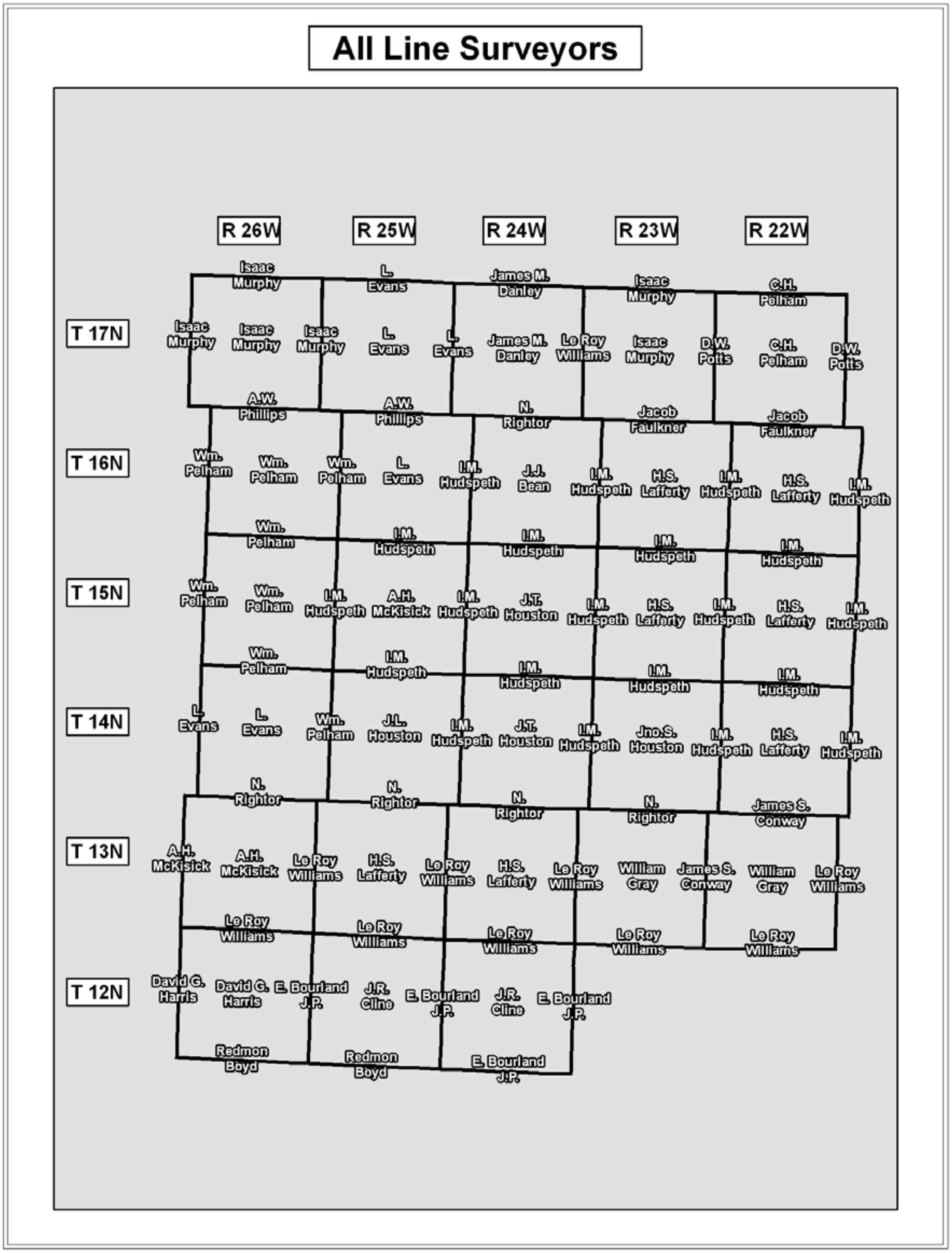


Figure 3.1. Surveyors responsible for township and section-line surveys.

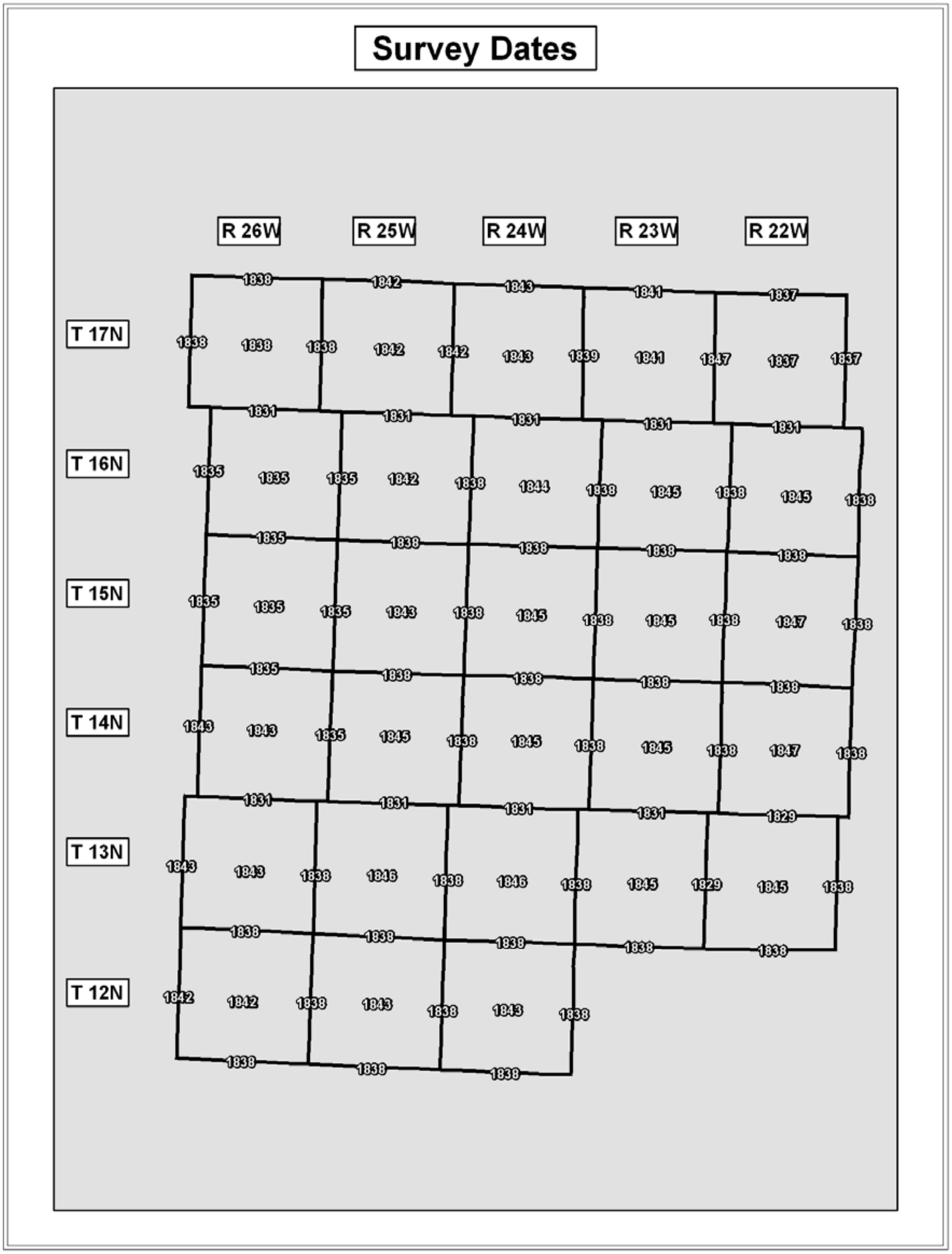


Figure 3.2. Dates of township and section-line surveys.

the office of the Commissioner of State Lands (Daniels 2000; Figure 3.3). This set of thirteen compact discs contained plat maps and the corresponding field and boundary notes, as well as a master index CD to aid in navigating the entire dataset. A menu-driven, Arc Macro Language user-interface program developed by James Harlan of the University of Missouri's Geographic Resource Center was used to digitize the survey data (J. Harlan, personal communication 2003). Digitization of all features into a GIS database (ArcInfo 8.3, ESRI 2002) proceeded in the direction of travel of the surveyor across the land . Survey records were stored on a township-by-township basis and a database of United States Geological Survey (USGS) PLSS boundary files for the whole state was obtained from the University of Arkansas' Center for Advanced Spatial Technologies (CAST 2005). These USGS township boundaries were used to geo-reference all geographic information entered. To ensure the relative position of any features digitized along each survey line, end points were established on each survey line and the relative length of each line was referenced to the corresponding section line of the PLSS boundary line. This ensured that all the features entered into the GIS were placed at the correct relative position, regardless of discrepancies in section line lengths between the survey notes and the equivalent USGS survey line.

Along each section line, posts were digitized at the midpoint (quarter-section corner) and terminals (section corner) of each surveyed section line. Just as with quarter and corner posts, meander posts (and their accompanying witness trees) were digitized at the edge of water features. Within the study area, surveyors recorded two to four bearing or witness trees each corner or meander post. Each bearing tree was typically selected out of a separate quadrant (i.e., northwest, northeast, southeast and southwest)

Chains	
80.00	to Corner of Sec 1.6.31 and 36 Townships 14 and 15 North Ranges 24 and 23 West
Chains	Chain Compared and taken up one half inch
North	along the East Side of Sec 36 Township 15 North Range 24 West
4.62	a hickory 7 in dia
29.20	to Bluff 40 ft high
40.00	Set a ¼ Sec post from which a white oak 5 in dia Bears S 60 W 14 links and a white oak 8 in dia Bears N 13 W 24 links
43.52	a Black oak 12 in dia
80.00	Set a post Corner to Sec 36 and 25 from which a white oak 30 in dia Bears S 26 W 28 links and a white oak 14 in dia Bears N 16 W 62 links Land mountainous and rocky Soil 3 rate Timber white oak Black oak and Spanish oak undergrowth oak Bushes and Grape Vines
North	along the east Side of Sec 25 Township 15 north Range 24 West
1.40	a white oak 30 in dia
40.00	Set a ¼ Sec post from which a Beech 6 in dia Bears S 4½ W 35 links and a Beech 12 in dia Bears N 68 W 15 links
40.31	a Beech 4 in dia
80.00	Set a post Corner to Sec 24 and 25 from which a Beech 8 in dia Bears S 63 W 65 links and a Beech 9 in dia Bears N 44½ W 34 links land mountainous and rocky Soil 3 rate Timber B oak white oak and Some Beech undergrowth oak Bushes March the 16th 1838
North	along the East Side Sec 24 Township 15 North Range 24 West
7.00	to Bluff 20 ft high
40.00	Set a ¼ Sec post from which a Black oak 15 in dia Bears S 33 W 32 links and a white oak 7 in dia Bears N 55 W 27 links
63.32	a white oak 24 in dia
80.00	Set a post Corner to Sec 24 and 13 from which a white oak 14 in dia Bears S 48½ W 58 links and a white oak 8 in dia Bears N 72 W 47 links Land hilly and rocky Soil 3 rate Timber white oak Black oak Some hickory undergrowth oak Bushes
Chains North	along the east Side of Sec 13 Township 15 North Range 24 West
4.64	a Spanish oak 12 in dia
40.00	Set a ¼ Sed post from which a Black oak 18 in dia Bears S 15 W 23 links and a Chinquepin 6 in dia Bears N 37 W 46 links
42.03	a white oak 12 in dia

-15-   1566

Figure 3.3. Sample page from transcribed GLO survey notes obtained from Arkansas Commissioner of State Lands.

surrounding the quarter and corner posts. The species, diameter (in inches), distance along the survey line (in chains and links), as well as distance to (in chains and links) and bearing from the respective post (e.g., 25 degrees NE quadrant) were entered for each tree data point. Tree point entries were also noted as being either corner-section-corner trees, quarter-section-corner trees, or line trees.

Line data entries consisted of vegetation, land and cultural resource descriptions, as well as the distance along the survey line each condition or feature extended. In addition to noting the beginning and ending points of each survey line, surveyors recorded a brief and often formulaic description of land characteristics and vegetation patterns encountered. Land descriptions most often focused on whether land was suitable for settlement in addition to the general topography of the land. These descriptions also included information about the general vegetation type (e.g., prairie, woodland) and if applicable, a more specific description of the dominant vegetation. Species were often labeled as “timber” to reference canopy species, or “undergrowth” to describe small trees, shrubs or vines.

Surveyors also described where cultural features fell along a survey line. These descriptions included signs of European, American and Native American settlement, such as trails, structures, and cultivated vegetation (Daniels 2000). Within the study area, roads and trails were the most common cultural features noted by surveyors (Figure 3.4). These transportation routes were most dense in the northern part of the study area. Similarly, most of the area’s structures and cultivated fields were found along floodplains in the northern townships.

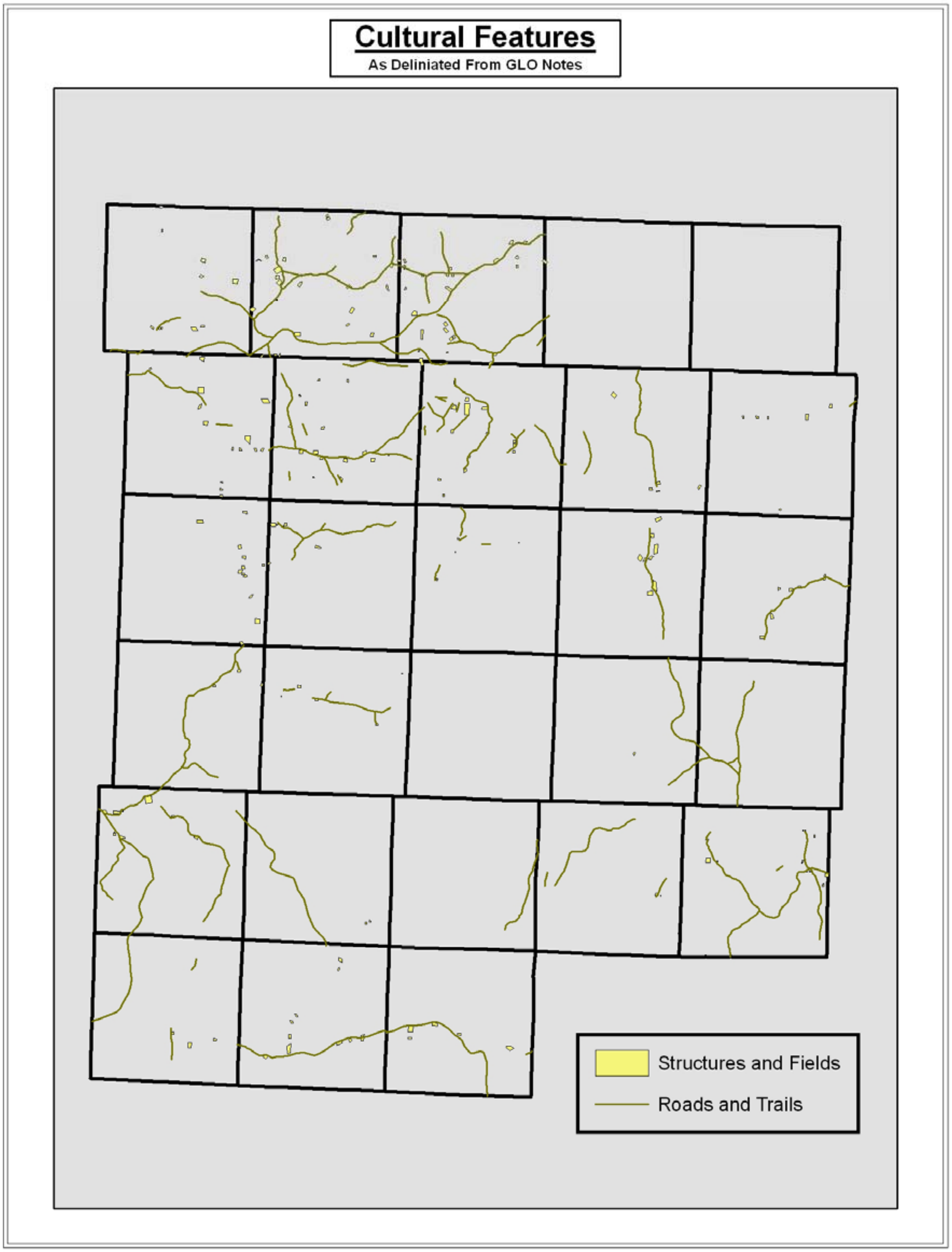


Figure 3.4. Map showing cultural features recorded by surveyors within the study area.

Interpolation of Landcover and Forest Types

Following transcription, landcover for the study area was interpolated using a method developed by James Harlan (J. Harlan, personal communication 2003) to improve on procedures initially employed by Batek et al. (1999). This process utilized both point data and vegetation line descriptions to resolve vegetative landcover. A keyword search performed on all vegetation line descriptions indicated that within the project extent, no areas were noted by the surveyors as being open grassland (prairie). Following this analysis, all vegetation line data was converted into a 50-meter resolution grid assigning a label of woodland.

In order to determine tree density and land cover, tree data points were associated to corner posts by identifying the closest corner or meander post within 226 meters. The bearing distance, number of tree data points around each post, and diameter of the associated trees were then normalized in order to produce area occupied per stem for each tree data point. This was then used to determine the density of stems per hectare, from which a surface model was produced assigning probability values ranging from 0-100 based on tree density. After calculating general stem density across the study area, at each tree point a proportional relationship of diameter to canopy cover was input for the appropriate species using a lookup table. Mean canopy cover at each point was calculated and then converted into total canopy cover using a probability value based on whether the grid cell is likely to be grassland or forest. Based on this probability value, a classification of open barrens and scrub cover (0-19%), open woodland (20-49%), woodland (50-79%), and forest (80-100%) was associated with each grid cell.

Because survey records for the study area recorded upland tree data points in much higher numbers than those in bottomland areas, forest types in these two topographic positions were resolved separately. Floodplains within the study area were delineated in a GIS using a USGS digital elevation model. These boundaries were then used to separate tree points that fell within floodplains from those located in upland portions of the study area.

To resolve tree species associations, a frequency analysis was performed on the tree point data to establish the most common species in the upland and bottomland portions of the study area. For the upland areas, a total of eighteen of the most common species and taxa were analyzed for covariance: white oak, black oak, hickory, black gum, red oak, post oak, Spanish oak, elm, beech, chinquapin, maple, pine, sugar tree, sweet gum, cherry, ash, blackjack oak and walnut. For the bottomland areas, twelve species and taxa were included in a separate covariance analysis: elm, hickory, black oak, white oak, hackberry, black gum, sycamore, ash, cherry, red oak and walnut. All tree data points corresponding to these species were then selected out and a 50-meter grid was produced for each species. Each grid cell was assigned a value ranging from zero to one hundred indicating the likelihood of that cell to contain a particular tree species.

The grids produced for each species were then combined and a maximum likelihood cluster analysis was completed in order to aggregate grid cells based on the different species' spatial covariance. For both the upland and floodplain analyses, a sampling interval of ten was chosen. This produced ten different clusters or species covariance samples which then were used to establish possible species associations. For each species cluster, a statistical file was produced that described the species composition of the sample. This file identified the total cells within each sample or potential species class as well as a focal mean value for each species included. This focal mean value was then used to determine the covariance or probability of co-occurrence of species within each sample.

For the upland portions of the study area, determination of potential species associations was based on a significant focal mean value of fifty or greater for primary associates, and twenty or greater for secondary associates. Because of its smaller total area and fewer data points, bottomland species associations were established using a focal mean value of thirty-five or greater to indicate primary associates and a value of ten or greater to indicate secondary associates. Following analysis of focal mean values, sample clusters containing similar species associates were identified and referenced to what were determined to be the final tree species associations. By overlaying the analyzed and referenced probability grids, a final grid was produced with only the cell values of the final associations as well as a cell value for open barrens and scrublands. This grid was then converted to a polygon coverage to be used in the final maps.

Data Analysis

The above procedures resulted in three data outputs: individual species distributions, interpolated general land cover and interpolated tree species associations. To interpret patterns produced from the survey notes, the three data sources were analyzed for abundance and distribution, as well as correlation to factors expected to affect vegetation patterns such as slope, aspect, topographic roughness and soil type (Table 3.1). Using both GIS software and statistical analysis, these patterns were assessed and quantified to better understand the distribution and composition of

Table 3.1. Environmental factors assessed in site preference analysis.

Environmental Factor	Categories	Final Data Form
Slope	Intervals of 5°	Normalized %
Topographic Roughness Index	Units of 5	Normalized %
Aspect	Intervals of 45°	Normalized %
Diameter per Aspect	1° and 2° Aspect Categories	Average diam. (cm)
SSURGO Soil Series	USGS series description	Top 5, Raw %

presettlement vegetation of the Boston Mountains, as well as their environmental controls.

Correlation of tree points, landcover and forest types to slope, aspect and a derived topographic roughness index was conducted in order to analyze the influence of topography on vegetation. Topographic roughness index is derived by analyzing the standard deviation of elevation within a 150 meter radius around each elevation grid cell; with higher TRI values indicating rougher topography (Holmes et al. 2000).

For general landcover types and tree species associations, an overall average slope and TRI value was calculated for each landcover type and tree species associations (e.g., open woodlands landcover, mesophytic oak forest type). In addition to an average slope and TRI value, each environmental factor with a numerical value was divided into intervals. To better analyze the effect of aspect, eight aspect categories were differentiated by creating categories of forty-five degree increments, established around each primary and secondary direction (Figure 3.5). Other numeric factors such as slope and topographic roughness index were also categorized into five unit intervals (i.e., 5º for slope classes, 5 units for topographic roughness index classes).

In addition to slope, aspect and TRI analysis, statistical analysis identifying the average diameter per aspect class was conducted for each species. While general aspect analysis shows which category a species most frequently fell on, this statistic identifies which aspect category a species achieved its largest diameters. These average diameters were then compared to the overall average stem diameters across the study area in order to identify what aspect class had site conditions optimal for a species' growth and development. The insights drawn from the above analysis, are used together to discover

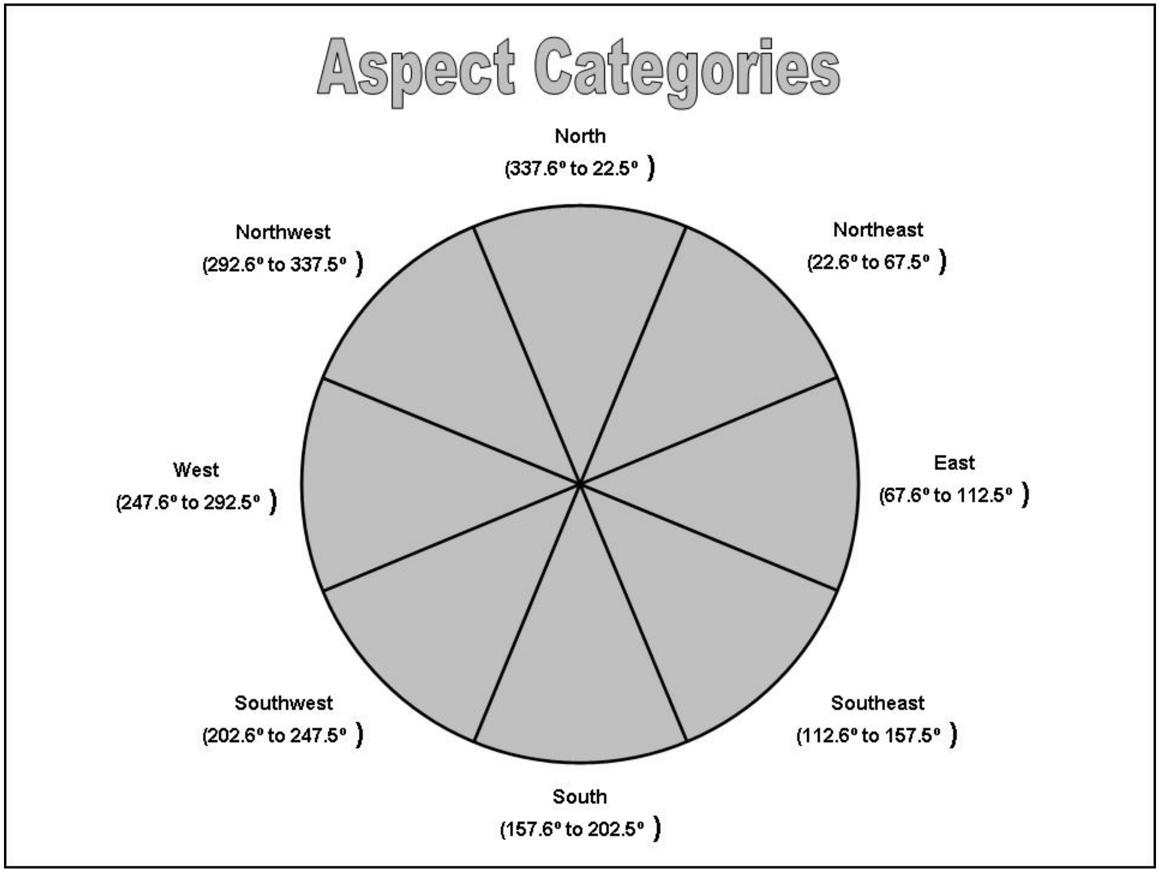


Figure 3.5. Diagram of aspect categories for site preference analysis.

what types of sites tree species most commonly fell on.

In addition to the slope, aspect and TRI, species associations were correlated to SSURGO soil series data. At the time of initial data analysis, three counties had available SSURGO soil data: Carroll, Newton and Madison; while the fourth county (Boone) was not available. For east forest type, the five most commonly occupied soil series are given.

For most of the analysis of topographical factors, the data are given in normalized form. Raw data results were normalized by totaling the number of tree points or total area for a environmental factor category (e.g., northwest aspect, 5-10 TRI value). The total for each category was then divided by the total area within the project extent, to produce a percentage of each category within the study area. The inverse of this percentage was then multiplied by the number of points or area for each species or interpolated cover type, within each environmental factor category. While the raw data give quantified information on how forest a landcover or tree species physically fell on the land, the normalized numbers give a better perspective on the natural affinities of the tree species, associations and landcover.

CHAPTER 4
RESULTS

Within the 28 township study area, GLO surveyors recorded 11,176 tree points and over 2000 township and section line vegetation descriptions, with a total of 48 taxa identified. Four general landcover types and eight tree species associations were derived from these point and line data. Results show the vegetation of the Boston Mountains included a mix of open barrens, oak-hickory woodlands and diverse, closed canopy mesophytic forests. This unique mosaic of landcover and forest types was also shown to be strongly influenced by the topography of the region.

Landcover Patterns

The four landcover types resolved in this project were: open (which includes barrens and scrubland), open woodlands, woodlands and forest (Table 4.1, Figure 4.1). Analysis shows that in the mid-nineteenth century, woodlands (50-79% canopy cover) and closed canopy forest (80-100% canopy cover) dominated the landscape of the Boston Mountains; covering 42.8% and 35.6% of the study area respectively. Across the study area, areas occupied by woodlands had a mean slope of 11.1º and a mean topographic roughness index value of 15.1. Closed canopy forests fell on more rugged sites with a mean slope of 11.4º and a mean TRI value of 15.6. Open woodland landcover (20-49% canopy cover) covered 19.92% of the study area and fell on areas with a mean slope of 10.5º and a mean TRI value of 15.1. Open barrens and scrub (0-19% canopy cover) covered the smallest percentage of the study area at only 1.7% and was found on the flattest sites with mean slope of 8.1º and a mean TRI values of 13.3.

Table 4.1. Landcover Patterns in the Study Area.

Landcover Type	Canopy Cover	Area (ha^2)	% Study Area	Mean Slope	Mean TRI Value
Open (barrens, scrub)	0-19%	4451.75	1.7%	8.1º	13.3
Open woodland	20-49%	52363.50	19.9%	10.5º	15.1
Woodland	50-79%	112480.75	42.8%	11.1º	15.1
Closed canopy forest	80-100%	93549.25	35.6%	11.4º	15.6

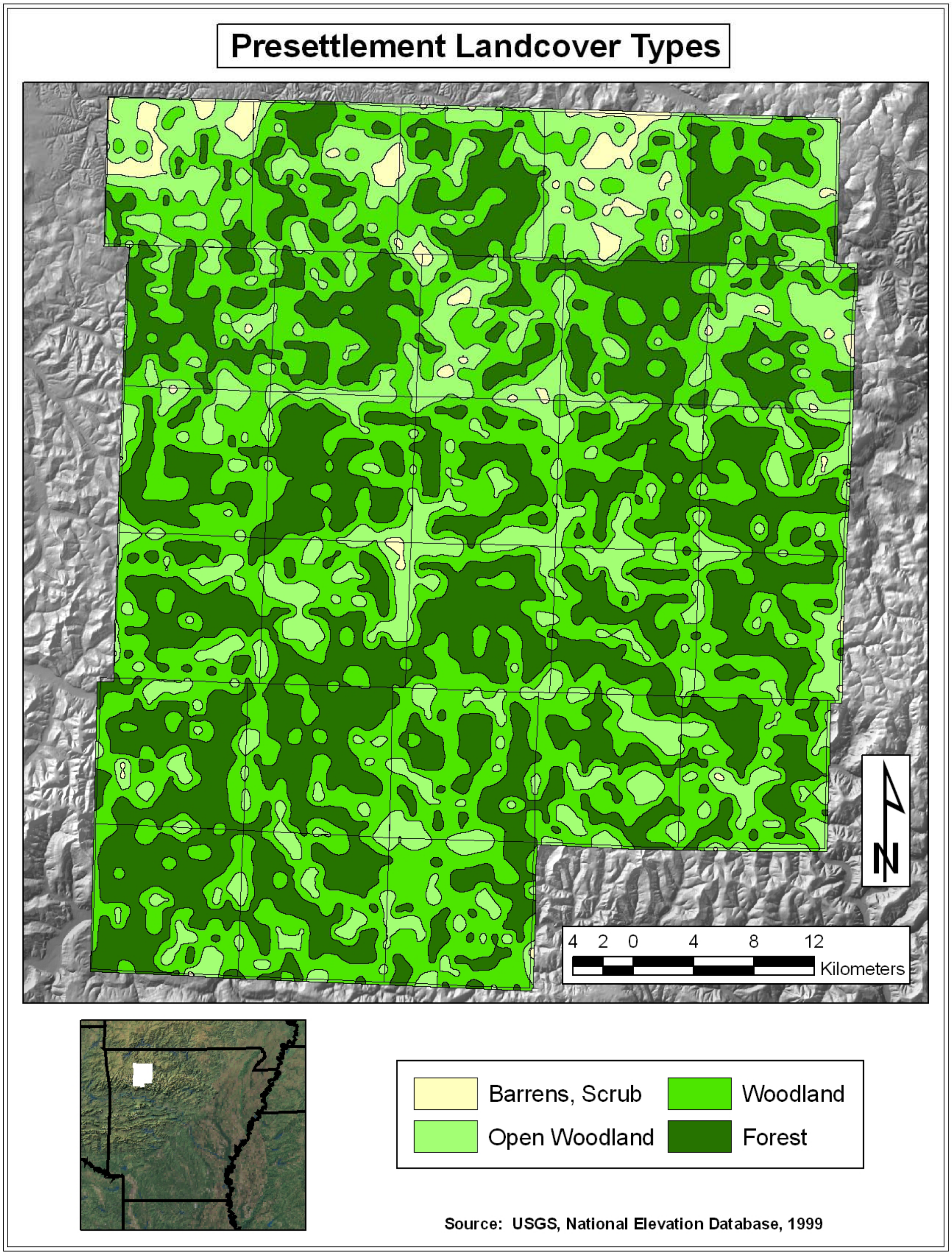


Figure 4.1. Map of presettlement land cover.

Normalized data analysis shows that the open landcover type (Figure 4.2) most often fell on slopes less than 10º (58.7%). Furthermore, open barrens and scrub were commonly found on areas with relatively little topographic diversity with the TRI classes of 0 to 4.9 and 5 to 9.9 having the highest distributions with 21.3% and 14.3% respectively. Not surprisingly, aspect analysis also shows that open barrens and scrub were most often found on flat sites (19.6%); with north and west facing slopes showing slightly higher distributions with 11.4% and 11.2% respectively. All other aspect categories fell between 9.2% and 10.4%.

Landscape analysis by classified topographic factors found that open woodlands (Figure 4.3) were most commonly found on areas with less than 9.9º slope (32.3%). Interestingly, the second highest distribution of open woodlands per slope class was found on areas with slopes of 30º or greater (15.2%). Analysis of distribution according to TRI categories was evenly distributed but did show patterns similar to the slope analysis. Areas with TRI values ranging from 0 to 4.9 (12.5%) and 5 to 9.9 (11.4%) as well as 35 to 39.9 (11.6%) and greater than 40 (11.5%) show slightly higher distributions. Slope analysis also shows a fairly uniform distribution, with open woodlands most frequently occupying flat areas (13.2%).

Analysis of woodland landcover (Figure 4.4) site preferences shows a fairly even distribution according to all the different environmental factors. Distribution percentages for all slope categories have a range of a little more than 2%, with woodlands most commonly growing on areas with 25 to 29.9º (15.7%). Except for the TRI category of 35 to 39.9 (9.3%), woodland growth was almost evenly distributed, with all other categories ranging from 11.2% to 11.5%. Also showing little preference for specific aspects, all

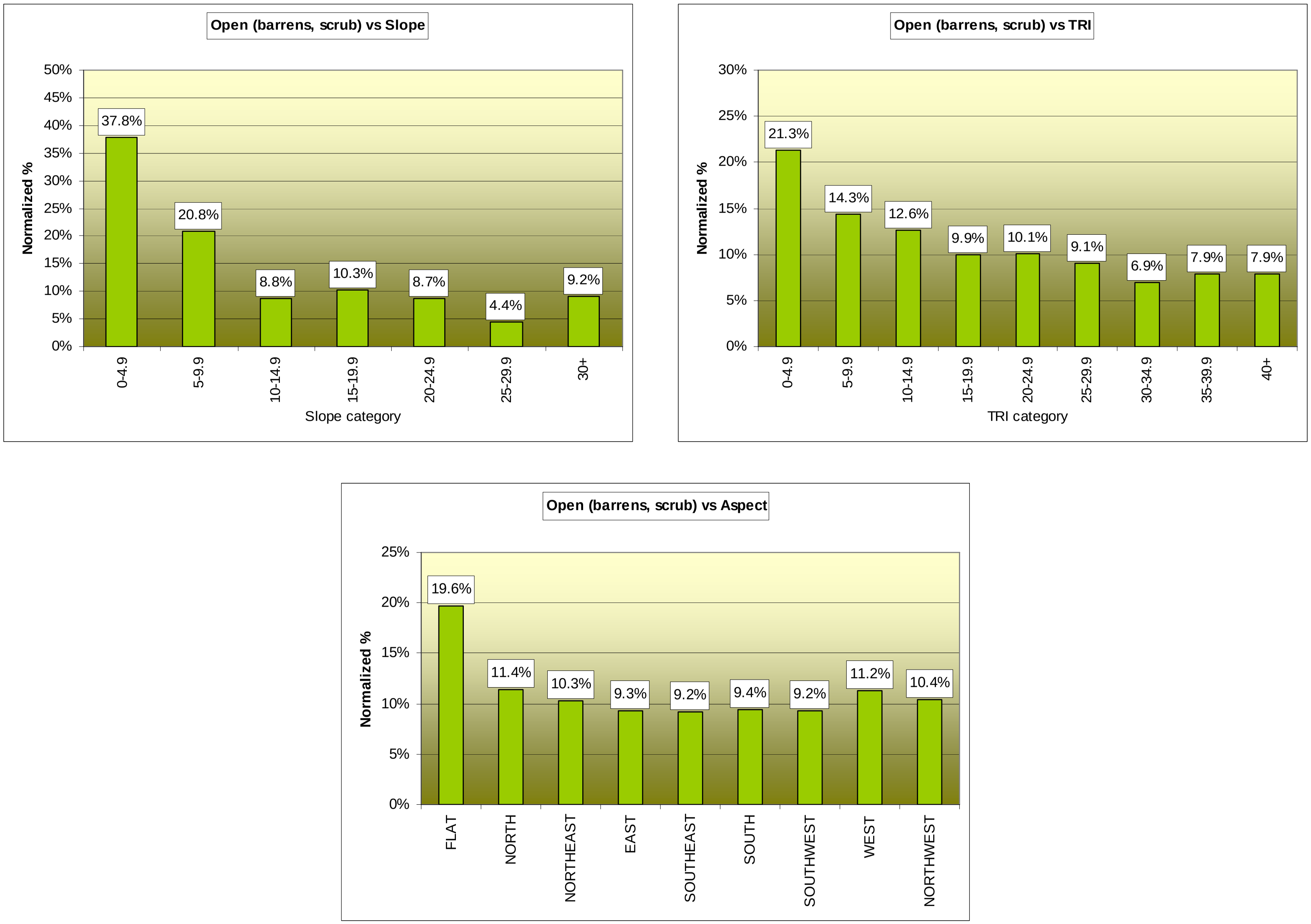


Figure 4.2. Open (barrens, scrub) landcover site analysis.

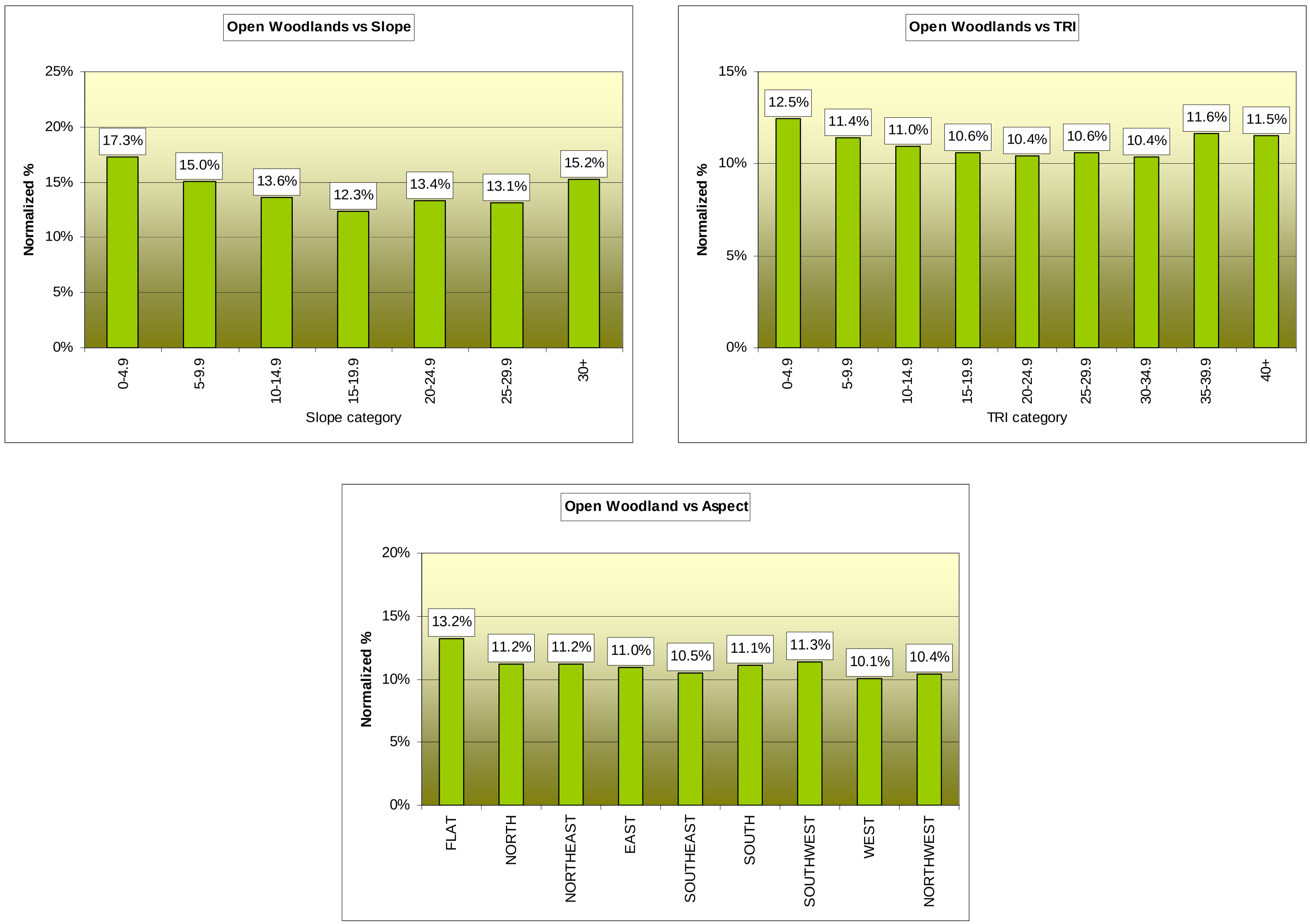
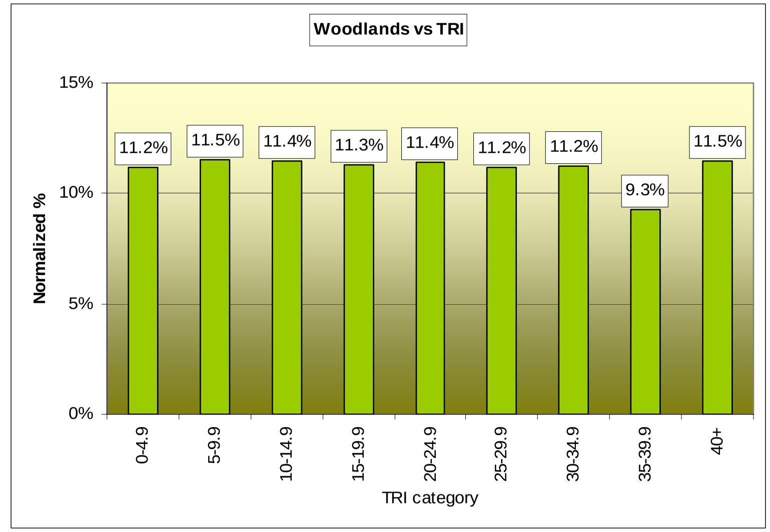


Figure 4.3. Open woodlands landcover site analysis.



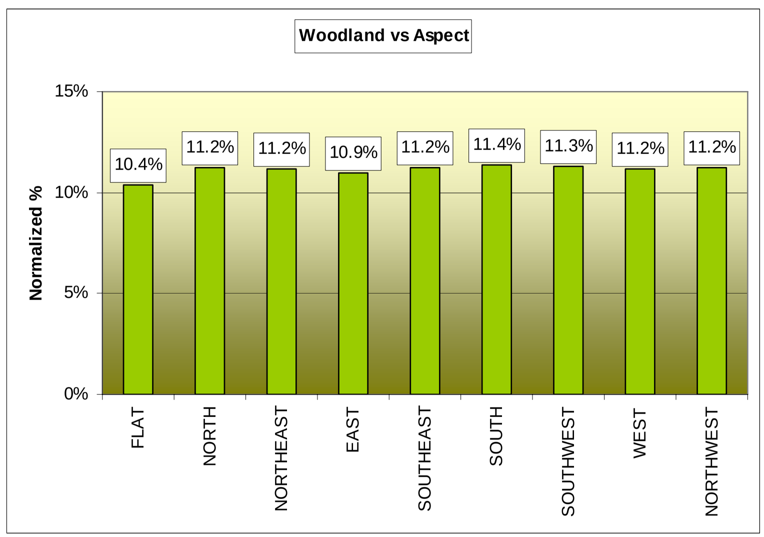


Figure 4.4. Woodlands landcover site analysis.

directional aspects contained between 10.9% and 11.4% of the total woodland landcover, with flat areas containing slightly less at 10.4%.

For closed canopy forest (Figure 4.5), normalized percentages demonstrate an affinity for moderate slopes with its distribution peaking on sites with 15 to 19.9º slopes (16.1%). Forests landcover shows a slight preference for more rugged areas with the TRI values range of 35 and 39.9 with 13.1% of the total forest landcover. Aspect distribution shows very little variation, with values ranging from 10.4% for flat areas to 11.6% for west facing slopes.

Individual Tree Species Patterns

Of the 48 recorded species or taxa references (Table 4.2; Figure 4.6), a total of nineteen were included for site preference analysis: white oak, black oak, hickory., blackgum, red oak, post oak, Spanish oak, elm, beech, chinquapin, maple, pine, sugar tree, sweetgum, cherry, walnut, ash, blackjack oak and hackberry. While oak and hickory species did dominate the study area, mesophytic species including beech, sweetgum and various elm, maple and ash species were shown to be important constituents of the presettlement forested landscape. Furthermore, the presence of other species such as American basswood, river birch and black locust served to highlight the diverse nature of presettlement forests in this region. In general, xerophytic species were most densely distributed in the flatter northwest corner of the study area, whereas mesophytic species were most common in the rugged eastern and southern portions of the study area.

White oak (*Quercus alba*; Figures 4.7 and 4.8) is a fairly cosmopolitan species

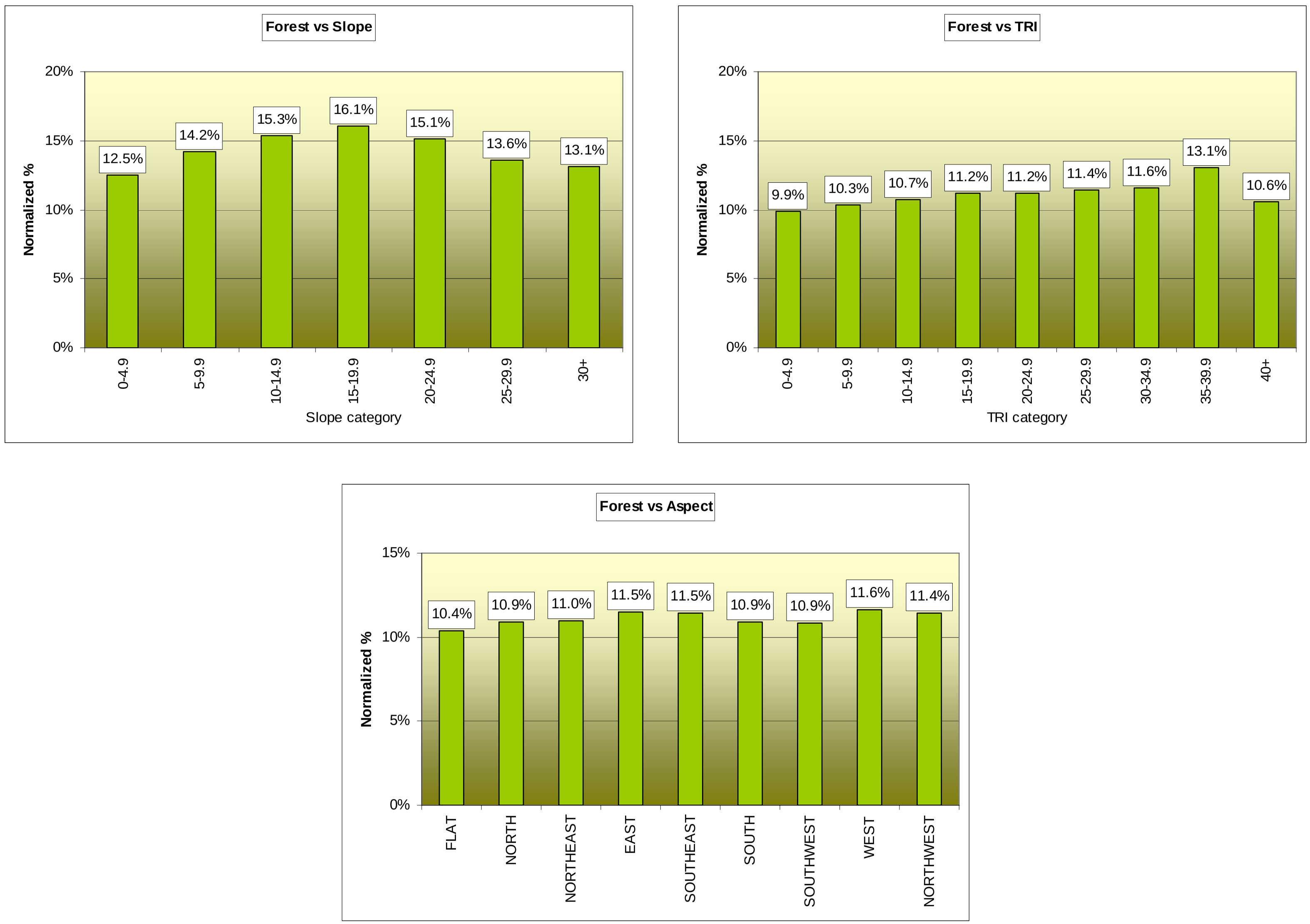


Figure 4.5. Forest landcover site analysis.

Table 4.2. Witness tree species and taxa recorded by surveyors (presumed scientific nomenclature follows Leopold, McComb and Muller 1998).

Recorded Name	Taxa or Species	# of Data Points	Percent Total	Average Diameter (cm)
white oak	*Quercus alba*	3895	34.85%	43.50
black oak	*Quercus velutina*	1976	17.68%	34.02
hickory	*Carya spp.*	942	8.43%	29.80
black gum	*Nyssa sylvatica*	650	5.82%	32.43
red oak	*Quercus rubra*	643	5.75%	37.75
post oak	*Quercus stellata*	548	4.90%	36.56
spanish oak	*Quercus falcata var. falcata*	432	3.87%	39.24
elm	*Ulmus spp.*	327	2.93%	28.03
beech	*Fagus grandifolia*	227	2.03%	32.06
chinquapin	*Castanea ozarkensis*	206	1.84%	28.59
dogwood	*Cornus florida*	191	1.71%	16.86
maple	*Acer rubrum* or *saccharinum*	167	1.49%	23.30
pine	*Pinus echinata*	130	1.16%	42.99
sugar tree	*Acer sacharum*	95	0.85%	33.93
sweet gum	*Liquidambar styraciflua*	91	0.81%	42.71
cherry	*Prunus serotina*	75	0.67%	31.70
walnut	*Juglans nigra*	74	0.66%	34.00
sassafrass	*Sassafras albidum*	69	0.62%	23.71
ash	*Fraxinus spp.*	61	0.55%	31.65
blackjack oak	*Quercus marilandica*	45	0.40%	21.90
hackberry	*Celtis occidentalis*	39	0.35%	35.10
linden	*Tilia americana*	39	0.35%	32.63
cedar	*Juniperus carolina*	28	0.25%	27.58
black locust	*Robinia pseudoacacia*	26	0.23%	25.20
sycamore	*Populus deltoides*	25	0.22%	52.93
ironwood	*Ostrya virginiana*	24	0.21%	16.51
box elder	*Acer negundo*	23	0.21%	24.30
mulberry	*Morus rubra*	21	0.19%	27.82
water oak	*Quercus nigra*	16	0.14%	41.43
locust	*Gleditsia or Robinia*?	15	0.13%	29.29
pin oak	*Quercus palustris*	15	0.13%	37.59
gum	*Nyssa or Liquidambar*?	10	0.09%	35.56
serviceberry	*Amelanchier arborea*	8	0.07%	18.10
wild cucumber	*Magnolia acuminata*	6	0.05%	28.36
blue ash	*Fraxinus quadrangulata*	5	0.04%	29.97
bur oak	*Quecus macrocarpa*	5	0.04%	44.70
oak	*Quercus spp.*	5	0.04%	28.45
redbud	*Cercis canadensis*	5	0.04%	17.27
birch	*Betula nigra*	4	0.04%	36.83
black ash	*Fraxinus nigra*	3	0.03%	27.94
willow oak	*Quercus phellos*	3	0.03%	35.56
buckeye	*Aesculus octandra*	2	0.02%	20.32
haw	*Viburnum spp?*	1	0.01%	20.32
horn beam	*Carpinus caroliniana*	1	0.01%	15.24
persimmon	*Diospyros virginiana*	1	0.01%	30.48
plum	*Prunus americana?*	1	0.01%	20.32
red haw	*Viburnum rufidulum*	1	0.01%	25.40

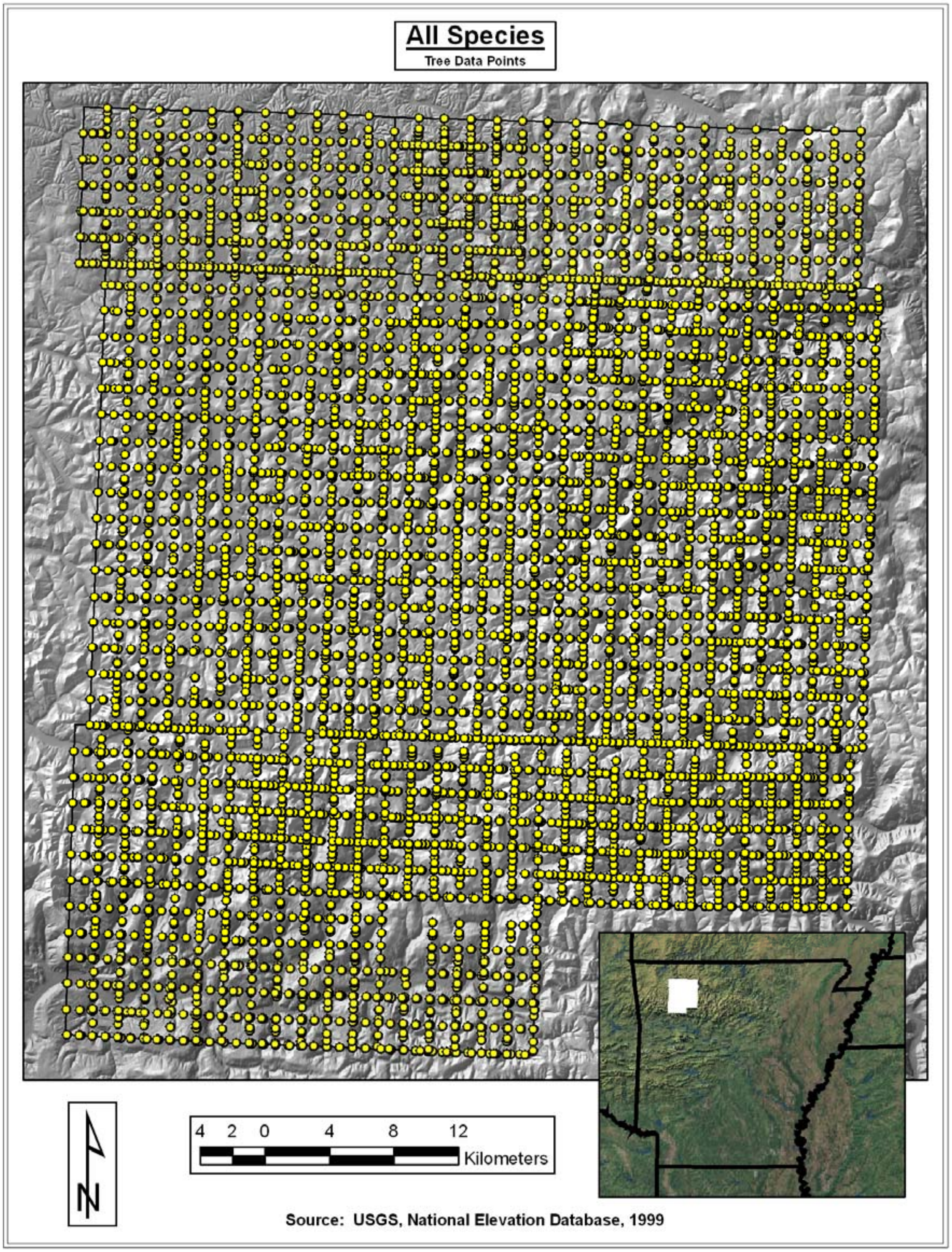


Figure 4.6 Map showing distribution of all digitized tree point data.

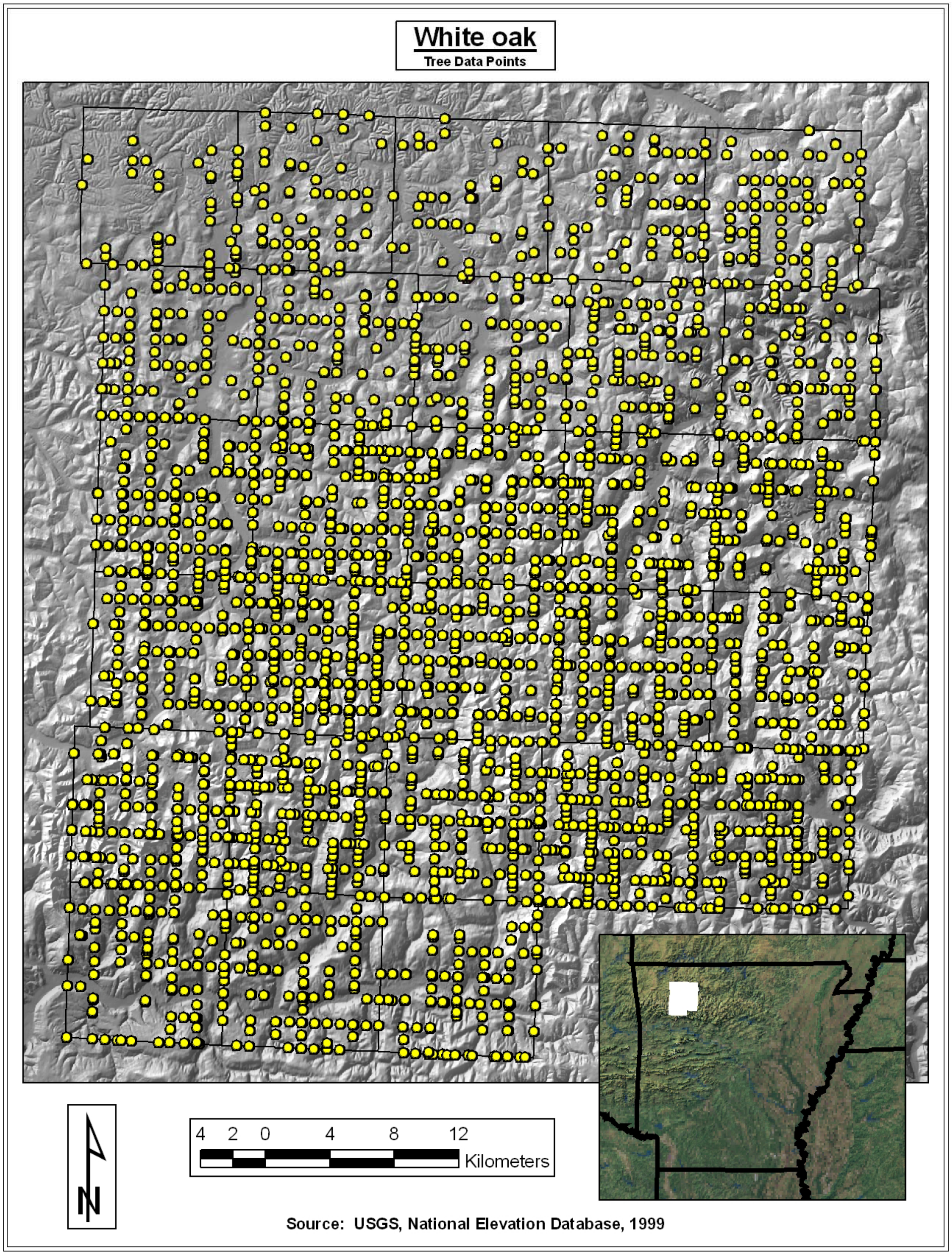


Figure 4.7 White oak data point distribution.

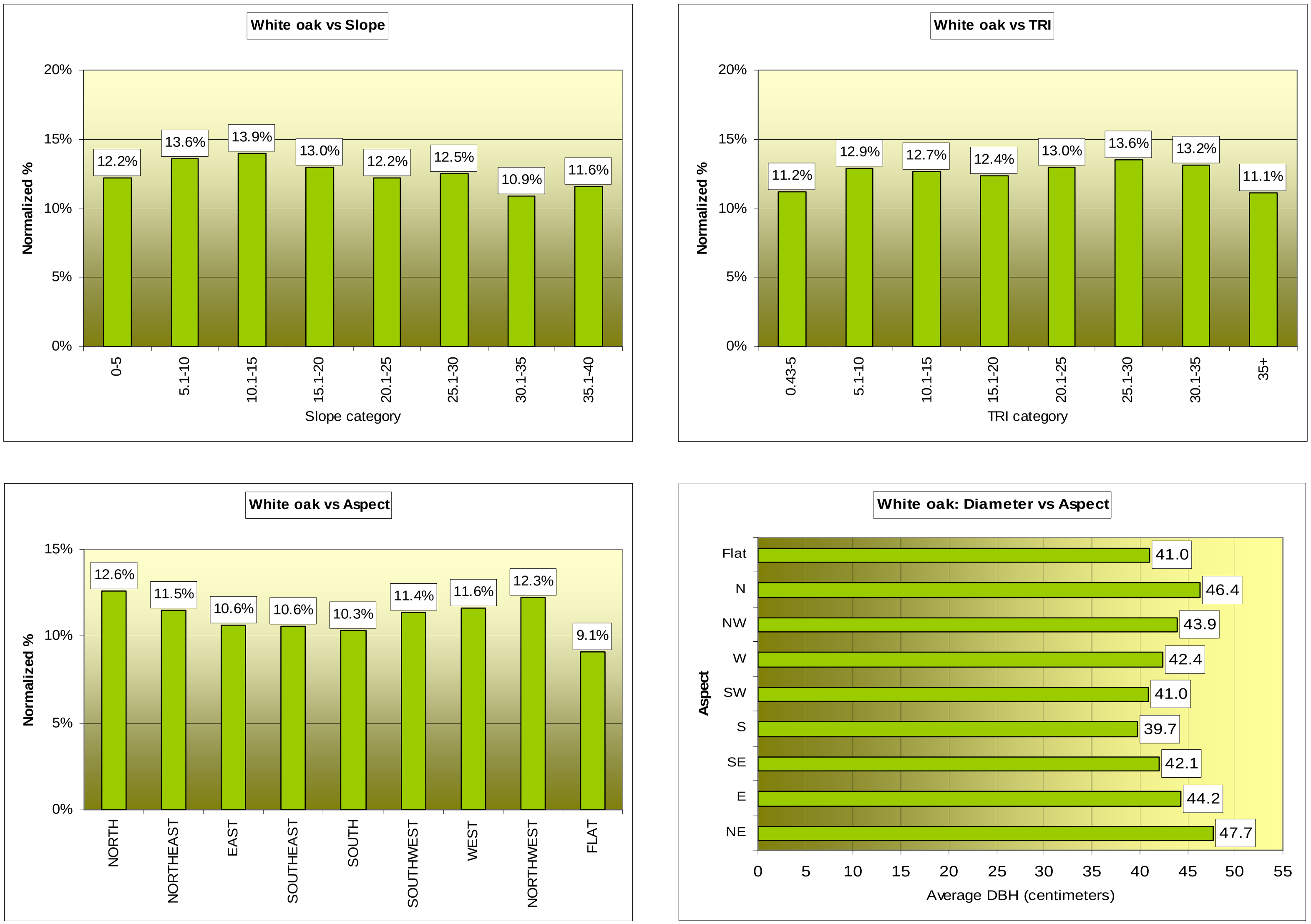


Figure 4.8 White oak site analysis.

throughout its range, and is one of the most important of deciduous species in the eastern United States. White oak was by far the most common species in the study area comprising 34.9% of all tree data points. In addition, it had a large average diameter at 43.5 centimeters. With a large number of point entries, white oak had a dense distribution throughout much of the study area. Only in the relatively flat northwest corner of the study area did white oak show a reduced density, where it appears to have persisted primarily in valleys and along streams.

Quantitative analysis shows that white oak had a fairly even distribution on all types of topographic positions. This species grew on all slope categories but was most commonly found on sites with 5.1 to 15º slopes (27.5%). It was also most commonly found on sites with a TRI values ranging from 25.1 to 35 (26.8%). Showing a bit of a tendency towards mesic sites, it was most often located on north (13.9%) and northwest (13.5%) facing slopes with its greatest average diameter measurements found on northeast and north facing slopes, at 47.7 and 46.4 centimeters respectively.

Throughout its range, black oak (*Quercus velutina*; Figures 4.9 and 4.10) is found on a variety of sites ranging from moist bottomlands to dry ridges. Within the study area, this species accounted for 17.7% of all tree point entries and had an average diameter of 34.0 centimeters. While surveyors recorded this species distributed throughout much of the study area, its most dense and extensive distribution was found in the relatively flat, northwestern portion of the study area. Recorded black oak stems were thinly distributed in many of the central townships, where red oak was most densely distributed. This species occurred primarily on sites with low slopes ranging from 0 to 15º (56.8%), and was also most common in areas where the TRI varied between 0 and 15 (42.1%). Black

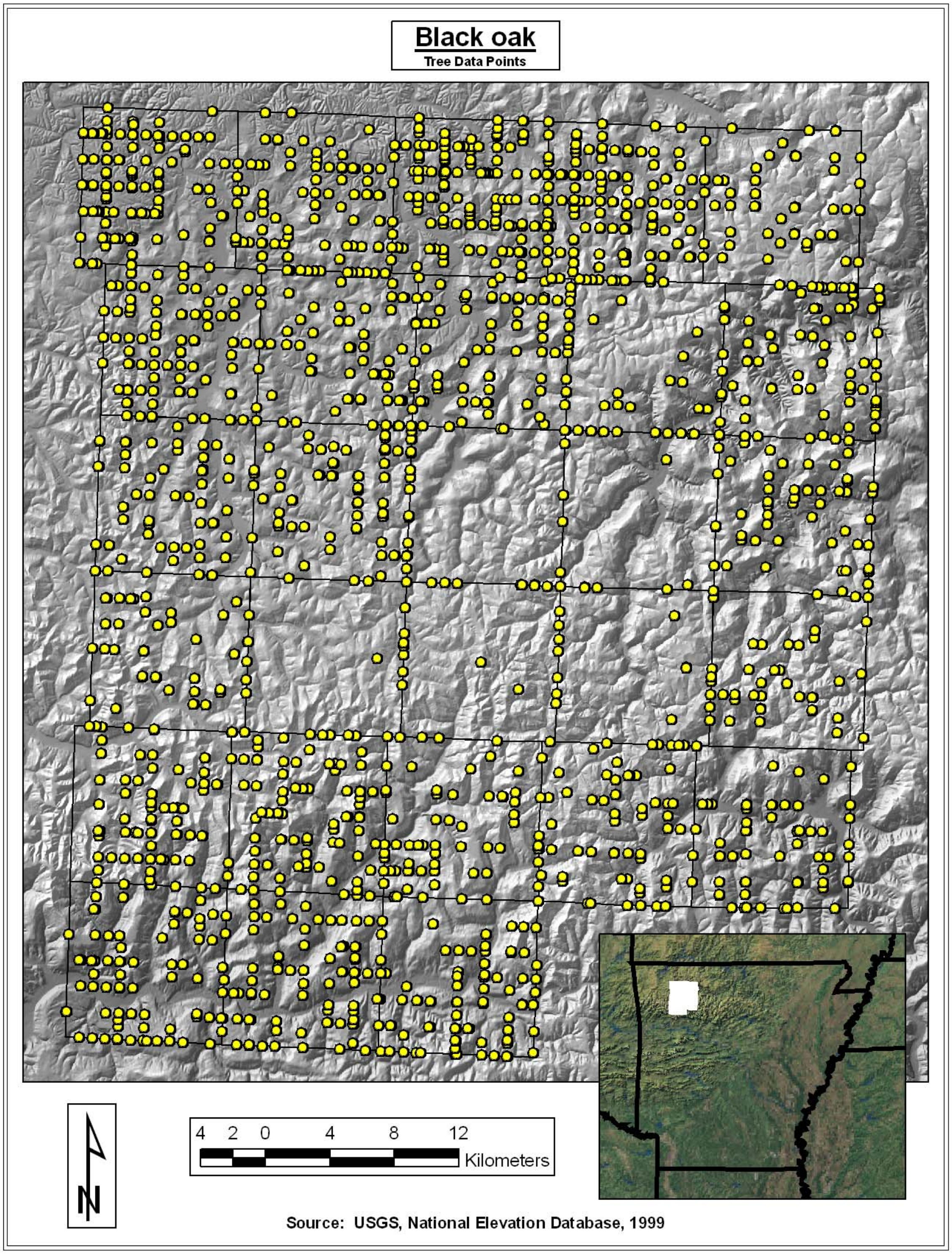
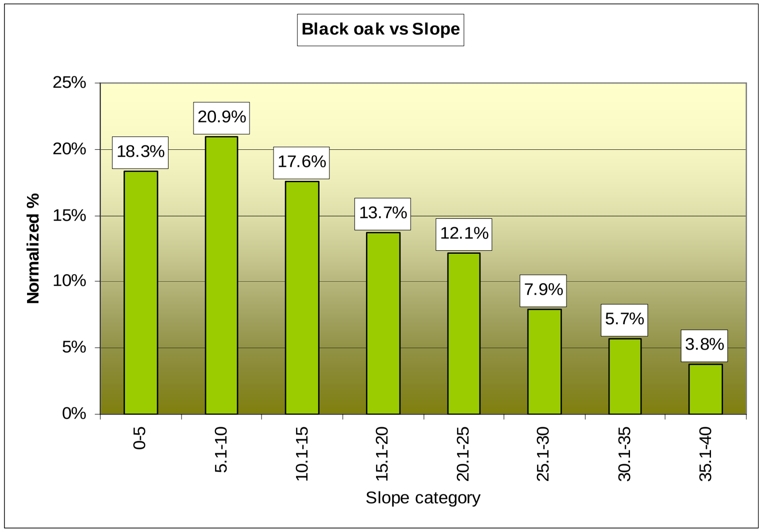
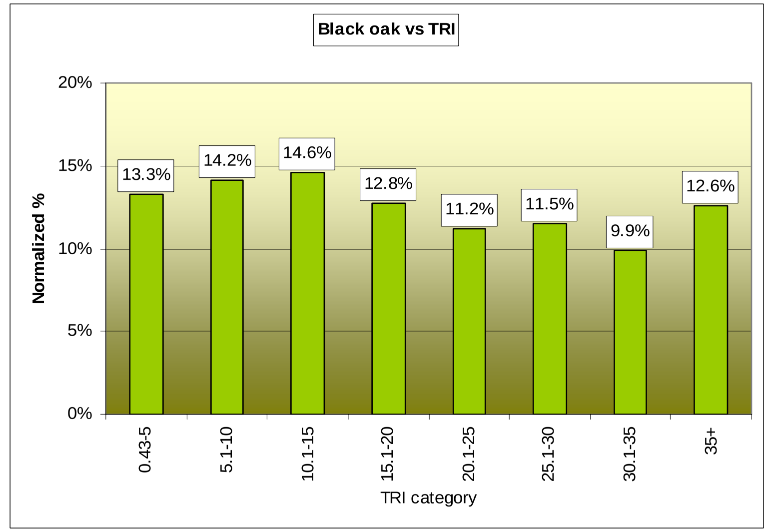
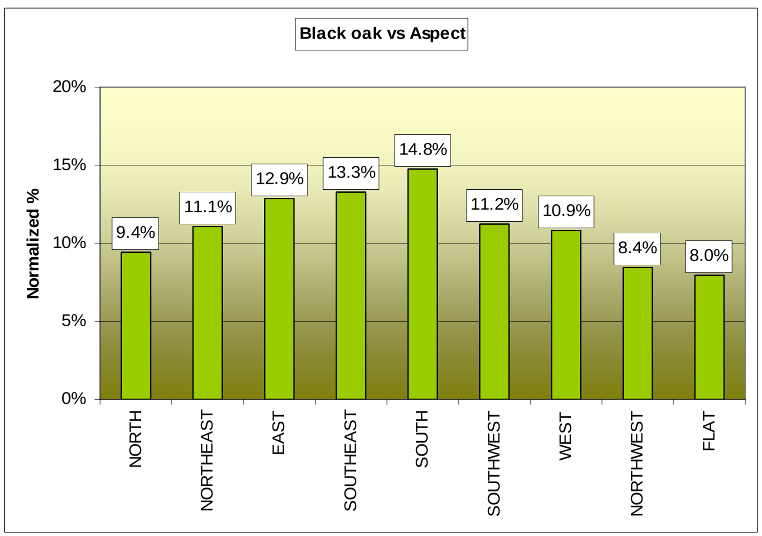


Figure 4.9 Black oak data point distribution.







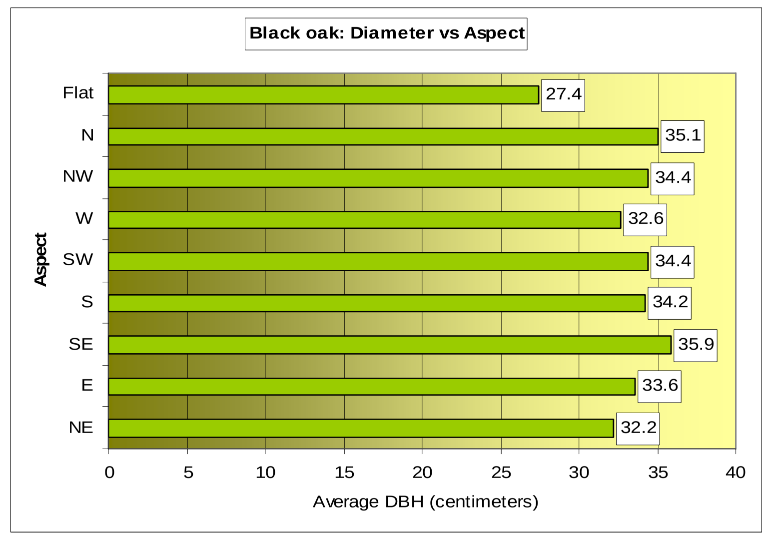


Figure 4.10 Black oak site analysis.

oak was most often found on south, southeast and east facing slopes but attained largest average stem diameters on southeast and north facing slopes with 35.9 and 35.1 centimeters respectively.

Although surveyors referred to hickories (*Carya* spp.) collectively, we can infer from contemporary range distributions that surveyors were likely referring to black (*Carya texana*), bitternut (*Carya cordiformis*), mockernut (*Carya tormentosa*), pignut (*Carya glabra*) and shagbark (*Carya ovata*) hickories. Throughout their ranges, these species are found on everything from bottomlands to protected, mesic upland sites to dry ridges. In general, hickories are common and widespread, but are rarely dominant in upland forests. In this study, hickory points comprised 8.4% of the total tree stems recorded. Surveyors recorded hickory (Figures 4.11 and 4.12) stems most densely in the eastern portion of the study area. Visual patterns show that hickories preferred more topographically diverse areas.

Categorized analyses did show some specific patterns, with hickory stems primarily found on slopes greater than 35.1º (24.7%). Although hickories were commonly found in areas with lesser TRI values of 15 to 25 (27.9%), the TRI value category of 35 or greater had the highest individual distribution with 17.9% of total stems recorded. Hickories in the study area most often fell on north, northeast and northwest aspects with these aspects comprising 43.5% of all hickory entries. This taxa had an average diameter measurement throughout the study area of 29.8 centimeters, with its largest average diameter measurements found on flat sites (31.9 cm) and north facing slopes (33.8 cm).

Like hickories, blackgum (*Nyssa sylvatica*, Figures 4.13 and 4.14) is a species

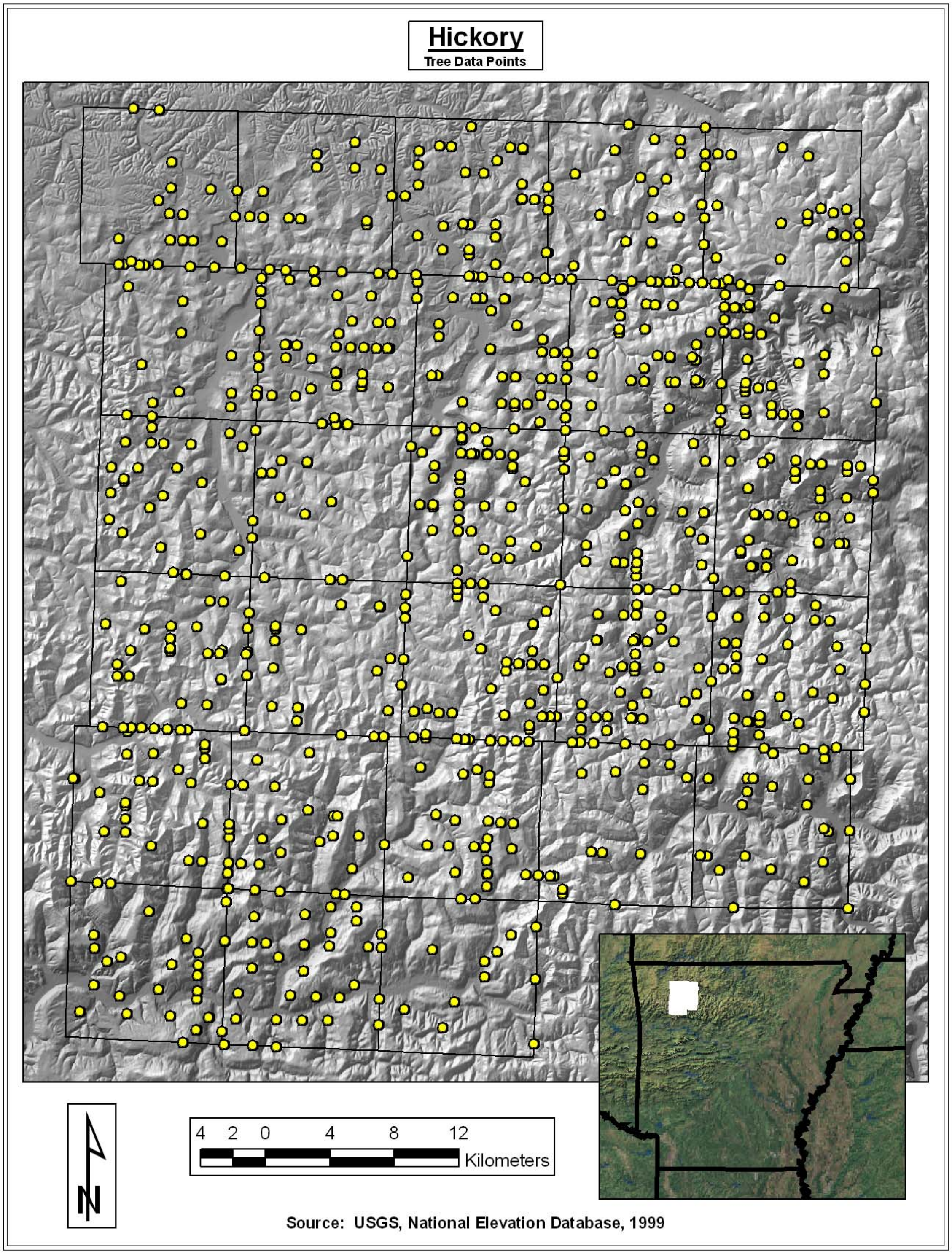


Figure 4.11 Hickory data point distribution.

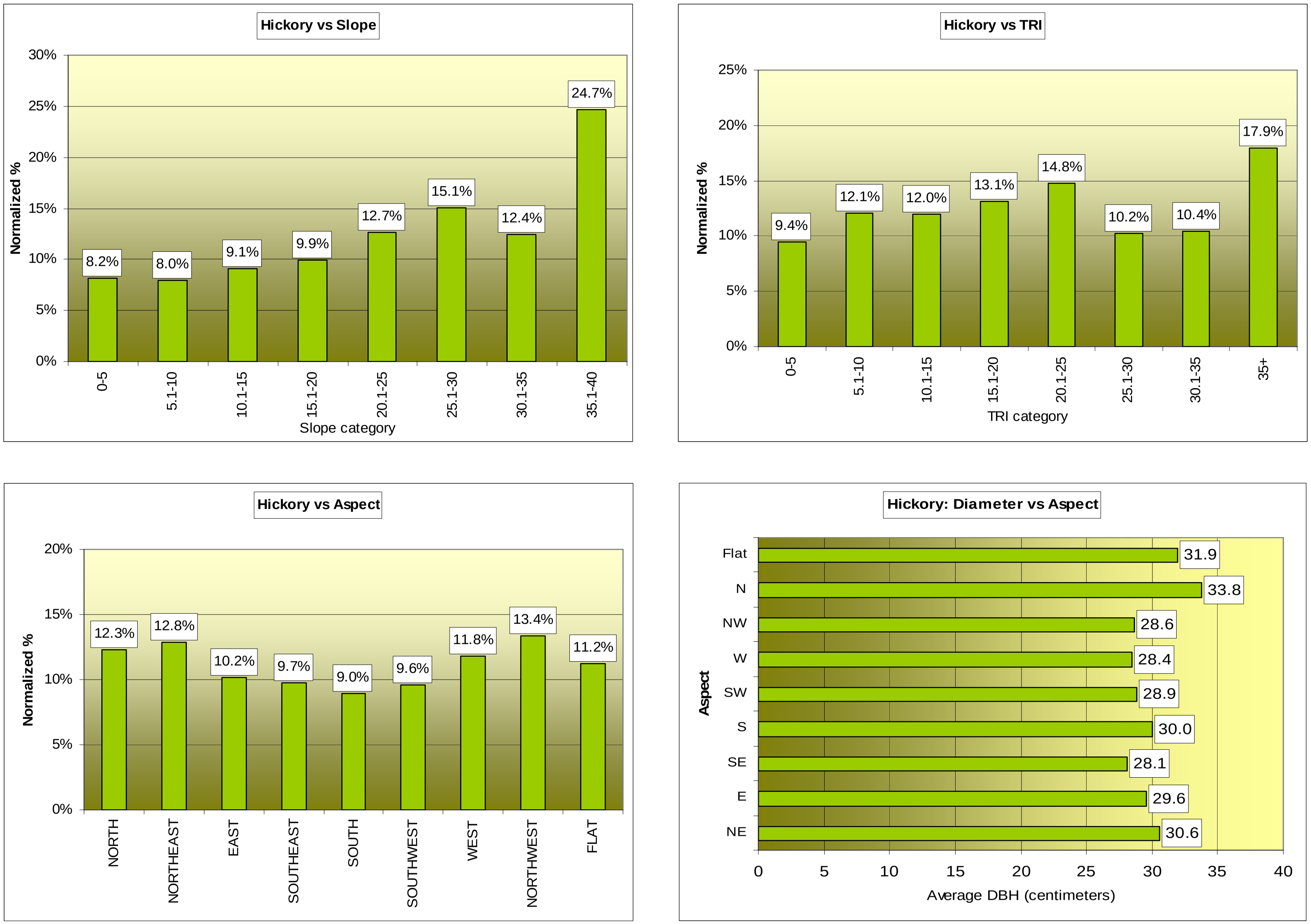


Figure 4.12 Hickory site analysis.

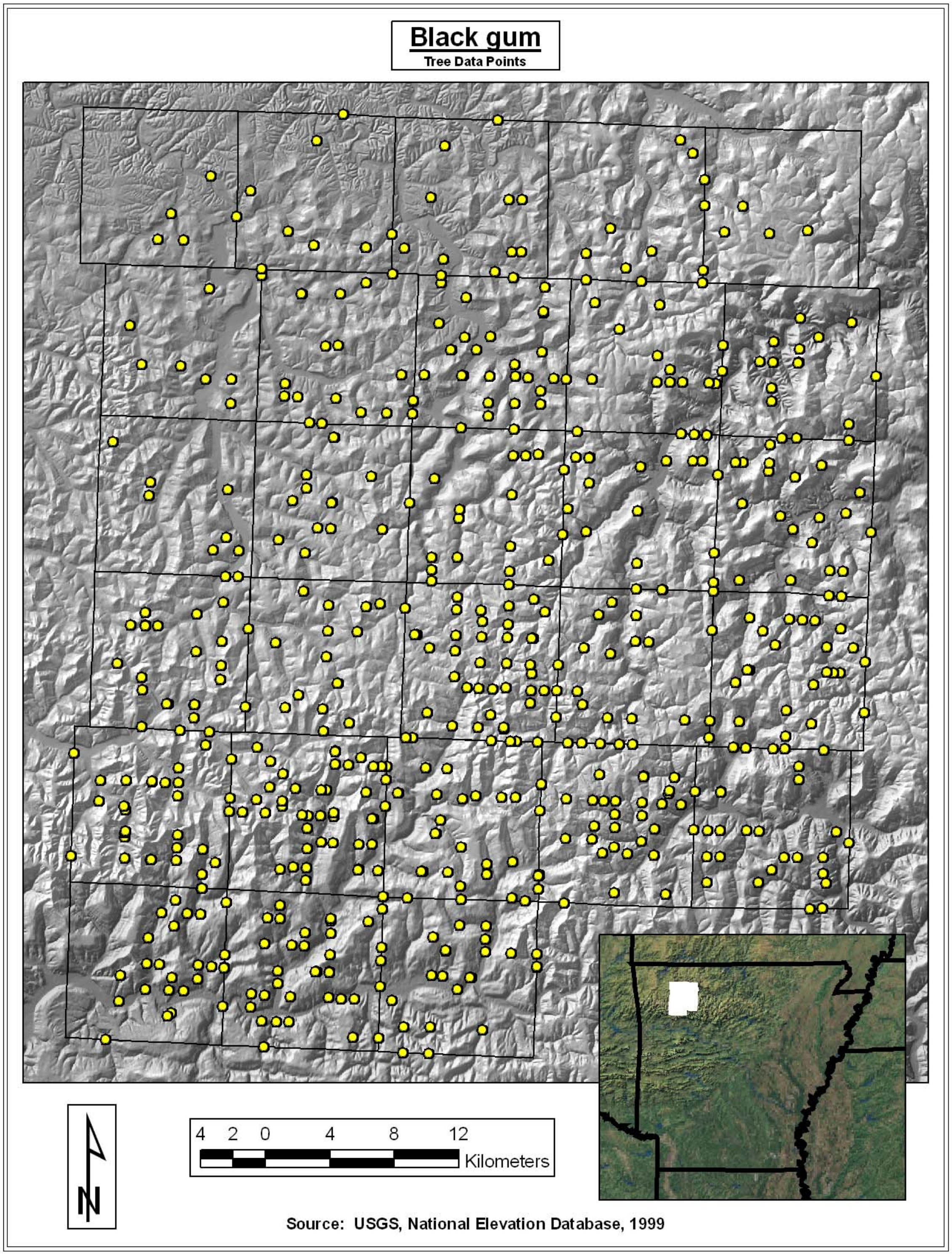


Figure 4.13 Black gum data point distribution.

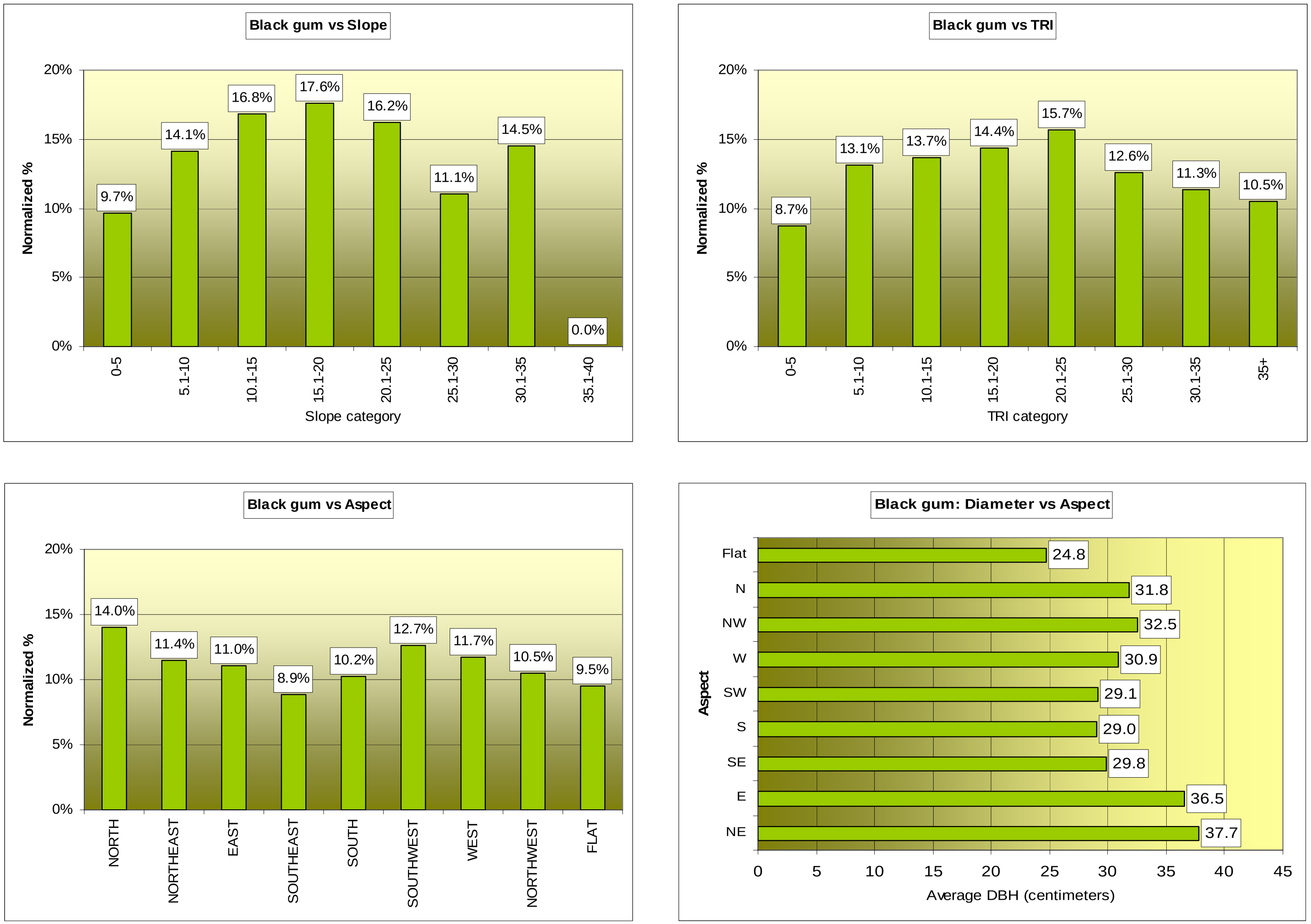


Figure 4.14 Black gum site analysis.

common to eastern forests but rarely dominant. Throughout its range blackgum is found on a variety of sites, from bottomlands to mesic uplands and drier upland sites. Within the study area, blackgum composed 5.8% of the total tree point entries, with its most dense distributions in the relatively rugged eastern and southern portions of the study area.

Quantitative analysis shows blackgum was most commonly found on slopes ranging from 10.1 to 25º (50.6%). Distribution according to topographic roughness peaked in areas with TRI values ranging from 20.1 to 25 (15.7%), with it relatively evenly distributed in areas with moderate TRI values. Aspect analysis shows that blackgum most often grew on north (14.0%) and southwest (12.7%) facing slopes. This species had an average diameter of 32.4 centimeters throughout the study area, with its largest average diameters found on northeast (37.7 cm) and east (36.5 cm) facing slopes.

Northern red oak (*Quercus rubra*; Figures 4.15 and 4.16), is a widespread mesophytic oak that is common in upland forests across much of eastern North America. This species accounted for 5.8% of the total tree data points, and displayed an interesting distribution. While not strictly confined to this area, red oak's distribution generally ran from the northeast corner to the center of the study area. As discussed above, red oak and black oak stem distributions displayed some interesting patterns, with red oak points being recorded primarily in several townships where black oak was largely absent. Possible causes of these patterns are further discussed in Chapter 5.

Red oak stems were most common in areas with low to moderate slopes of less than 20º (60.0%), and in areas with topographic roughness index values less than 20 (56.5%). Northern red oak most commonly grew on flat areas (19.4%). On directional

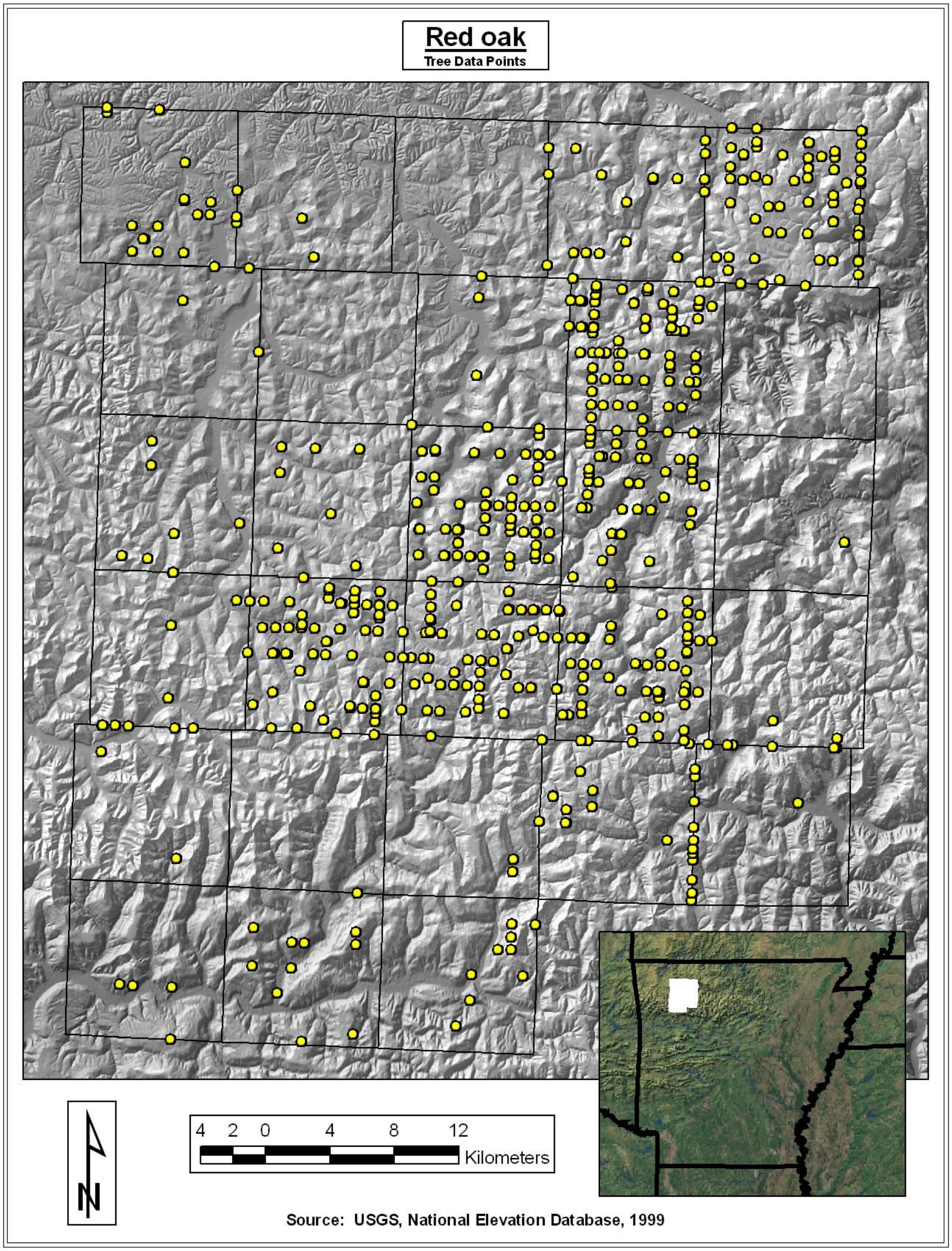


Figure 4.15 Red oak data point distribution.

Figure 4.16 Red oak site analysis.

aspects, red oak had its highest densities on east (11.3%), southeast (11.7%) and south (11.4%) facing slopes. Red oak had a relatively large overall average diameter measurement of 37.7 centimeters. This species attained its largest diameter measurements on flat sites (46.3 cm) as well as northeast facing slopes (43.9 cm).

Post oak (*Quercus stellata*; Figures 4.17 and 4.18), is a xerophytic oak species that is generally found in dry woodlands and on sandy ridges throughout its range. In the study area, post oak entries comprised 4.9% of all data points with an average diameter of 36.6 centimeters. Like many of the other xerophytic species identified in this project, it most densely populated the relatively flat, northwestern corner of the study area.

Quantitative analysis shows post oak's highest stem densities found on the lowest slope categories, with 0-5º, 5.1-10º and 10.1-15º slopes having densities of 27.8%, 20.8% and 15.8% respectively. This species shows a similar distribution according to topographic roughness, with post oak stems being most often found on areas with a TRI index value of 10 or less (43.3%). Aspect analysis shows that post oak was found primarily on southeast facing slopes (18.3%), with it also commonly falling on east (13.8%) and south (13.2%) facing slopes. Average diameters were fairly similar for all aspects with east (38.5 cm), south (37.8 cm) and north (37.8 cm) facing slopes as well as flat sites (38.1 cm) having relatively large diameter measurements.

Spanish oak (*Quercus falcata* var. *falcata*; Figures 4.19 and 4.20), also known as southern red oak, is predominantly found in the southeastern United States where it typically grows on dry sites in upland forests. Spanish oak stems account for 3.9% of all tree points in the study area and had an average diameter of 39.2 centimeters. Mapped point distributions show that this species tended to grow most densely in the more rugged

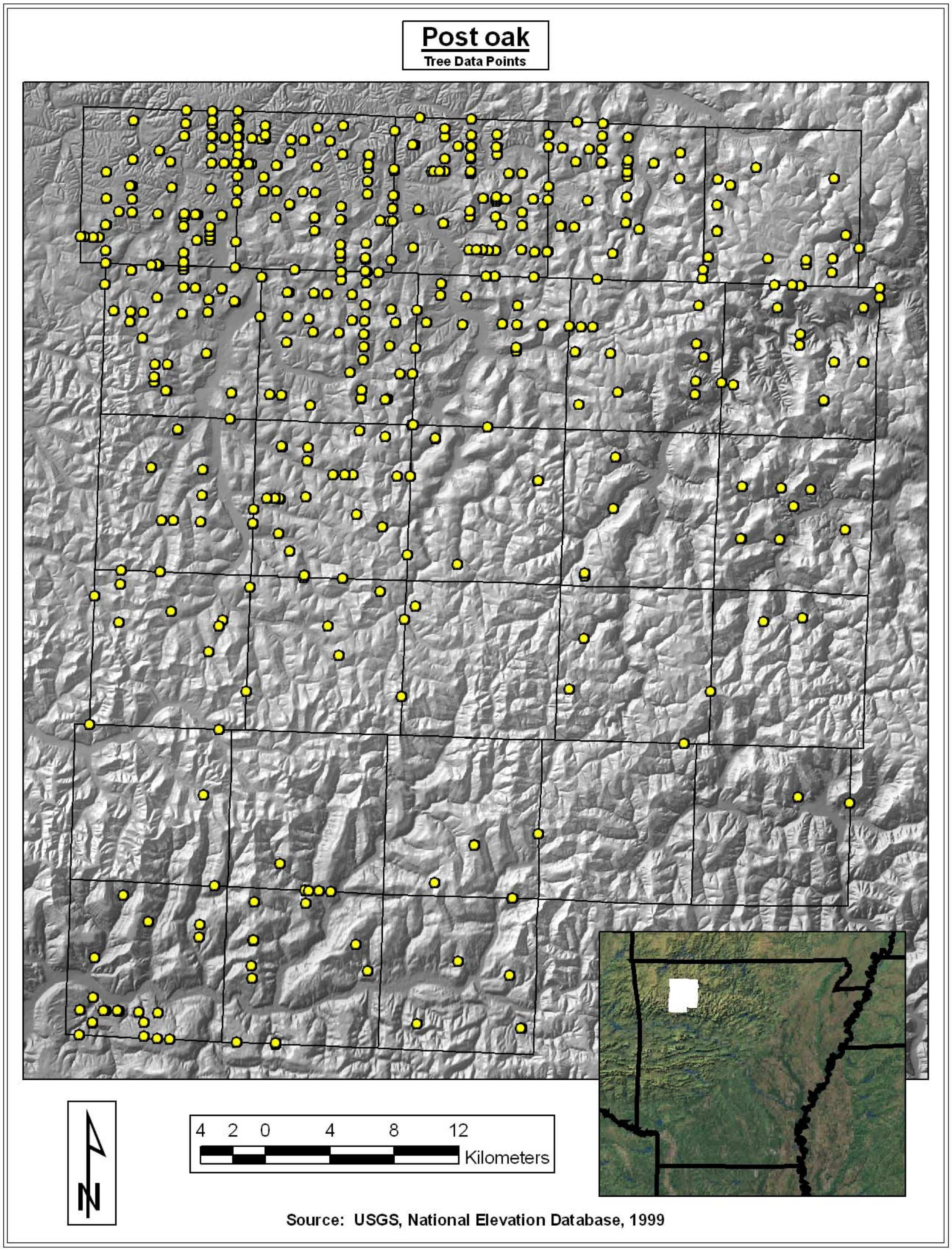


Figure 4.17 Post oak data point distribution.

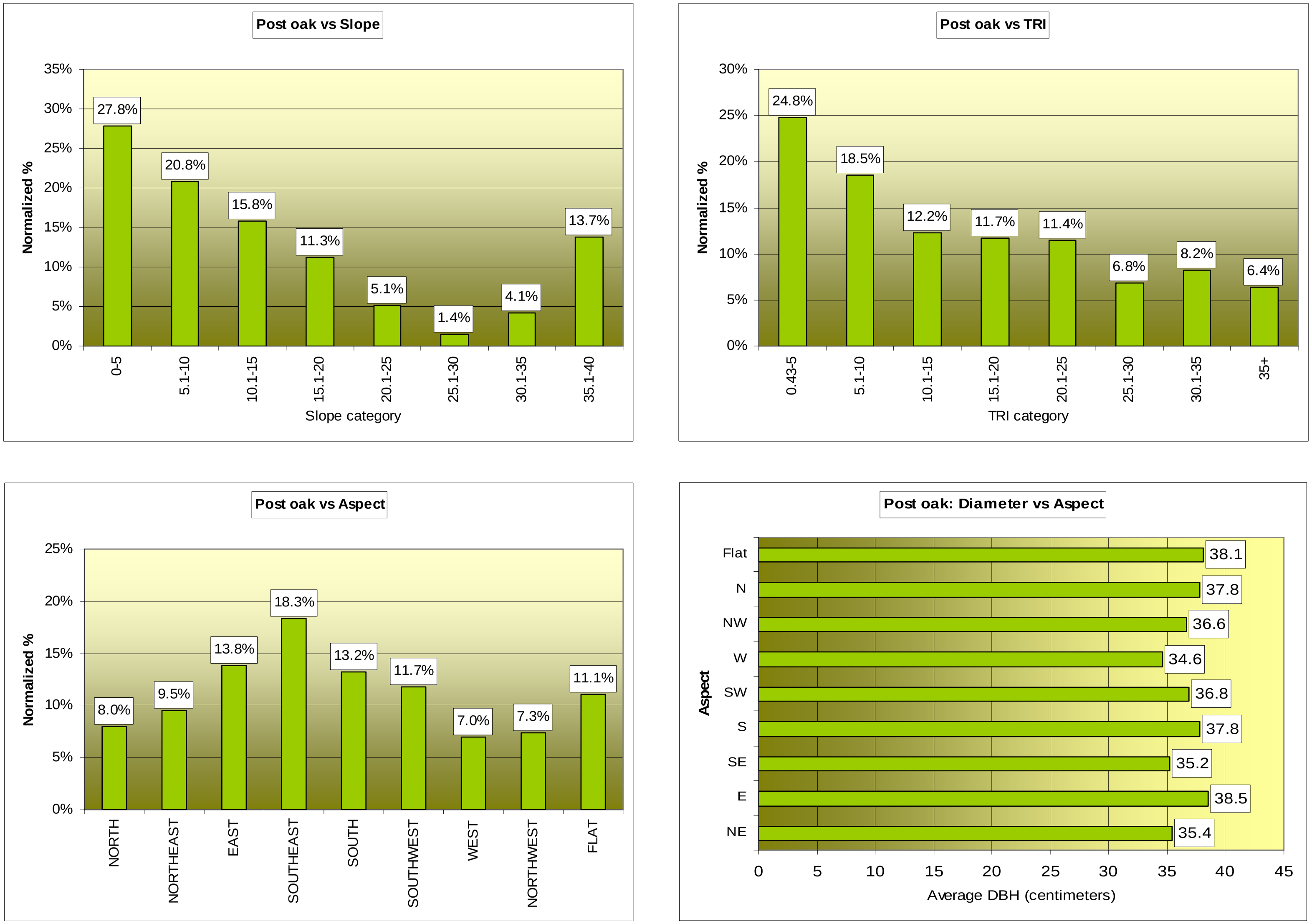


Figure 4.18 Post oak site analysis.

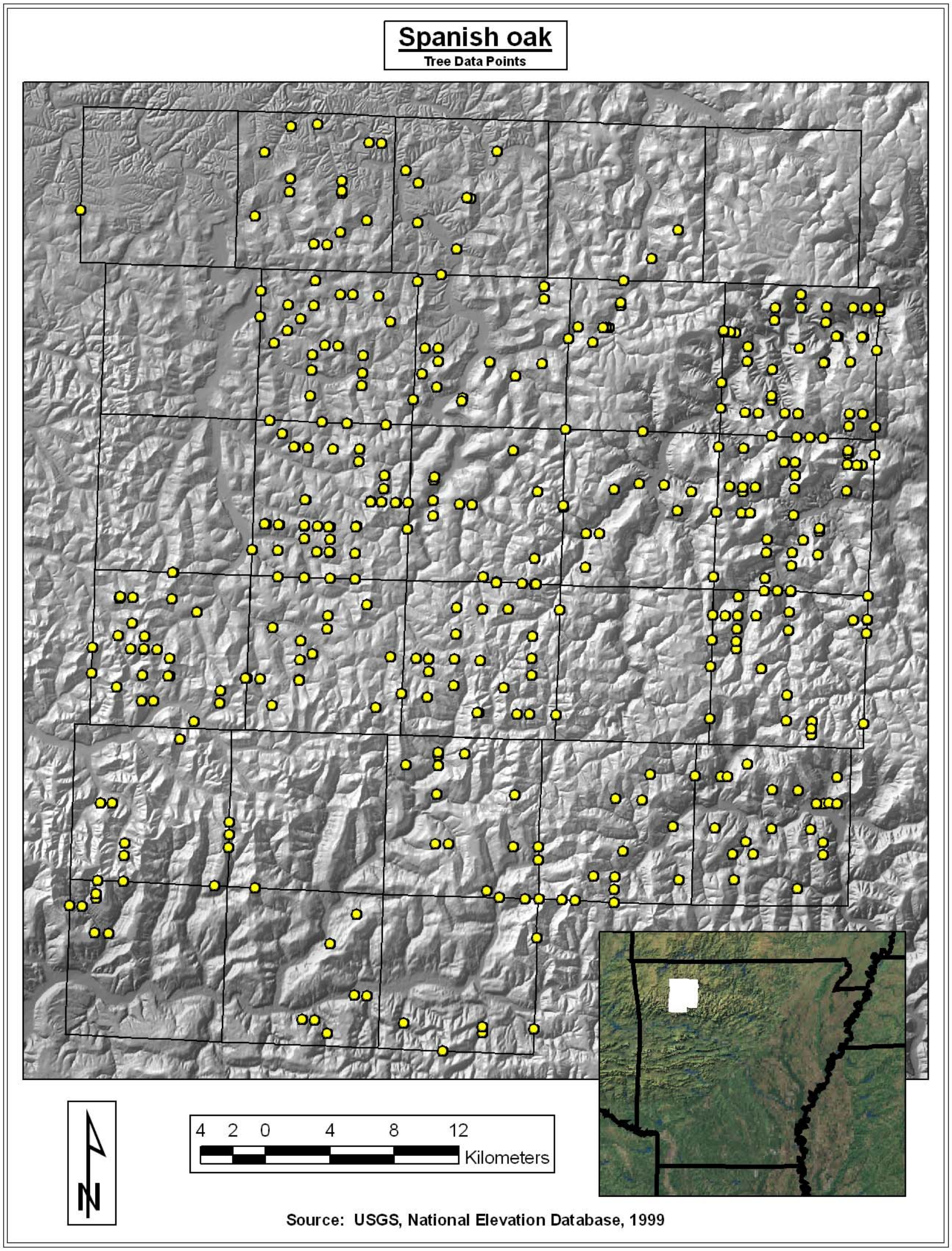


Figure 4.19 Spanish oak data point distribution.

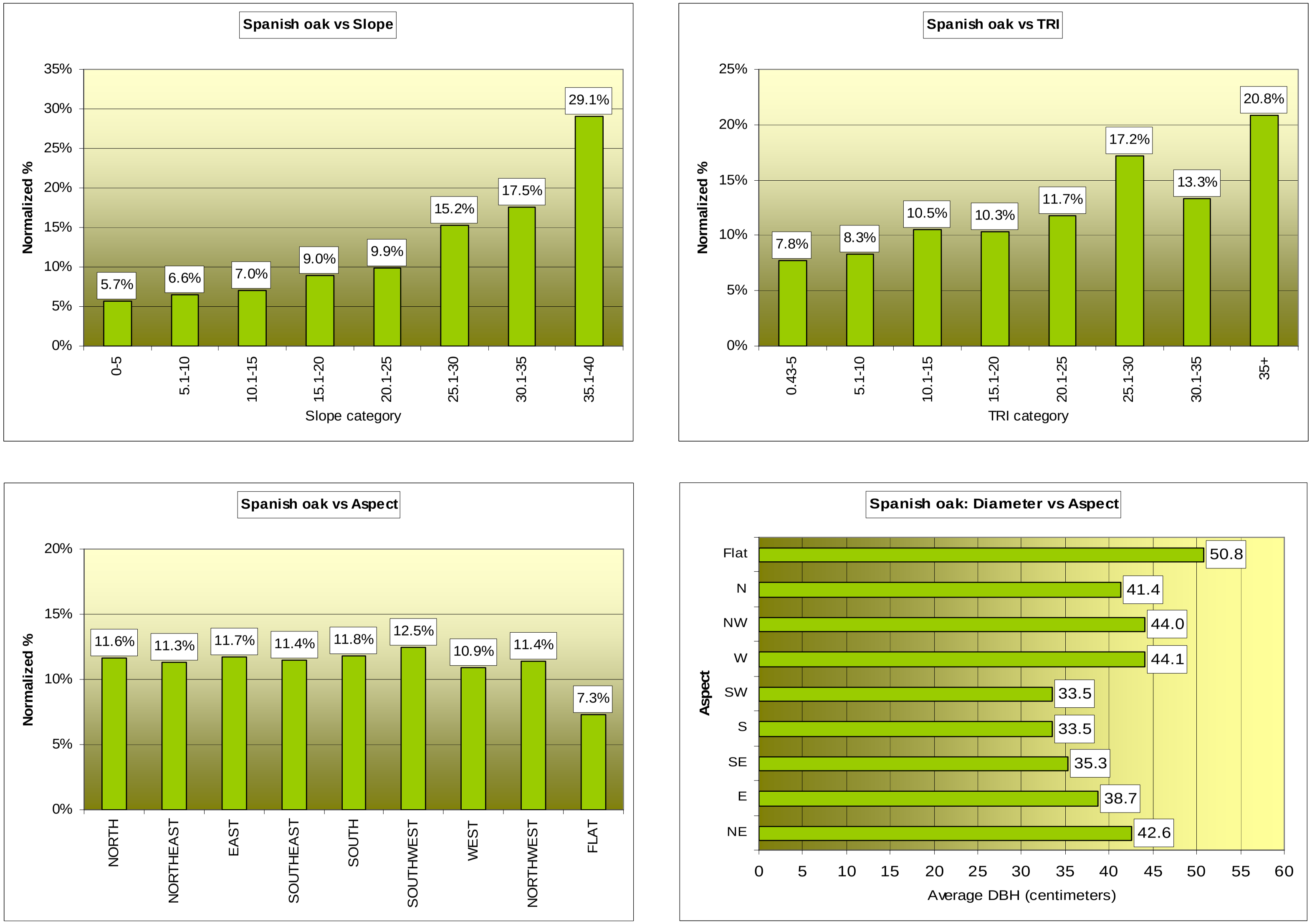


Figure 4.20 Spanish oak site analysis.

central and eastern portions of the study area.

Analysis shows Spanish oak was most often found on steep slopes of 35.1º and greater (29.1%) and in rugged areas with TRI index values of 25.1 and greater (51.3%). Interestingly, its aspect distribution was fairly even between directional aspect categories, varying between 10.9% and 12.5%; with stems growing on flat sites totaling only 7.3%. While topographic position analysis shows Spanish oak points infrequently distributed on flat sites, it averaged its greatest average diameter on these sites with 50.8 centimeters. It also grew well on west, northwest, northeast, and north facing slopes with average diameter measurements of 44.1, 44.0, 42.5 and 41.4 centimeters respectively.

Like the designation of "hickory", surveyors recorded all elm species collectively. Similarly, we can determine what species this reference alluded to by referencing the natural ranges of North American elm species. Within the study area several elm species ranges overlap including winged elm (*Ulmus alata*), American elm (*Ulmus americana*), slippery elm (*Ulmus rubra*), as well as the rare and scattered September elm (*Ulmus serotina*; Figures 4.21 and 4.22). Throughout their ranges, these species are found on a mixture of sites including bottomlands, upland slopes and dry ridges.

Elm entries accounted for a total of 2.9% of all tree points with an overall average diameter of 28.0 centimeters. Most elm stems fell on the north side of the main east-west ridge. Surveyors recorded a significant distribution of elm stems in the northwestern corner of the study area, primarily in bottomlands and adjacent slopes. In the more rugged central portions of the study area, elm points were found further upslope. More in-depth analysis supports these visual patterns, with elm stems predominantly located on sites with slopes less than 5º (14.0%) and slopes of 35.1º or greater (33.3%).

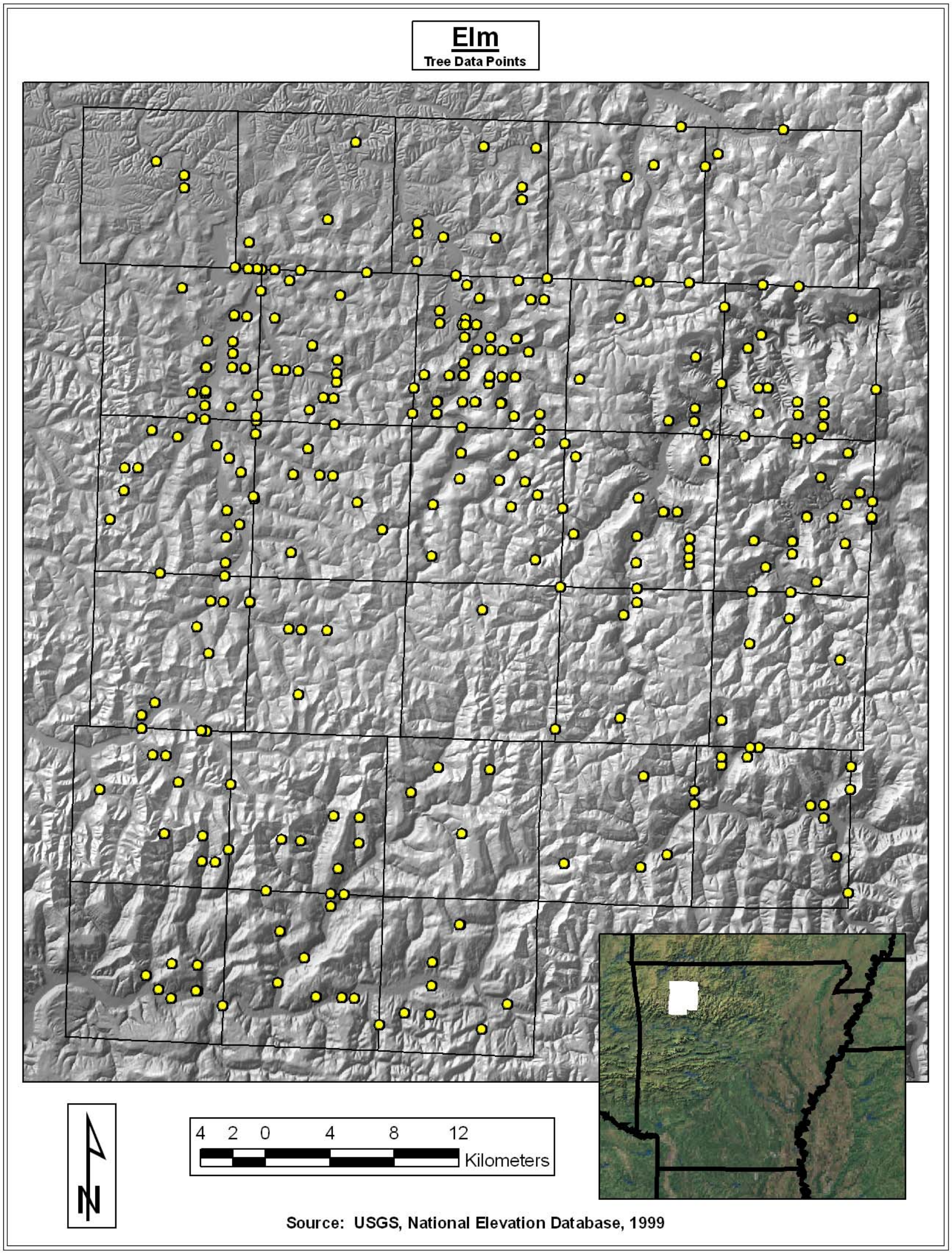


Figure 4.21 Elm data point distribution.

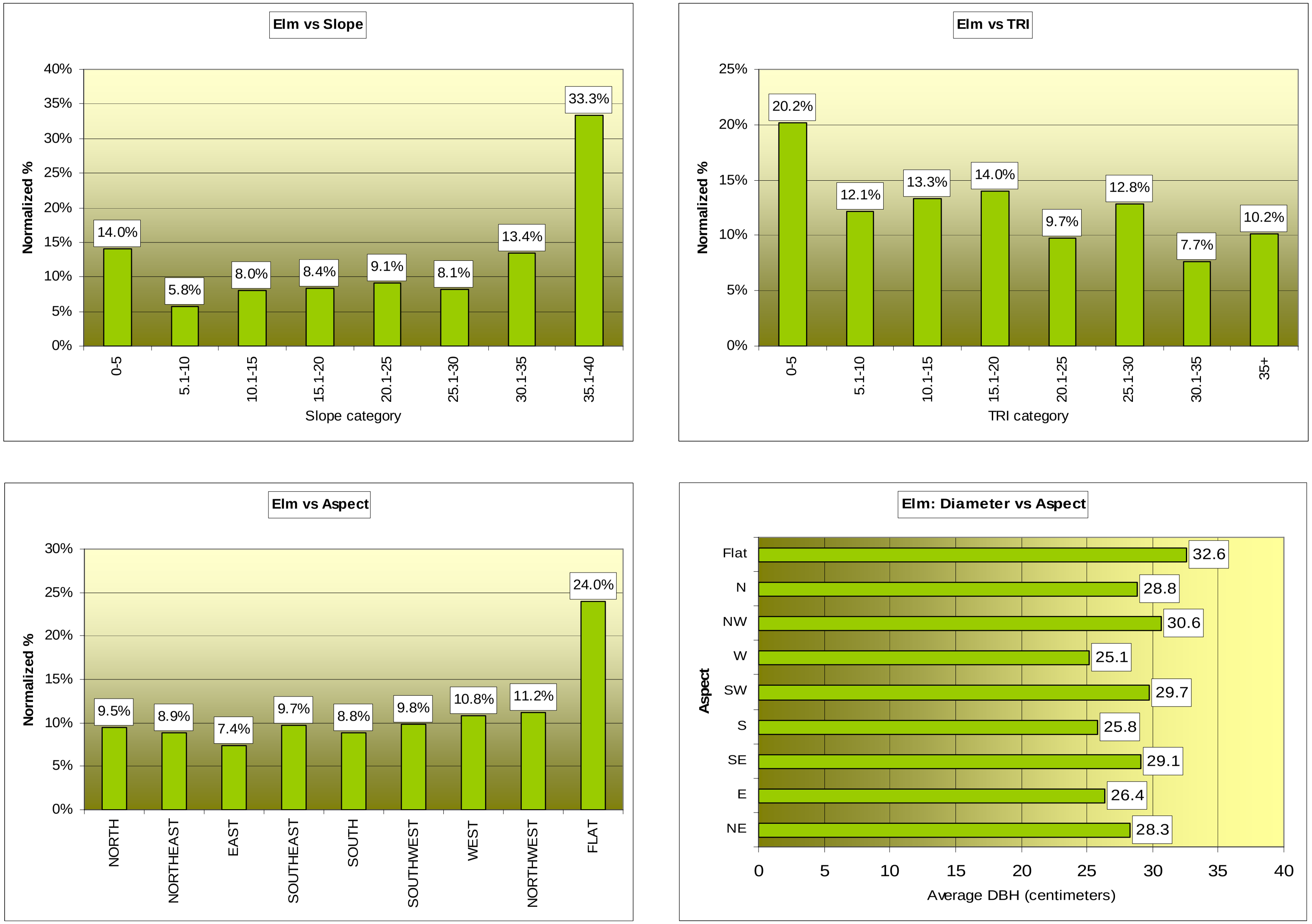


Figure 4.22 Elm site analysis.

Topographic roughness analysis shows an affinity towards bottomland sites, with elms stems recorded most often on areas with TRI values of 5 or less (20.2%). This taxa's preference for bottomlands is clearly shown by its highest densities (24.0%) and largest average diameters (32.5 cm) occurring on flat sites. Elm species also grew well on northwest, southwest, southeast, and north facing slopes with average diameter measurements of 30.6, 29.7, 29.1 and 28.8 centimeters respectively.

American beech (*Fagus grandifolia*; Figures 4.23 and 4.24), is a slow growing, mesophytic species found throughout much of the eastern United States. Throughout the study area, American beech stems comprised 2.0% of all tree stems and had an average diameter of 32.1 centimeters. The mapped distribution of beech data points was striking. This species was recorded by survey notes as exclusively occurring in the southeastern half of the study area, primarily in the most rugged portions. Both slope and TRI analysis show that this species favored steep slopes with 30.1% of stems falling on slopes of 30.1-35º and 24.1% falling on slopes ranging from 20.1-25º. Furthermore 69.5% of beech tree points fell on areas with TRI values of 25.1 or greater. Analysis shows beech was most often found on northwest (19.6%), west (16.1%) and north (13.3%) facing slopes. Surveyors recorded the largest beech stems on northeast and east facing slopes, with average measurements of 36.4 and 34.0 centimeters respectively.

Within the study area, surveyors recorded a species colloquially referred to as chinquapin. Although this may be a reference to chinkapin oak, it is believed that surveyors were recording Ozark chinkapin (*Castanea ozarkensis*; Figures 4.25 and 4.26) stems. While Ozark chinkapin is a chestnut species considered to be endemic to the Ozarks and Ouachitas, it is closely related to the Allegheny chinkapin common in the

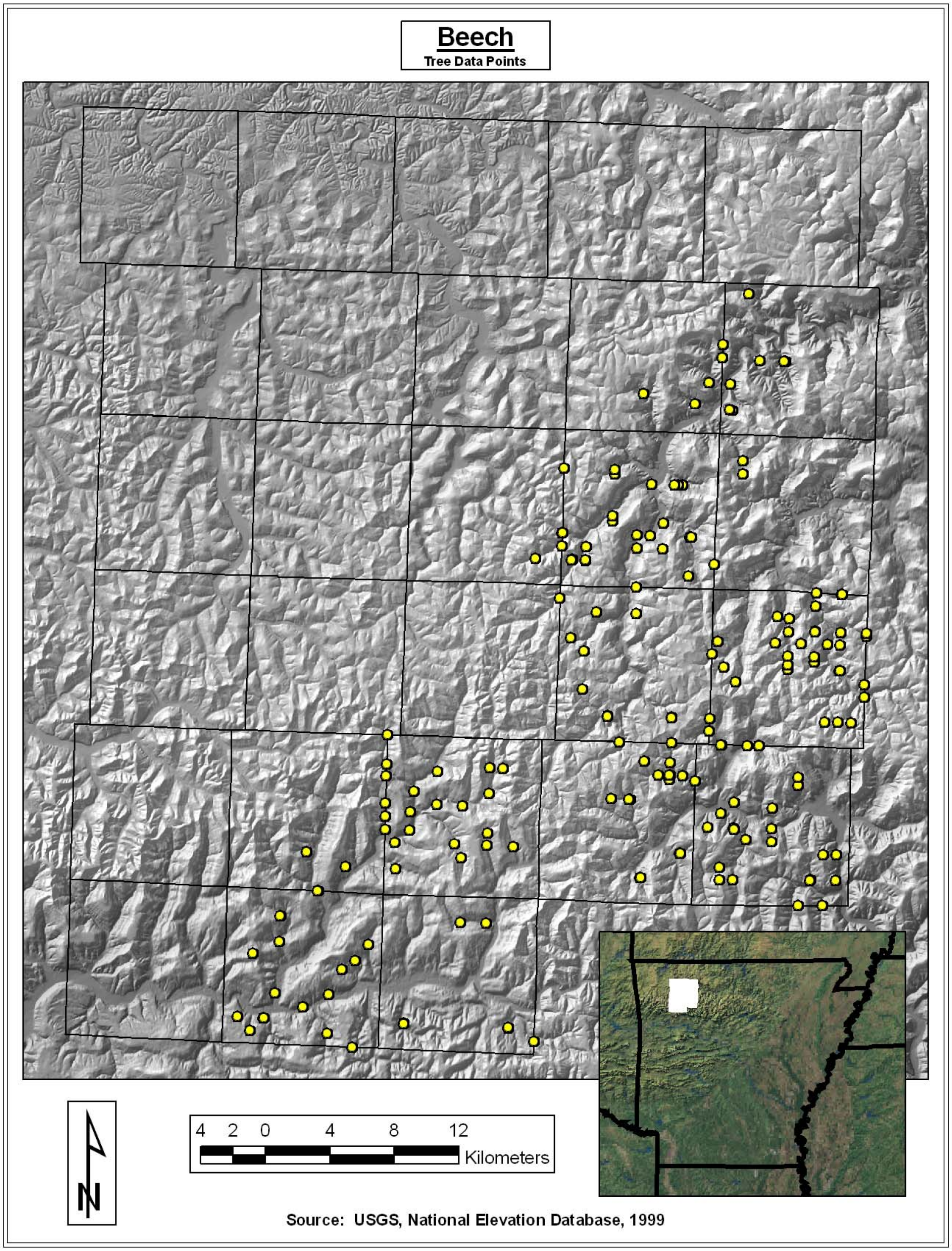


Figure 4.23 Beech data point distribution

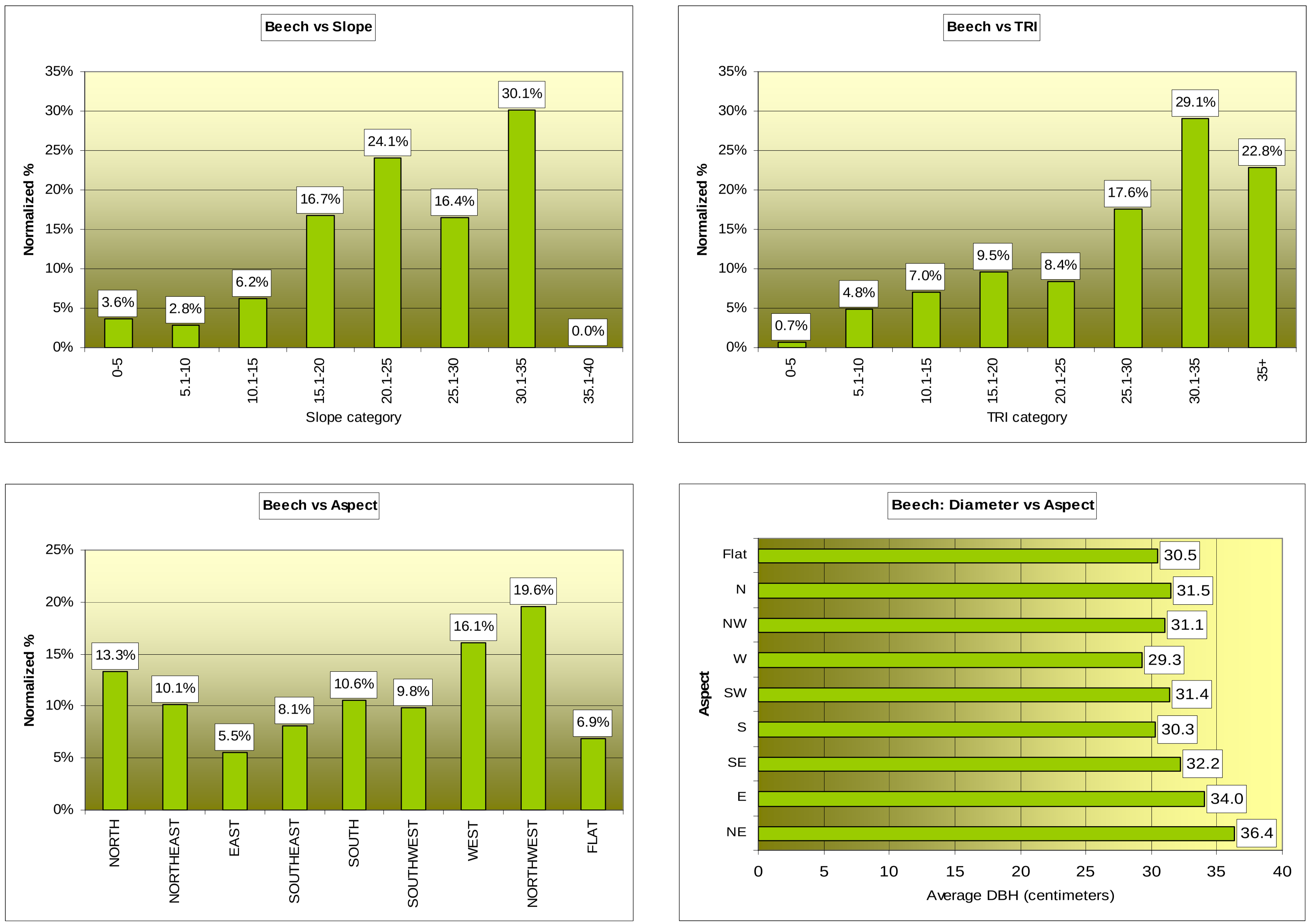


Figure 4.24 Beech site analysis.

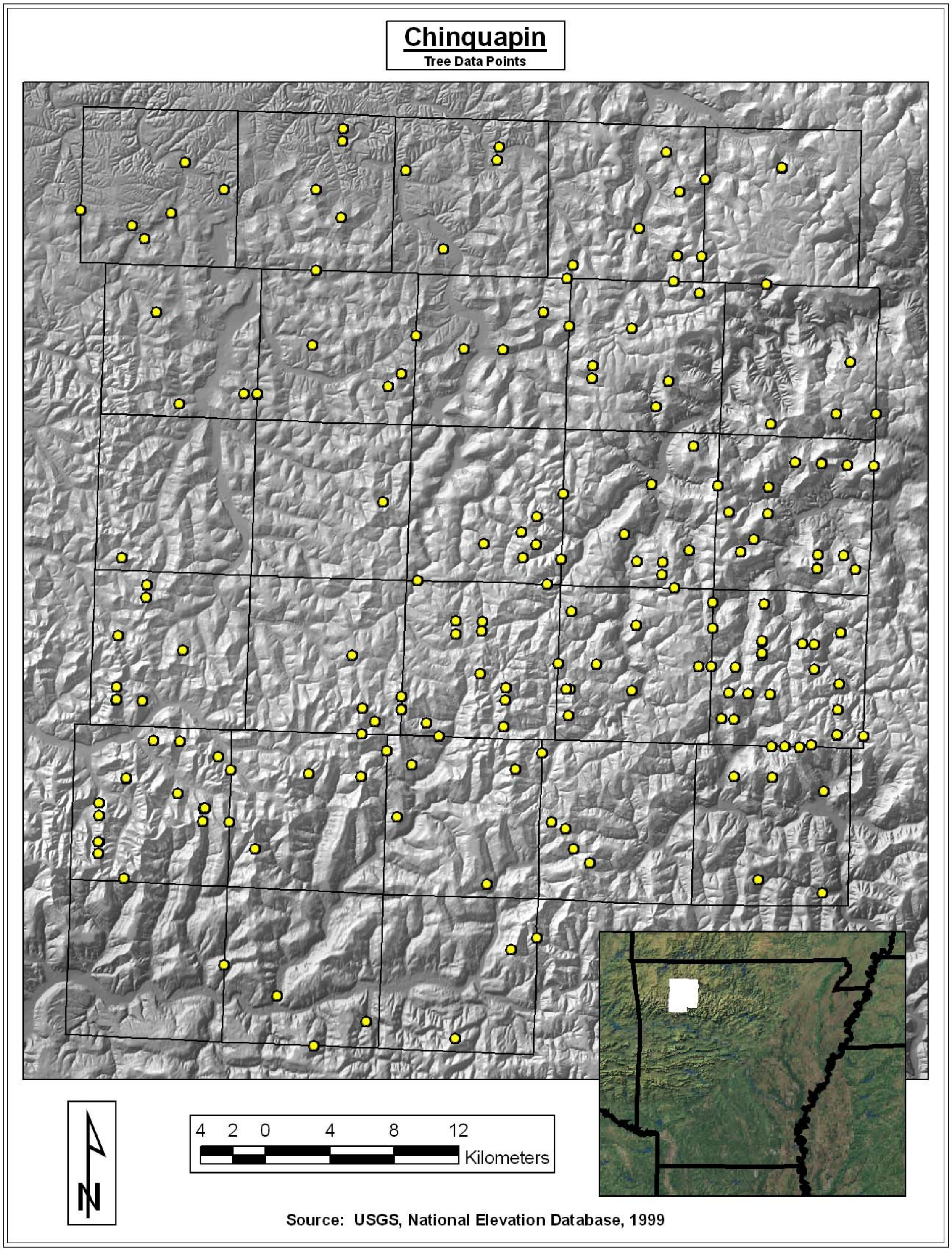


Figure 4.25 Chinquapin data point distribution.

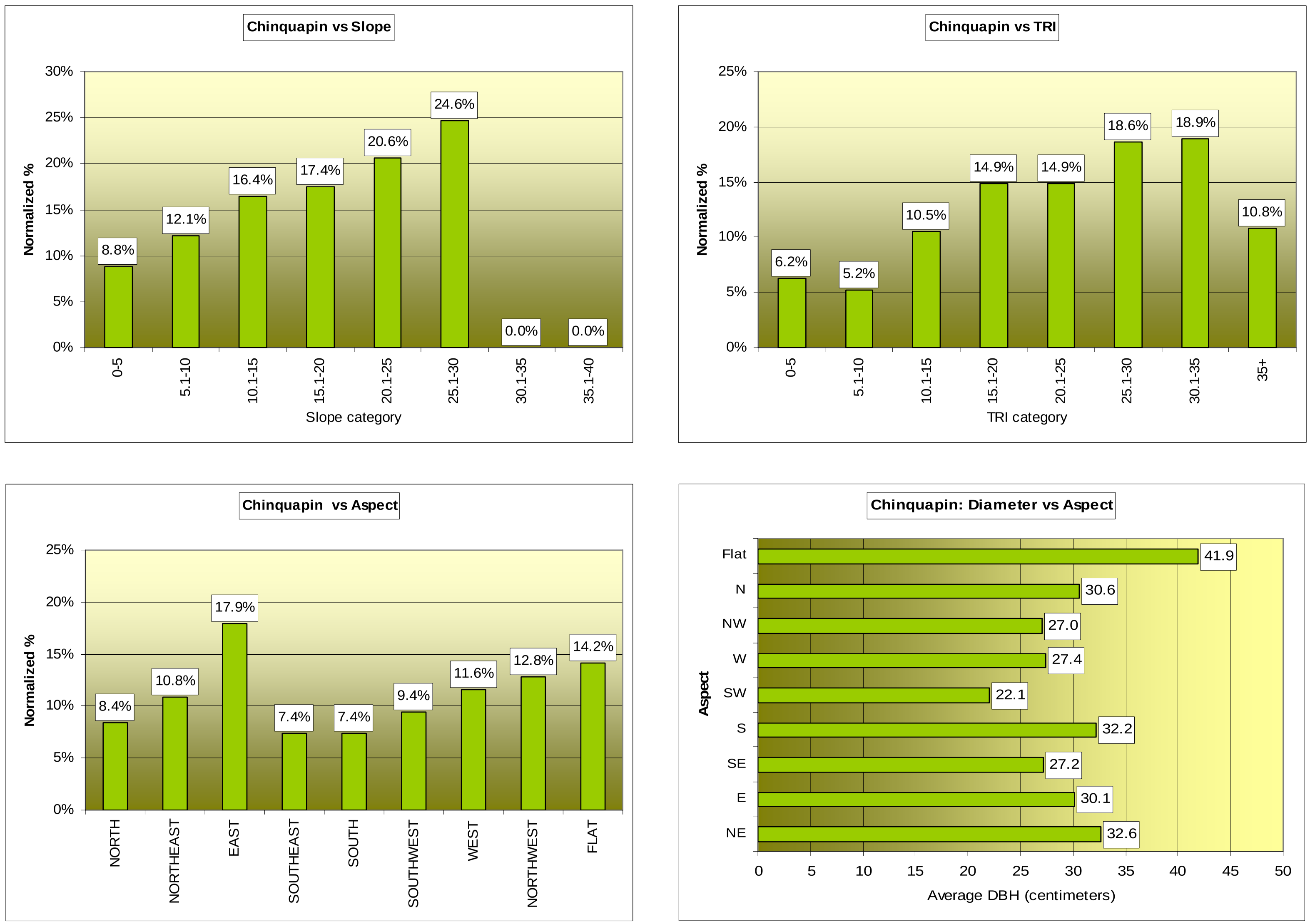


Figure 4.26 Chinquapin site analysis.

eastern United States. As with other members of the *Castanea* genus, this species is susceptible to chestnut blight. While it has now been reduced to a shrubby stump sprouter, Ozark chinkapin attained heights of 60 feet or more at the time the Boston Mountains were surveyed.

Ozark chinkapin stems composed 1.8% of all tree records and had an average diameter of 28.6 centimeters. While the map of Ozark chinkapin data points shows it was found in all but one township, this species grew most densely in the rugged, eastern portions of study area. Distribution according to slope shows a steady increase from the lowest slope class of 0-5º (8.8%) up to 25.1-30º (24.6%), while no points fell in the two highest slope classes. Ozark chinkapin preferred topographically diverse areas with the TRI classes of 25.1 to 30 and 30.1 to 35 containing 37.5% of recorded stems, and the TRI classes of 15.1 to 20 and 20.1 to 25 accounting for 29.8%. Aspect analysis shows that Ozark chinkapin was most often found on east (17.9%) and northwest facing slopes (12.8%). It also commonly fell on flat sites (14.2%), where it grew to its greatest diameter of 41.9 centimeters. This species also grew well on northeast, south, north and east facing slopes with average measurements of 32.6, 32.2, 30.6 and 30.1 centimeters respectively.

Surveyors simply recorded "maple" stems (Figures 4.27 and 4.28) for 1.5% of the total data points. While separate from sugar maple (see below), this could be either *Acer rubrum* (red maple) or *Acer saccharinum* (silver maple). In the study area, maple stems were primarily recorded in the central and southern portions of the project extent. Maple data points fell most often on moderate slopes of 5.1 to 20º (65.3%). This taxa also preferred areas with low to moderate TRI values, with the classes of 10.1 to 15 (16.0%)

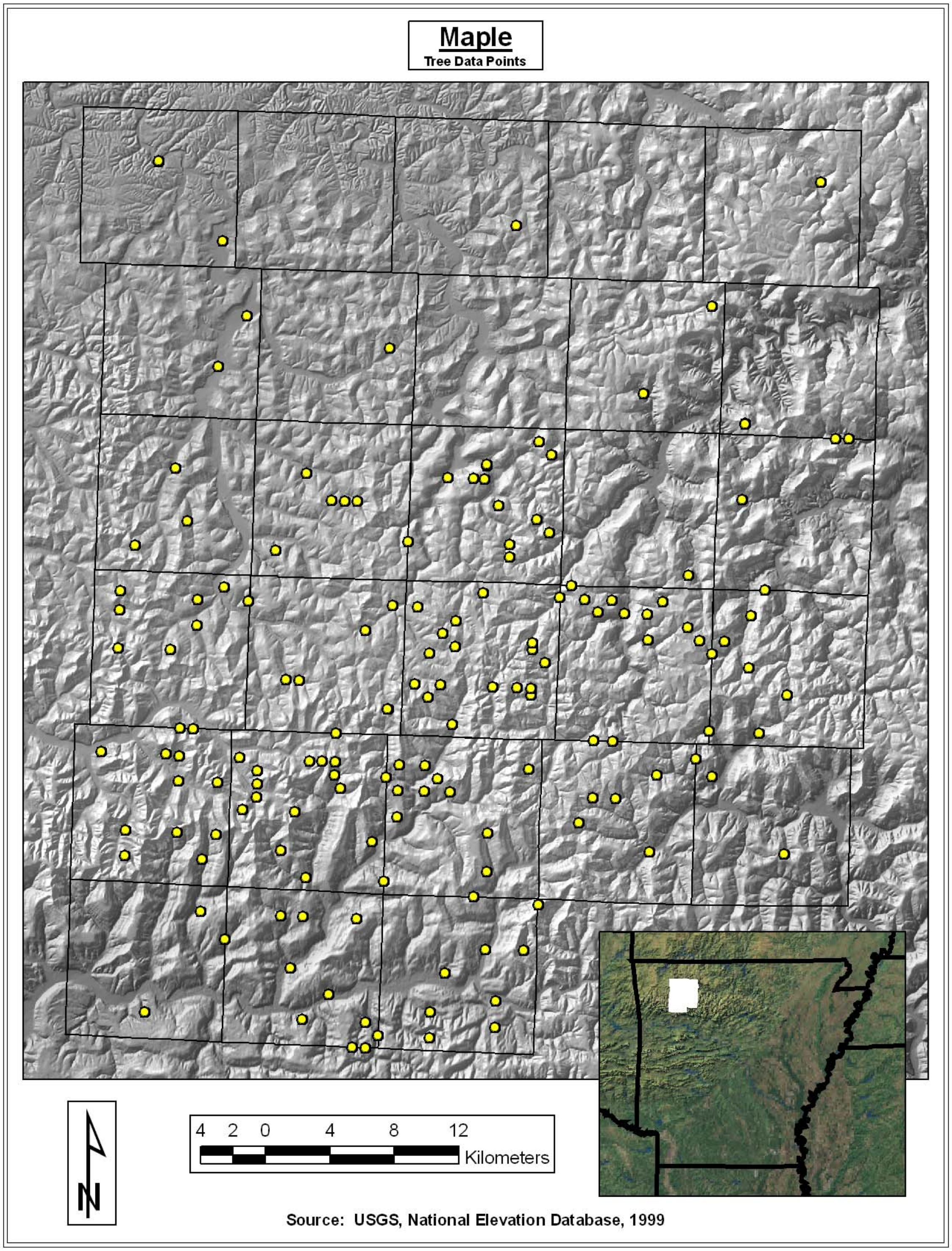


Figure 4.27 Maple data point distribution.

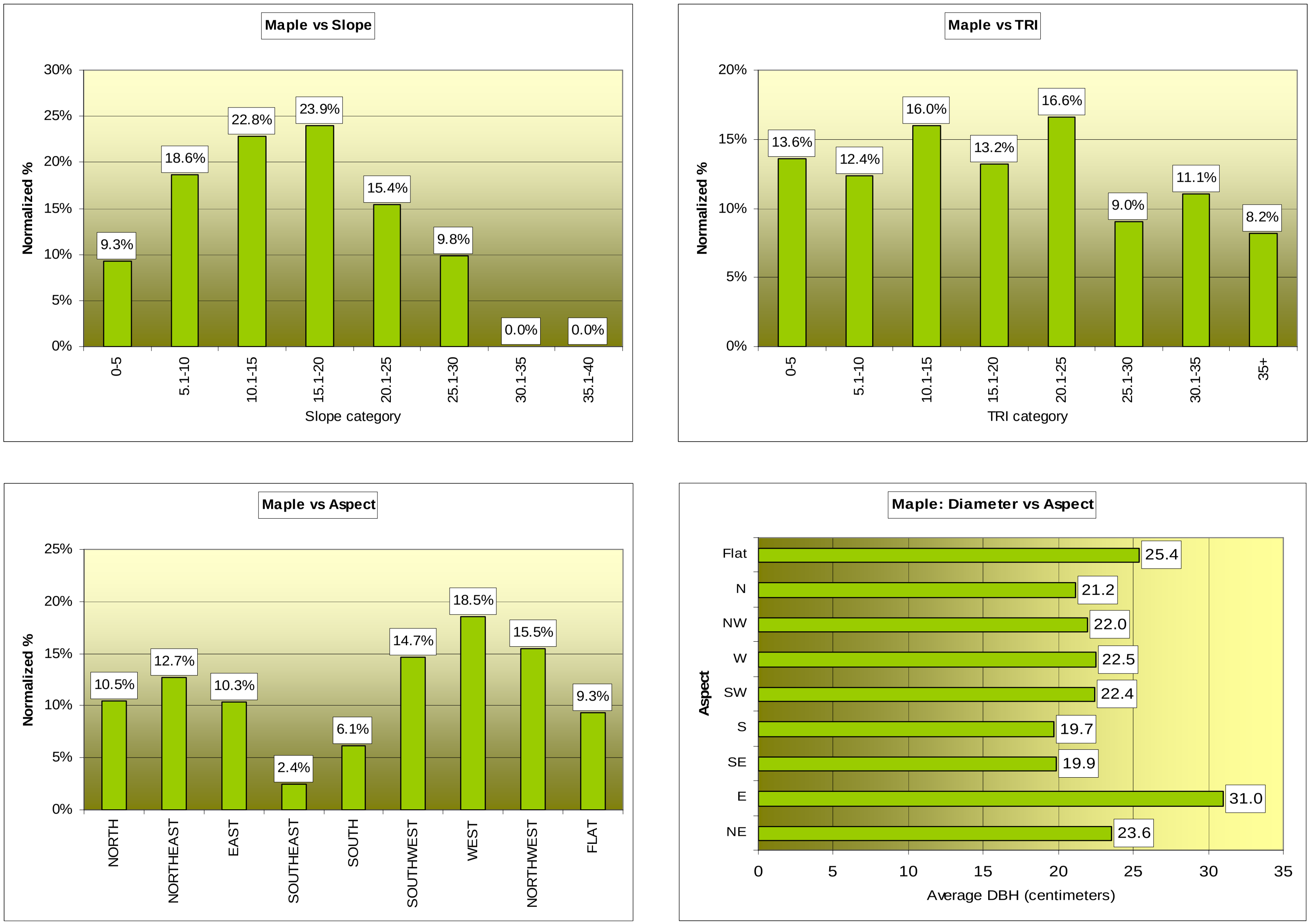


Figure 4.28 Maple site analysis.

and 20.1 to 25 (16.6%) having the highest stem densities. Further analysis shows a preference for west (18.5%), northwest (15.5%) and southwest (14.7%) facing slopes. While maple stems had an overall average diameter of 23.3 centimeters, they attained their greatest measurements on east facing slopes and flat areas with average diameters of 31.0 and 25.4 centimeters respectively.

Like “elm” and “hickory,” “pine” was a generic designation used by surveyors throughout the study area. Because shortleaf pine (*Pinus echinata*; Figures 4.29 and 4.30) is the only *Pinus* species native to the Boston Mountains region, we can assume that this is the species surveyors were referring to. In the study area surveyors recorded shortleaf pine for 1.2% of the total tree points, with a relatively large average diameter of 43.0 centimeters. Shortleaf pine was noted very thinly in most of the townships, but did have dense clusters of points in the southeastern corner of the study area.

Survey records noted shortleaf pine as occurring primarily on sites with steep slopes of 25.1 to 35º (52.1%). While shortleaf pine tended to grow most often on areas with a TRI value of 30.1 to 35 (30.5%), it also shows a slight tendency towards moderate TRI values of 15.1 to 20 (17.5%). Aspect analysis shows an inclination towards xeric aspects, with southeast (23.5%), south (21.2%) and southwest (20.3%) facing slopes having the greatest normalized densities. While it had the highest stem counts on xeric slopes, shortleaf pine grew to its greatest average diameter measurements on east and north slopes with 52.4 and 50.8 centimeters respectively.

Sugar maple (*Acer saccharum*; Figures 4.31 and 4.32) was colloquially referred to as sugar tree by surveyors. Throughout its natural range it is a mesophytic maple species that prefers cool slopes and rich soils. While maps show its contemporary range stopping

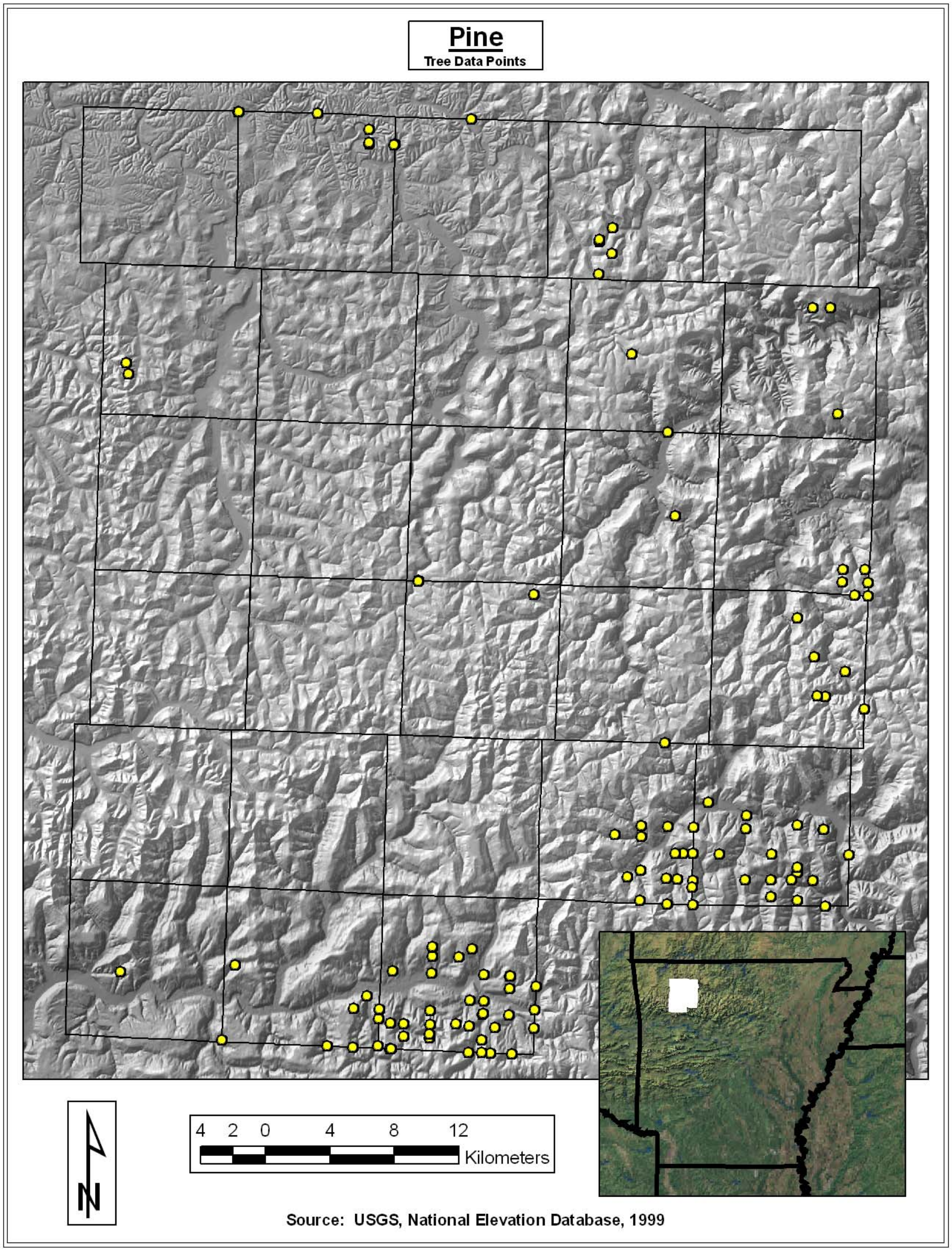


Figure 4.29 Pine data point distribution.

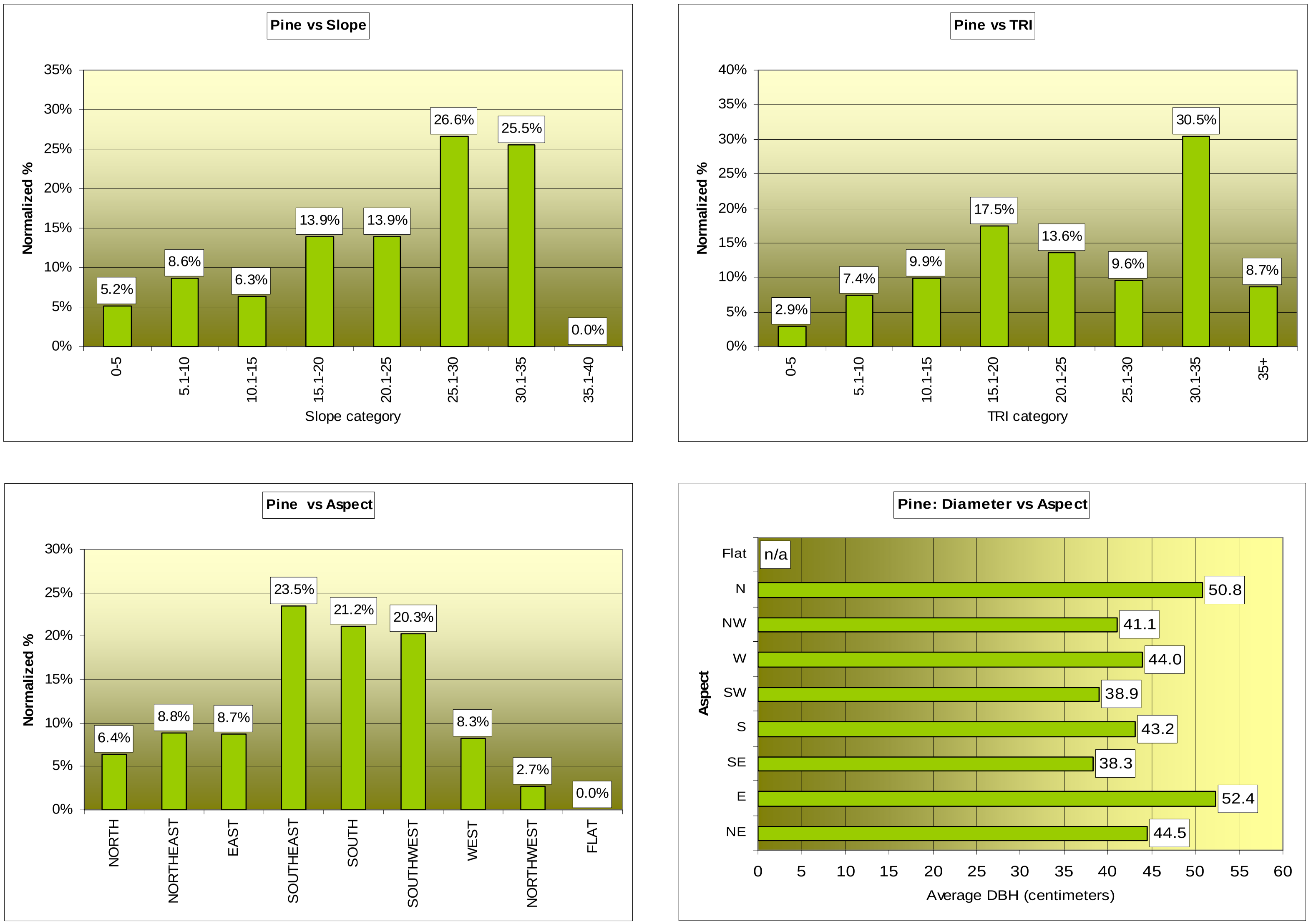


Figure 4.30 Pine site analysis.

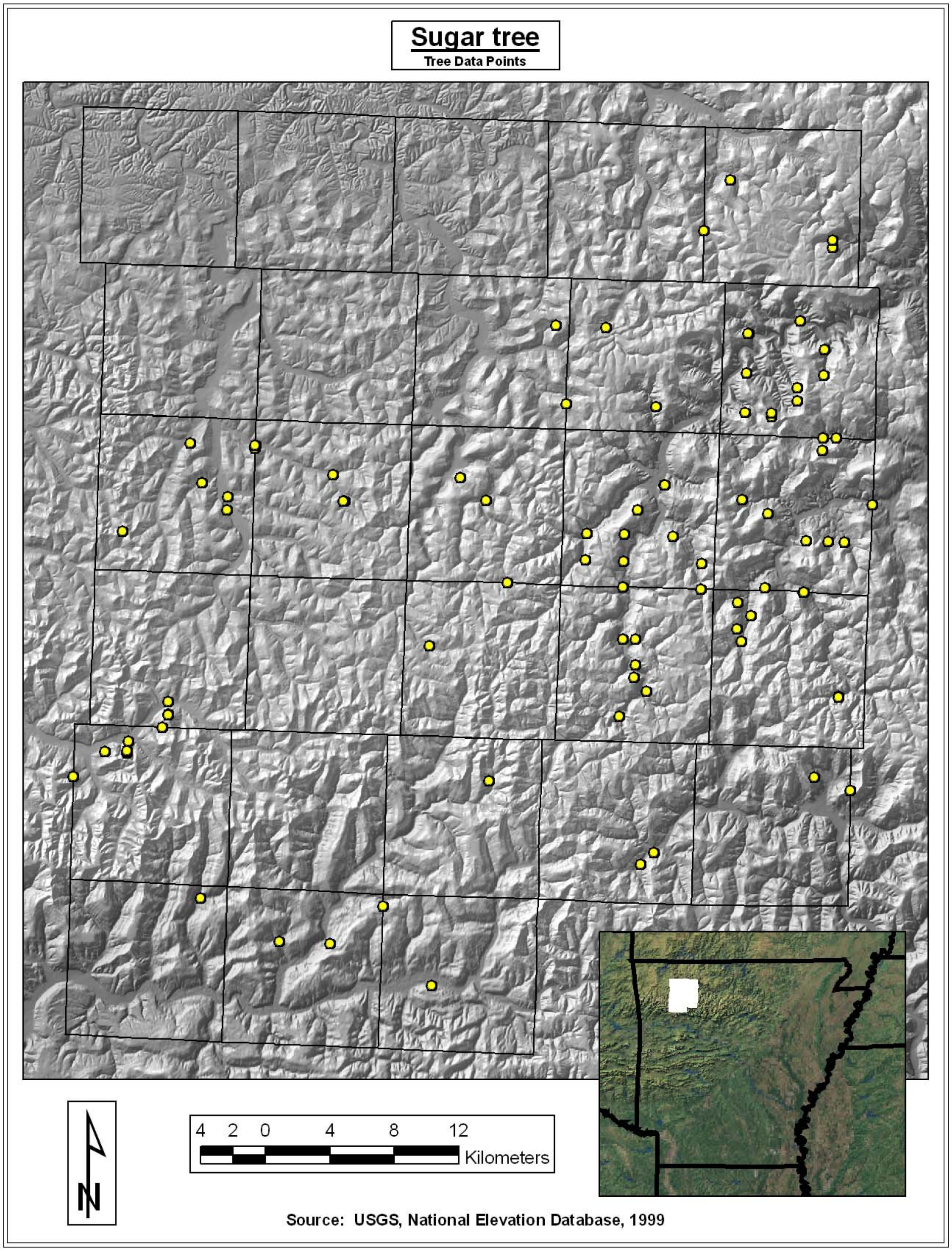


Figure 4.31 Sugar tree data point distribution.

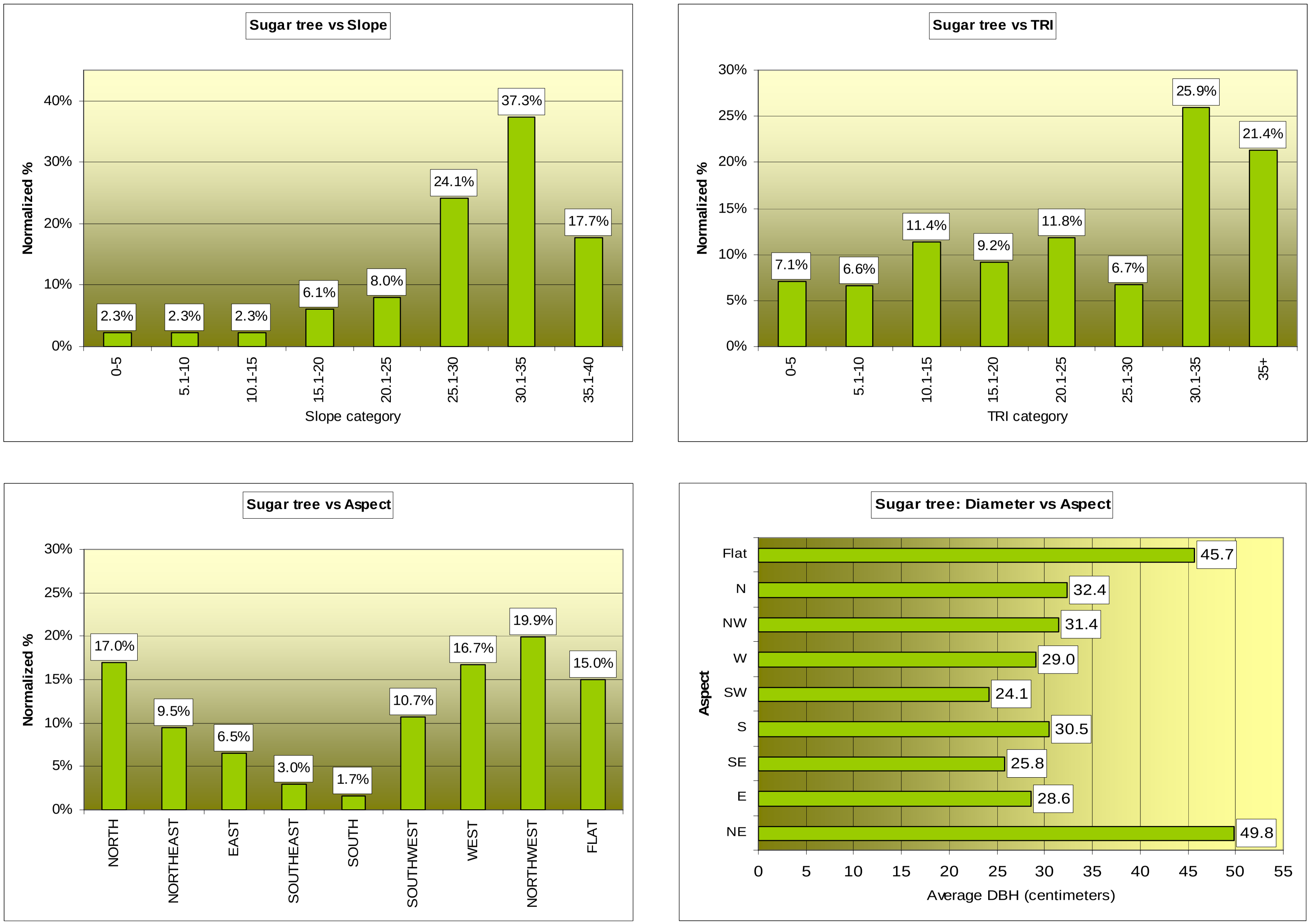


Figure 4.32 Sugar tree site analysis.

in southern Missouri with no extension into the Boston Mountains, sugar maple accounted for 0.9% of all tree data points (Burns and Honkala 1990; Figure 4.33). In the study area, this species had an average diameter measurement of 33.9 centimeters. Surveyors recorded sugar maple's most dense point distributions in the eastern portion of the study area. Normalized data analysis shows sugar maple preferred steep slopes of 25.1º or greater (79.1%) as well as topographically diverse areas with TRI values of 30.1 and greater (47.3%). Displaying an affinity for mesic sites, sugar maple tended to grow most often on northwest (19.9%) and north (17.0%) facing slopes, with west (16.7%) slopes and flat (15.0%) areas also displaying significant densities. By far, sugar maple grew to its greatest diameters on northeast slopes and flat sites, with average measurements of 49.8 and 45.7 centimeters respectively.

Throughout its range, sweetgum (*Liquidambar styraciflua*; Figures 4.34 and 4.35) is an extremely adaptive species with a slight preference for bottomlands. This species was primarily found in deep valleys located in the eastern and southern parts of the project extent. In the study area, this species composed 0.8% of all tree points in the study area and had an average diameter of 42.7 centimeters.

Although throughout much of its range sweetgum prefers bottomlands sites, analysis shows an affinity for both upland and bottomland sites. Within the study area sweetgum stems tended to fall most densely on steep slopes from 30.1 to 35º (40.0%); as well as areas with high TRI values from 25.1 to 30 (18.3%) and greater than 35 (23.2%). Analysis also shows an affinity for flatter sites, with significant densities on slopes of 0 to 5º (15.7%) and sites with TRI values ranging from 0 to 5 (13.5%). Moreover, examination of aspect distribution shows a significant bias towards flat sites with a

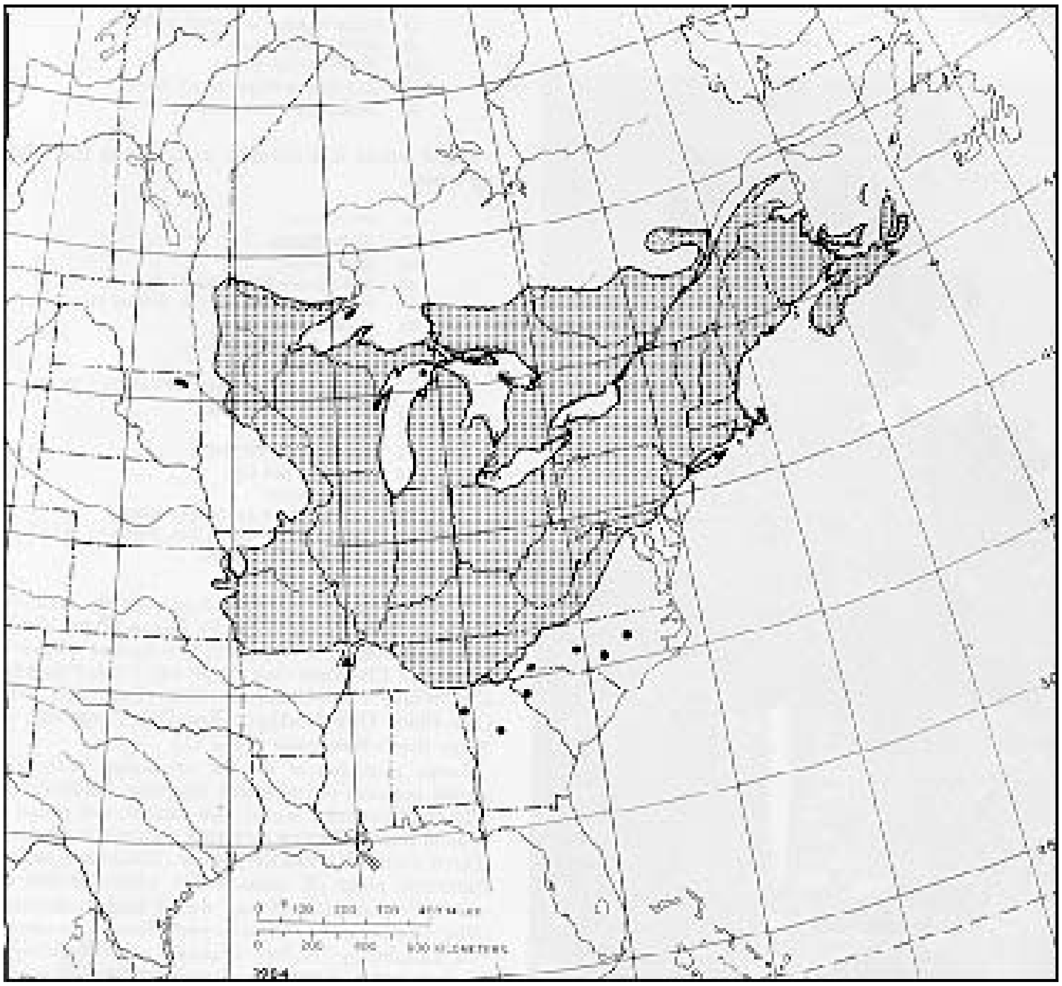


Figure 4.33. Contemporary range of sugar maple (Honkala and Burns 2002).

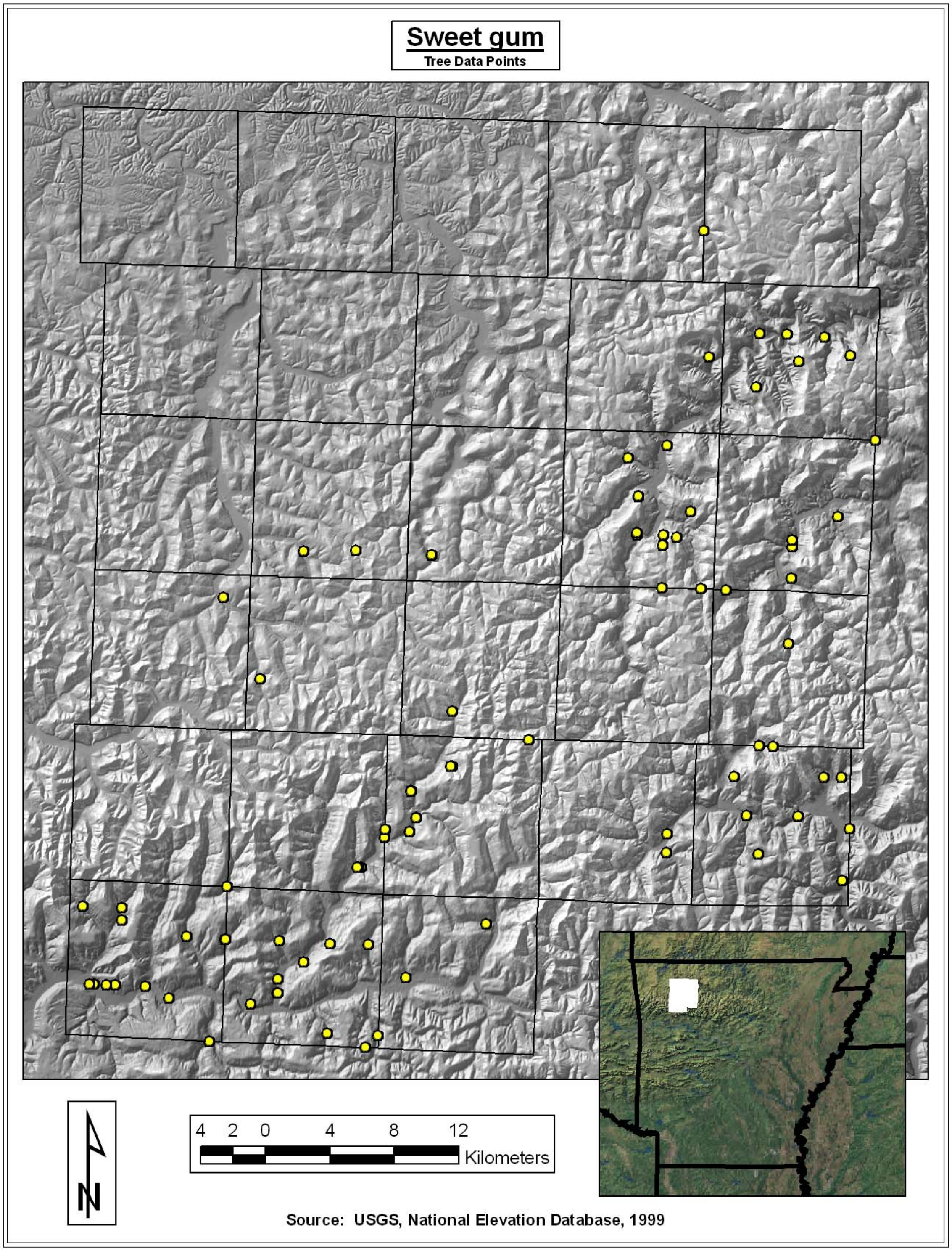


Figure 4.34 Sweet gum data point distribution.

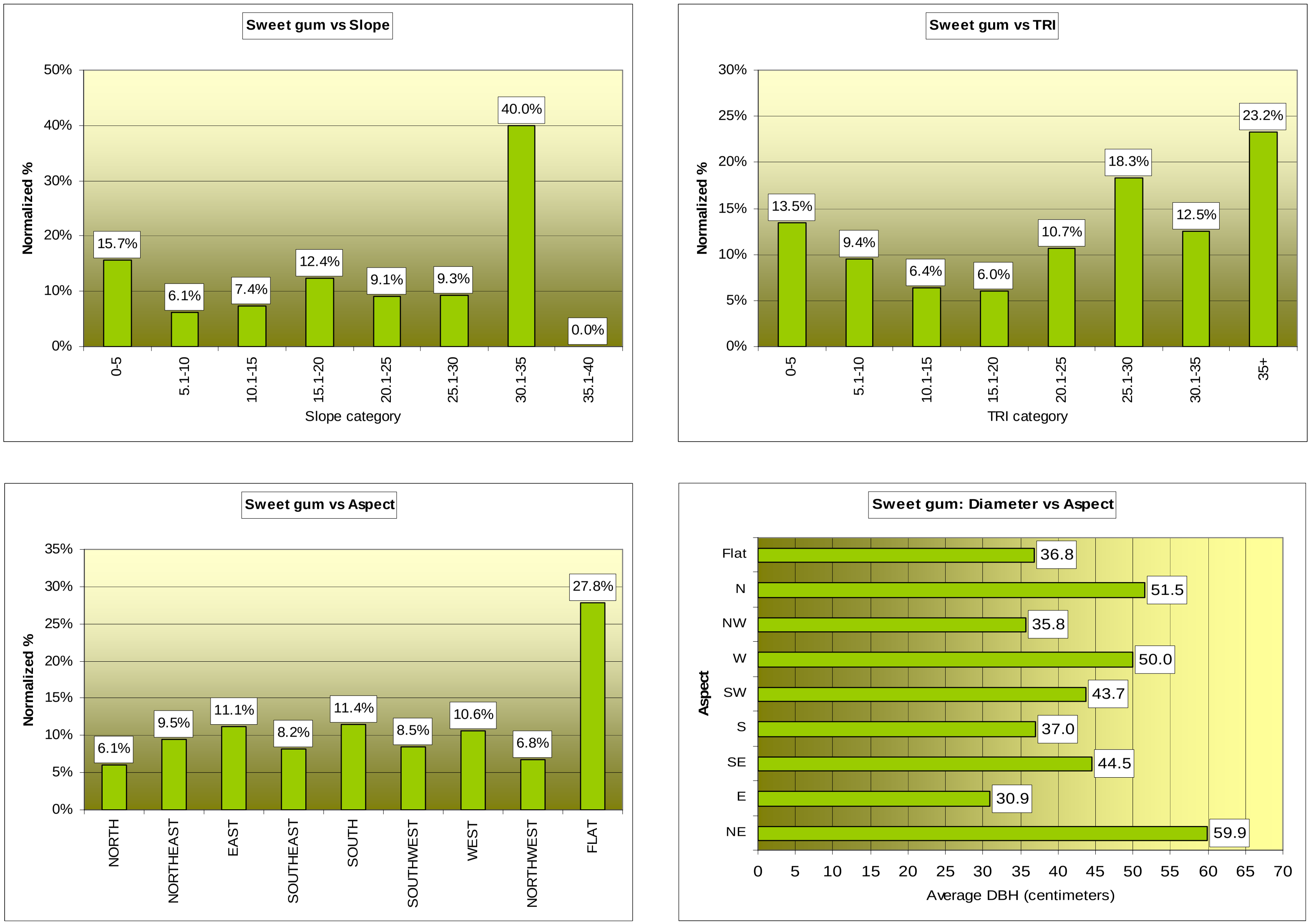


Figure 4.35 Sweet gum site analysis.

normalized distribution of 27.8%. All other directional aspects had distributions of 11.4% or less. Sweetgum attained its largest average diameter measurements on northeast (59.9 cm), north (51.5 cm) and west (50.0 cm) facing slopes.

Black cherry (*Prunus serotina*; Figures 4.36 and 4.37), was simply referred to as cherry in surveyor notes. This is one of the most widely distributed hardwood species in North America, located from Nova Scotia down to Texas and even into Central America. Throughout its North American range black cherry is found on a variety of sites, but it is most frequently found in moist woodlands. Survey records for the study area show black cherry comprised 0.7% of all tree data points and had an average diameter of 31.7 centimeters. Mapped point distributions show black cherry thinly dispersed throughout the study area, with a slightly increased density in the northern townships.

Slope correlation shows that black cherry favored flatter sites with 29.2% of its total entries found on slopes of 0 to 5º and 28.4% recorded on sites with a TRI value ranging from 0 to 5. This distinct trend continued in the aspect analysis where black cherry's highest stems densities (31.4%) and greatest average diameter of 62.2 centimeters were also found on flat sites.

Black walnut (*Juglans nigra*; Figures 4.38 and 4.39) was simply recorded as walnut in survey notes. Throughout its natural range, black walnut is predominately a bottomland species; but is also found on moist upland sites with rich soils. Black walnut accounted for 0.7% of the total data points recorded and had an average diameter of 34.0 centimeters. Within the study area, black walnut was most densely distributed in the valleys of the northern half of the study area.

This species' affinity for bottomlands sites was evident in distribution analysis as

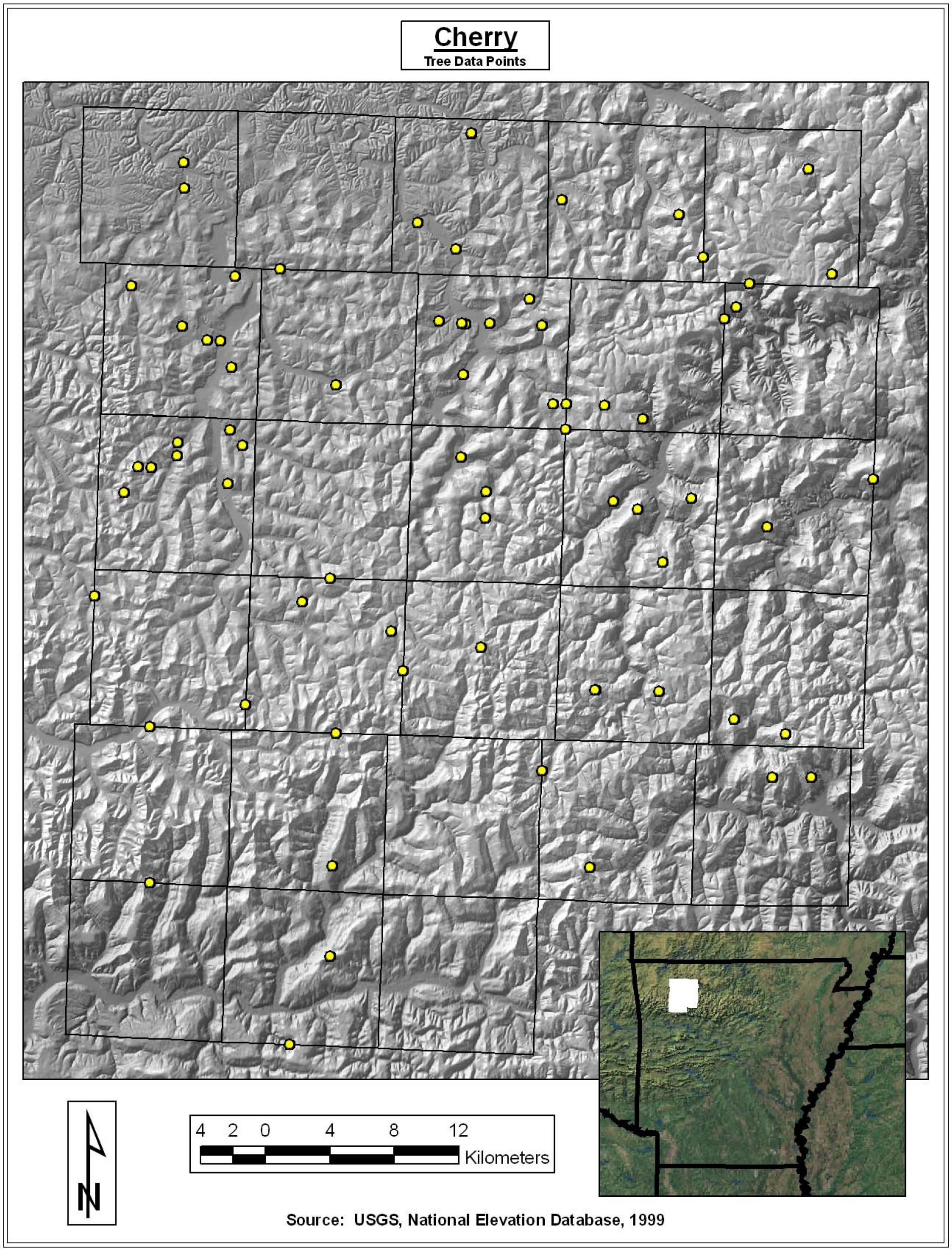


Figure 4.36 Cherry data point distribution.

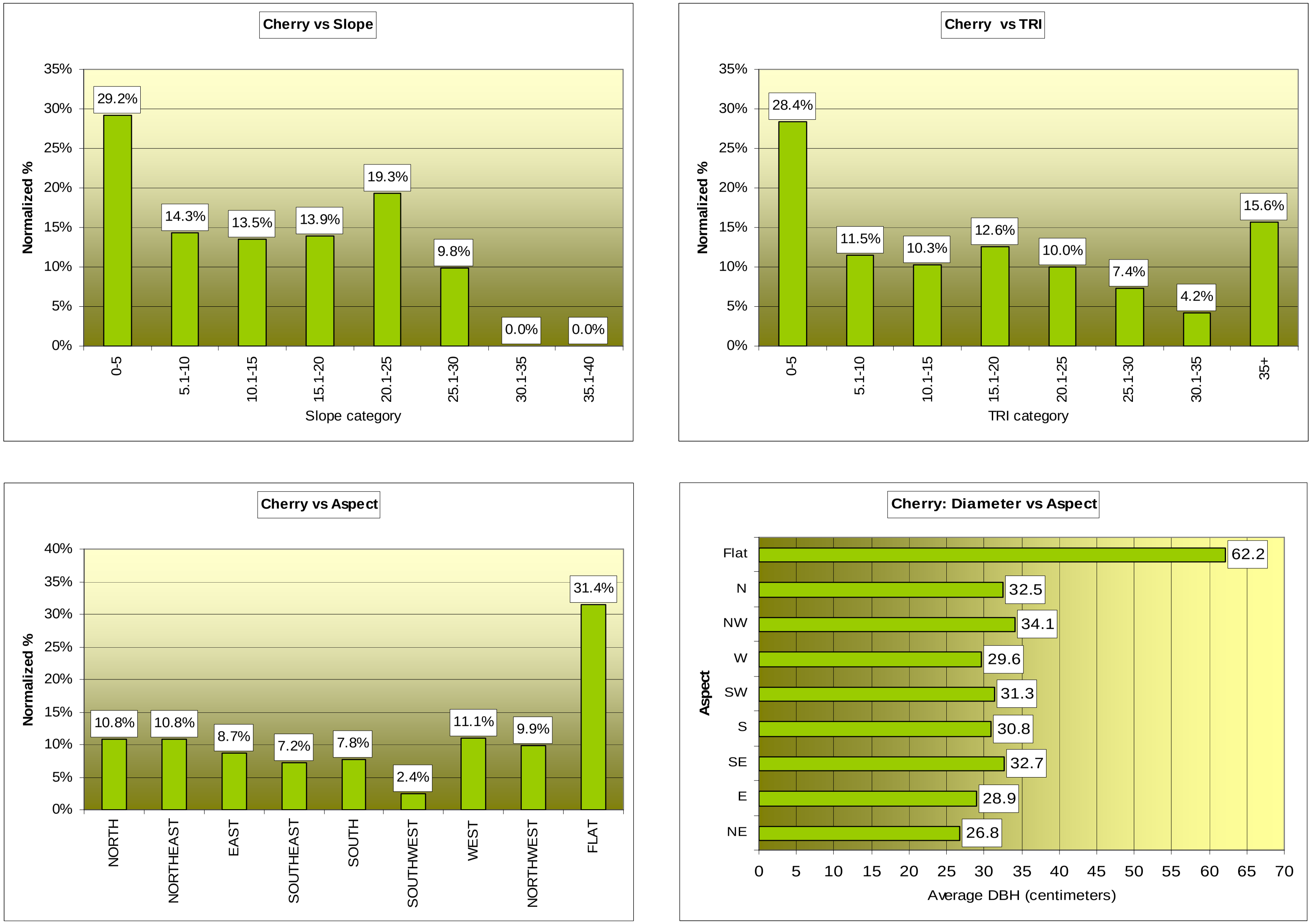


Figure 4.37 Cherry site analysis.

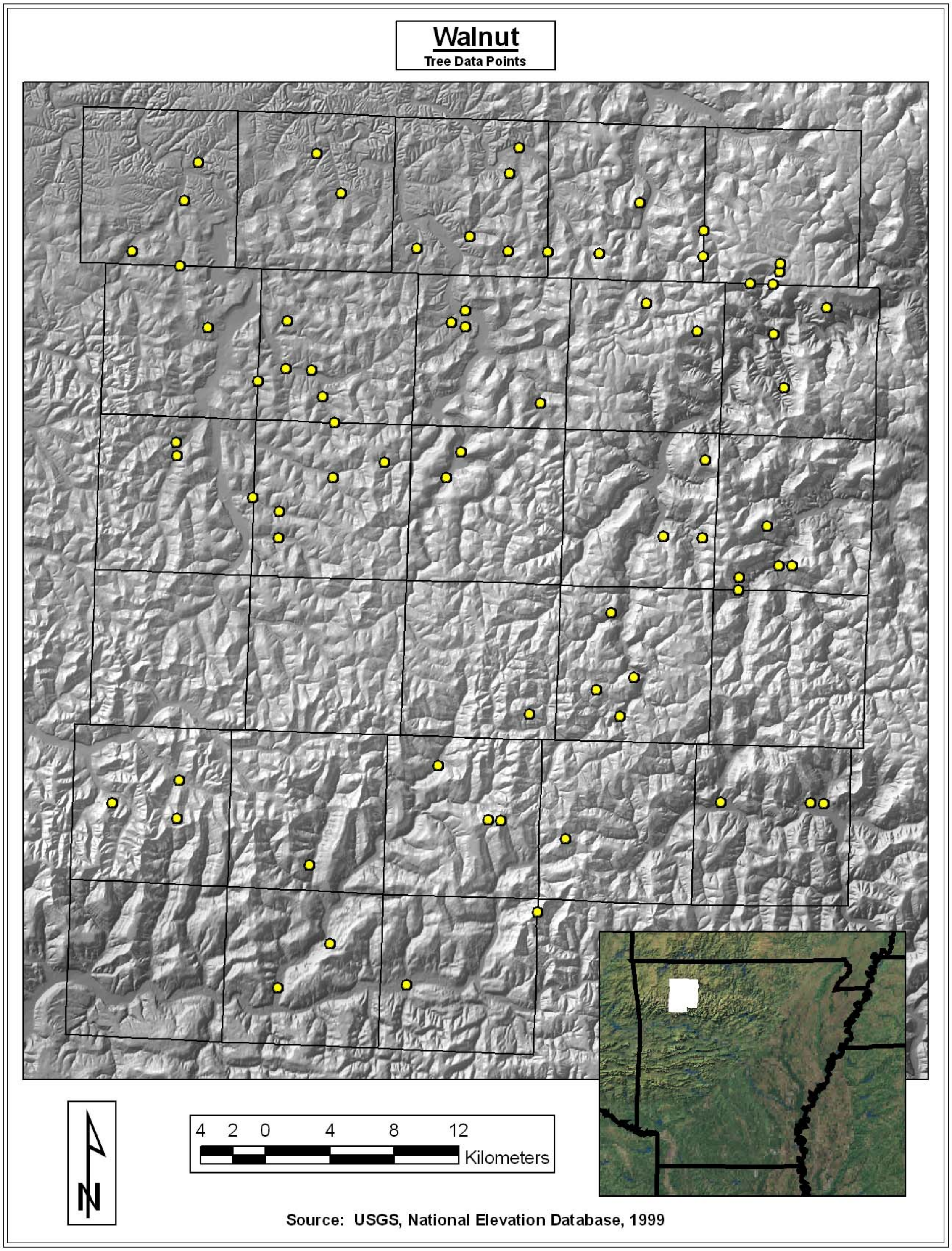


Figure 4.38 Walnut data point distribution.

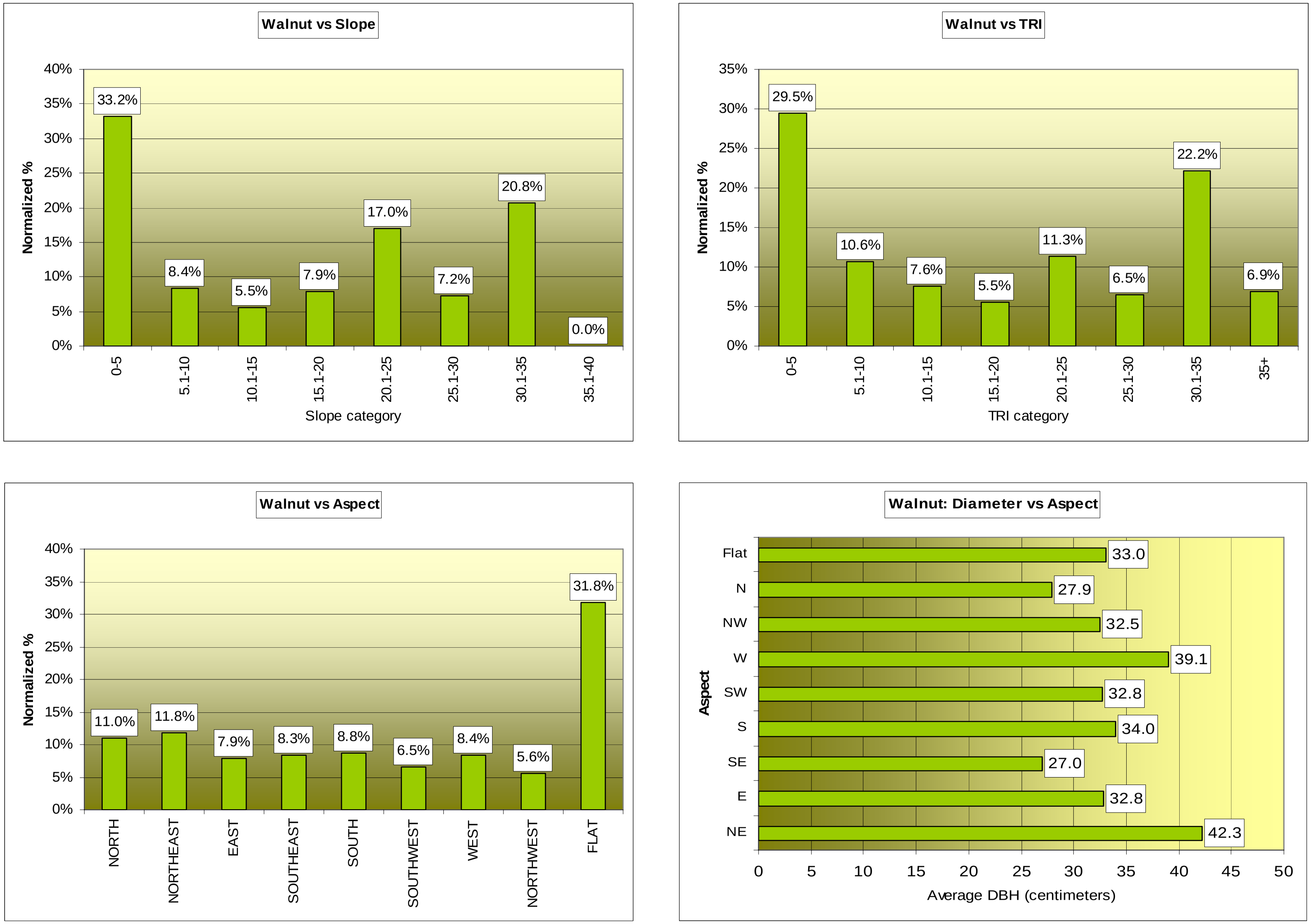


Figure 4.39 Walnut species site analysis.

black walnut stems were most common on areas with 0 to 5º slopes (33.2%) as well as areas with TRI values of 0 to 5 (29.5%). However, areas with slopes of 30.1 to 35º and TRI values from 30.1 to 35 had significant distributions of 20.8% and 22.2% respectively. Aspect analysis substantiates this species' natural tendency towards bottomlands sites with 31.8% of all stems falling on flat sites. Further analysis identifies black walnut's largest average diameters recorded on northeast and west facing slopes, with average measurements of 42.3 and 39.2 centimeters respectively.

Ash was another generic term used by surveyors to note all ash (*Fraxinus*) species encountered (Figures 4.40 and 4.41). Two ash species have natural ranges that cover much of eastern North America, namely white ash (*Fraxinus americana*) and green ash (*Fraxinus pennsylvanica*). Another species that is sparsely distributed in the eastern United States but has part of its range possibly overlapping the study area is blue ash (*Fraxinus quadrangulata*). Black ash (*Fraxinus nigra*) is a bottomland species with a contemporary range that does not include the Boston Mountains, but was specifically recorded in small amounts by surveyors. In eastern deciduous forests, white ash is the most cosmopolitan of all ash species and is most often found on moist to dry upland sites; while green ash is the most widely distributed ash species in North America and is most commonly found on wet bottomland sites. Throughout its range, blue ash is typically found on dry ridges.

Surveyors noted ash stems for a total of 0.6% of all tree data points, with this species' most dense distributions recorded in the rugged eastern portions of the study area. Tree point analysis reflects some of the differing site preferences of the various ash species found in the Boston Mountains. Slope analysis shows an affinity towards steeper

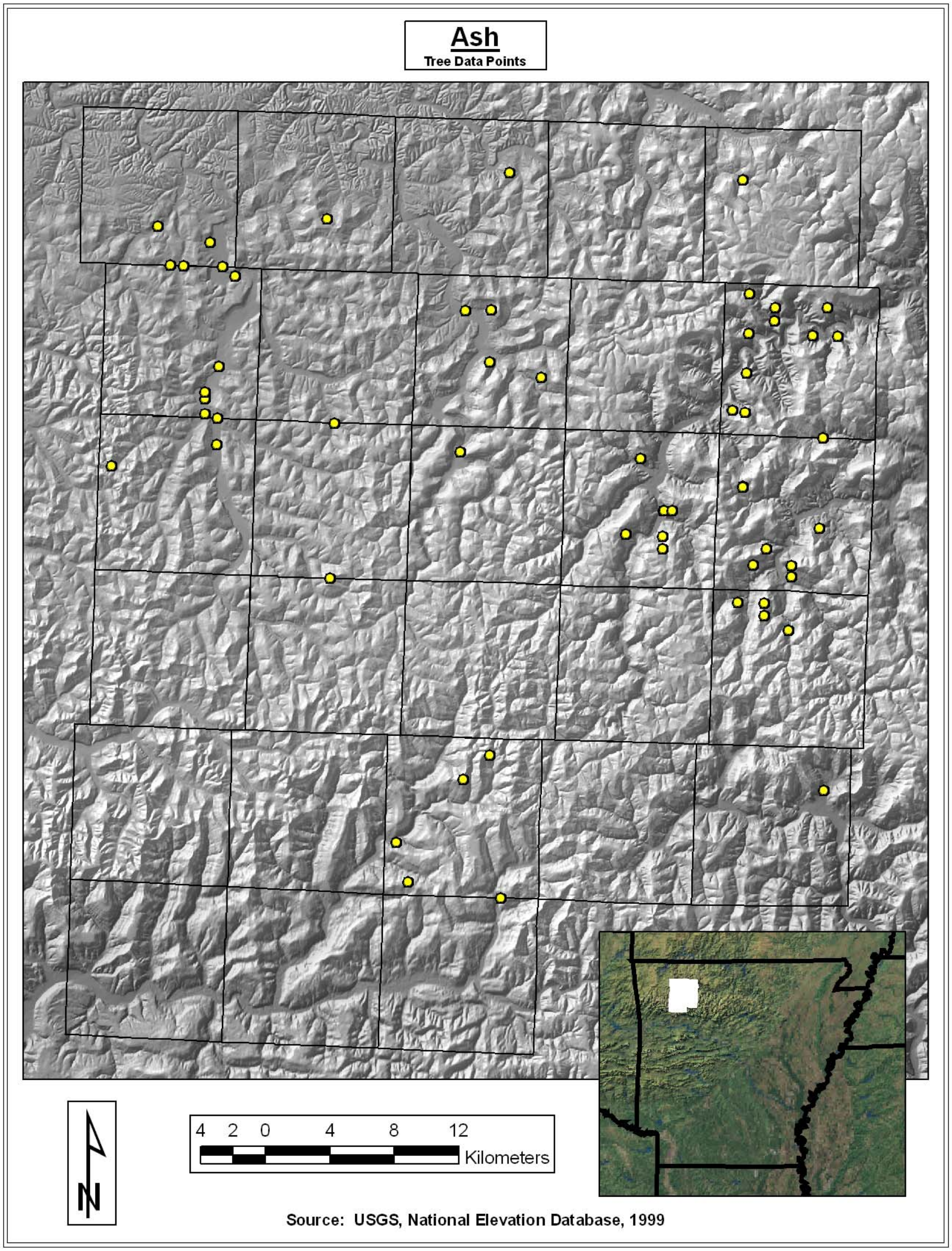


Figure 4.40 Ash data point distribution.

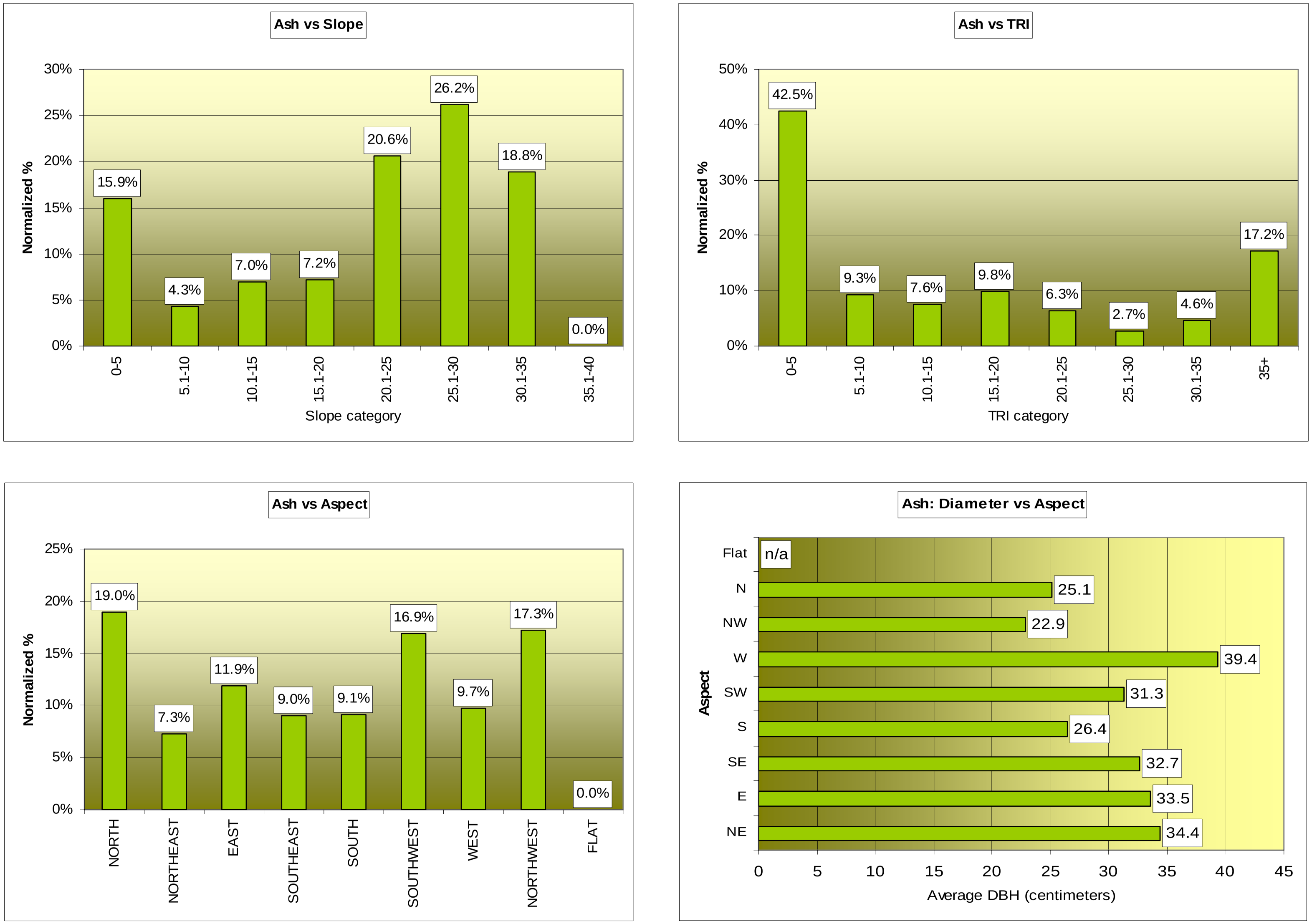


Figure 4.41 Ash site analysis.

slopes ranging from 20 to 35º (65.6%); with a significant distribution also found on areas with the lowest slope class of 0 to 5° (15.9%). Conversely, topographic roughness analysis shows ash stems primarily found on sites with the lowest TRI value class of 0 to 5 (42.5%) with a much lower, but notable distribution on the highest TRI class of 35 or greater (17.2%). Distribution according to aspect shows analogous patterns with significant distributions on mesic north (19.0%) and northwest (17.3%) facing slopes as well as more xeric southwest facing slopes (16.9%). Throughout the study area, ash stems had an average diameter measurement of 31.6 centimeters, with the highest average diameter of 39.4 centimeters occurring on west facing slopes. Ash stems also recorded above average stem diameters on northeast (34.4 cm), east (33.5 cm) and southeast (32.7 cm) facing slopes.

Throughout its range, blackjack oak (*Quercus marilandica*; Figures 4.42 and 4.43) is a small oak common to dry, infertile sites. This species was a rare upland oak species in the presettlement vegetation of the Boston Mountains, comprising only 0.4% of all tree data points. As with the other xerophytic species, blackjack oak was found primarily in the relatively flat northern portions of the study area. Slope analysis shows a tendency to grow on areas of low slopes ranging from 0 to 10º (57.9%) as well as moderate slopes of 20.1 to 25º (23.7%). Correlation of tree points to TRI index shows blackjack oak stems primarily occurring on areas with TRI values of 5.1 to 10 (31.3%), with a significant distribution also found on sites with values of 25.1 to 30 (19.1%). This species' stem densities were highest on east (25.1%), southeast (19.4%) and south (16.3%) facing slopes. While blackjack oak had a small overall average diameter of 21.9 centimeters, and it achieve significantly above average diameter measurements on

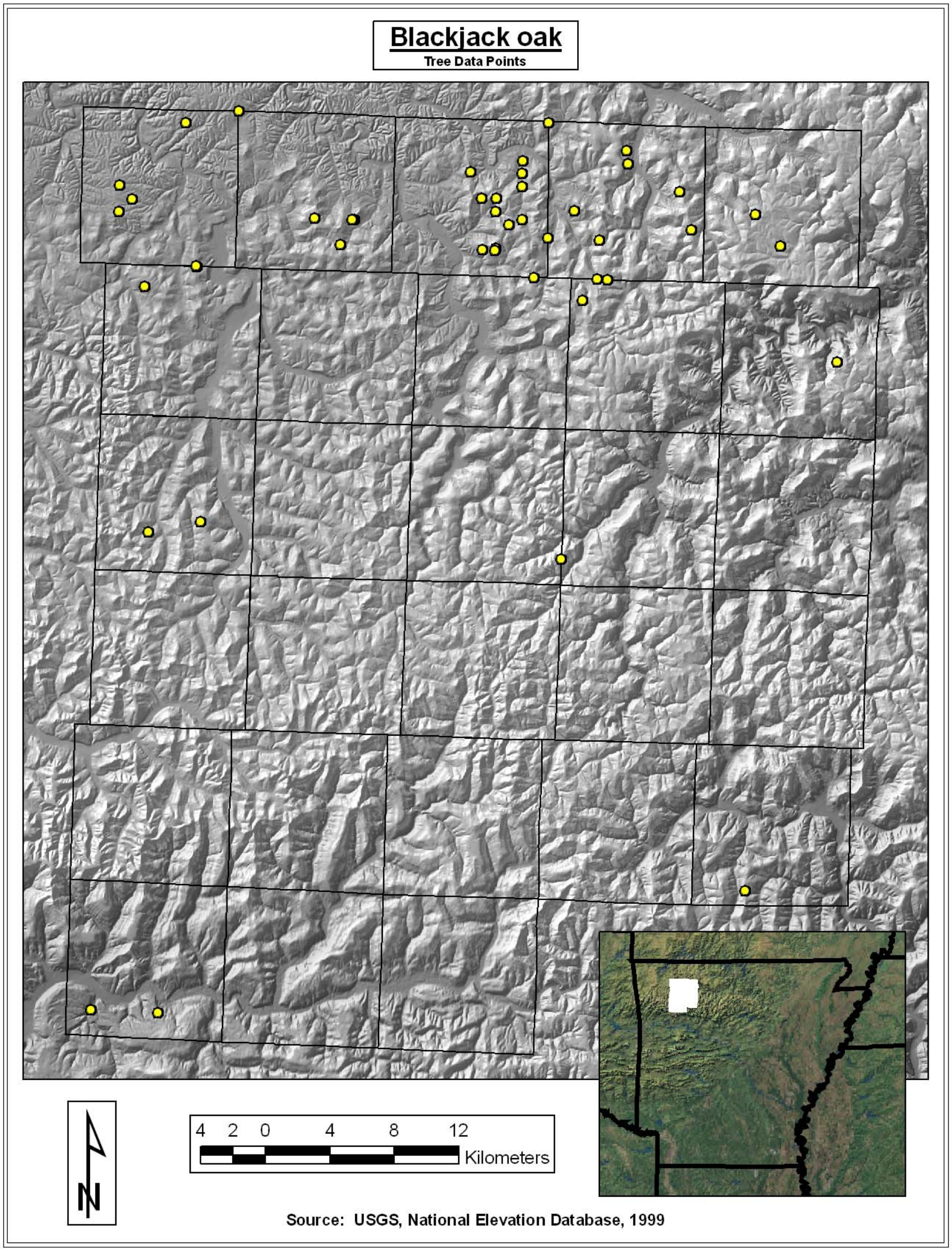


Figure 4.42. Blackjack oak data point distribution.

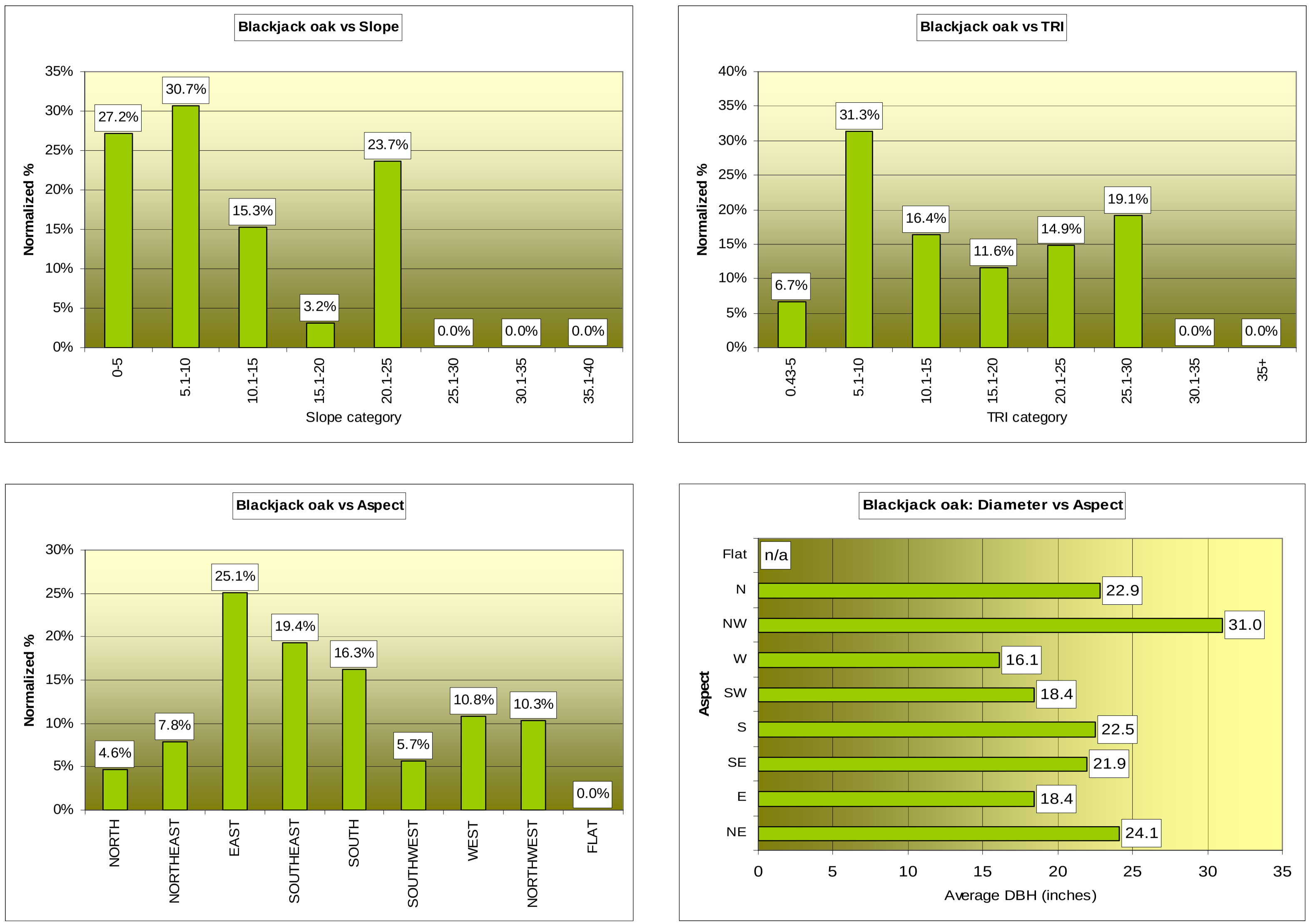


Figure 4.43. Blackjack oak site analysis.

northwest (31.0 cm.) as well as northeast (24.1 cm.) facing slopes.

Throughout its range, hackberry (*Celtis occidentalis*; Figures 4.44 and 4.45) is commonly found in and adjacent to moist bottomlands. With only a total of 0.4% of all tree data points within the study area, analysis shows hackberry frequently inhabited the broad floodplains found in the northwestern and north-central townships. In the study area its affinity for bottomland sites is clearly shown by slope, TRI and aspect analysis; with its highest normalized densities predominantly falling on the flattest categories with 66.5%, 59.8% and 47.9% respectively. This species had an average diameter of 35.1 centimeters and like many other species it grew to its largest average stem measurements on north (45.2 cm.) and northeast (40.2 cm.) facing slopes. Not surprisingly, hackberry also grew well on flat sites with an average diameter of 40.6 cm.

It is important to note that dogwood (*Cornus florida*; 1.7%) and sassafras (*Sassafras albidum*; 0.6%) both had a notable amount of survey records (Table 4.2). Because these are typically understory species, they were not included in the individual species site preference analysis.

Interpolated Forest Type Patterns

In addition to the four landcover types differentiated, the project identified eight distinct tree species associations throughout the study area (Table 4.3; Figure 4.46). Of the eight, three associations are considered floodplain forest types: elm bottomland, white oak-sycamore bottomland and hackberry-elm-black oak bottomland. Five associations are considered upland forest types: xerophytic oak, white oak-black oak, white oak-red oak-black oak, mesophytic oak, and mixed mesophytic. Although the

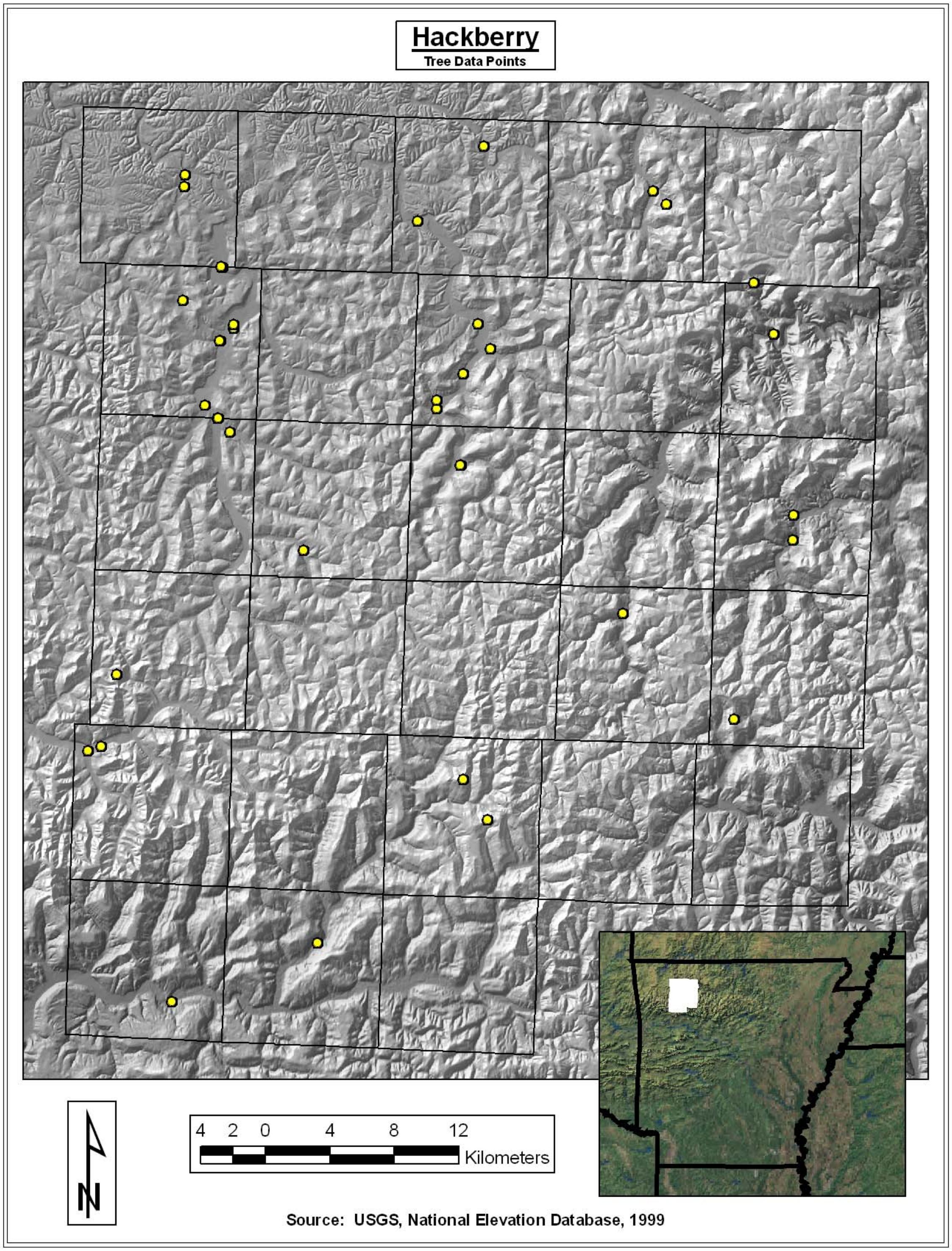


Figure 4.44. Hackberry data point distribution.

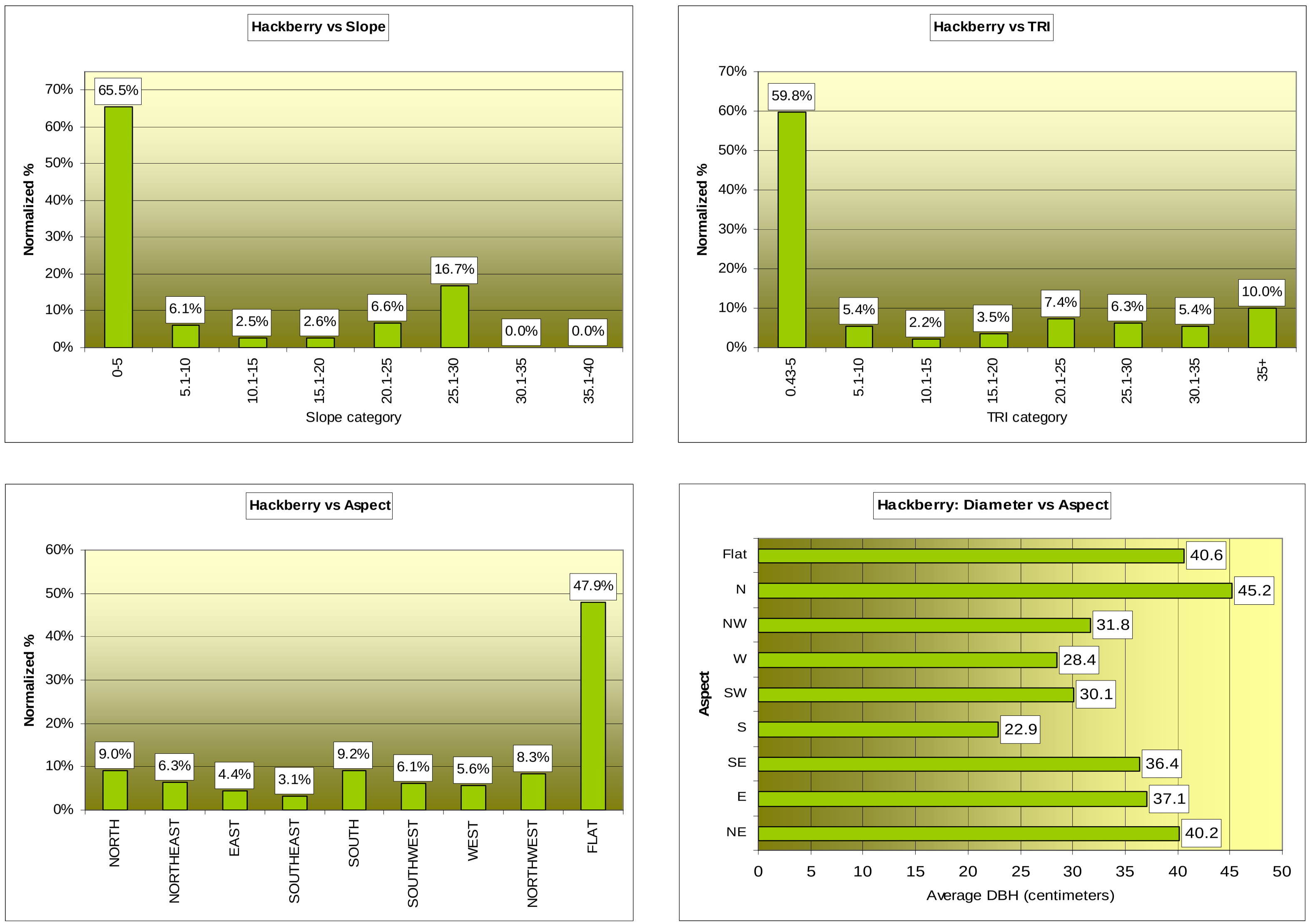


Figure 4.45. Hackberry site analysis.

Table 4.3. Forest type patterns in the study area.

Species Association Name	Primary Associate(s)	Secondary Associates	Area (ha^2)	% Study Area	Mean Slope	Mean TRI Value
Xerophytic Oak	white oak, black oak, post oak	hickory, Spanish oak, blackjack oak, blackgum	50146.48	19.5%	11.3º	16.1
White Oak-Black Oak	white oak, black oak	Spanish oak, hickory	24359.78	9.5%	9.1º	13.2
White Oak-Red Oak-Black Oak	white oak, red oak, black oak	hickory, blackgum, Spanish oak, post oak	56957.96	22.1%	10.8º	15.2
Mesophytic Oak	white oak, black oak, blackgum, hickory	maple, elm, red oak, beech, Spanish oak	99268.26	38.5%	11.8º	15.9
Mixed Mesophytic	white oak, hickory	Spanish oak, elm, sugar maple, beech, blackgum, chinkapin, red oak, sweetgum, ash	22119.55	8.6%	14.6º	18.0
Elm bottomland	elm	walnut, ash, red oak	1514.90	0.6%	2.2º	8.2
White Oak-Sycamore bottomland	white oak, sycamore	elm, blackgum	1469.80	0.6%	2.8º	9.6
Hackberry-Elm-Black Oak bottomland	hackberry, elm, black oak	cherry, ash, hickory	2044.81	0.8%	2.00º	6.4

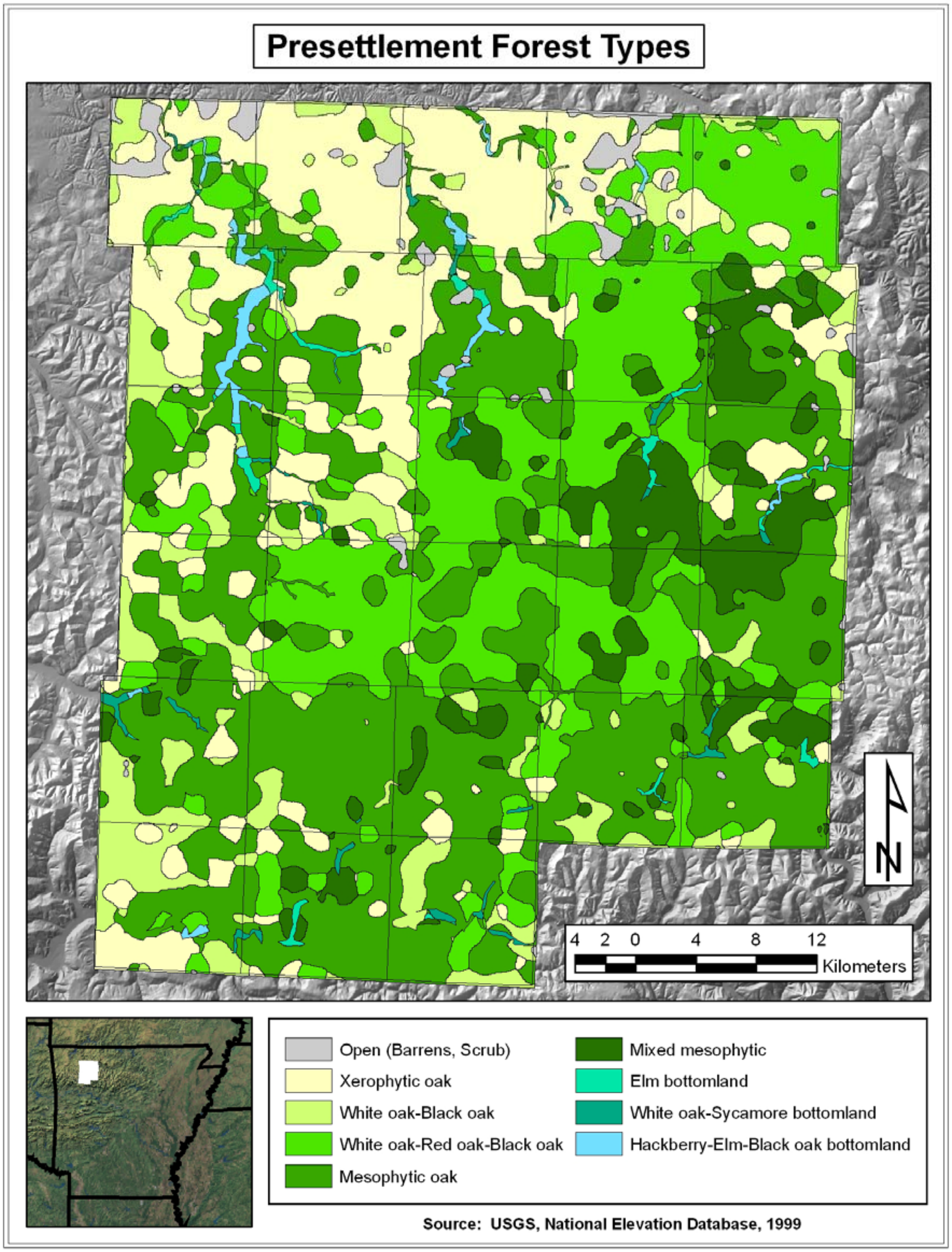


Figure 4.46. Map of presettlement forest types.

bottomland associations covered less than 2% of the study area, these important and distinct forest types were identified during the separate analysis of floodplains and upland areas as described in Chapter 3. Distribution of these forest types reflects the influence of topography on individual tree species, with the xerophytic oak forests preferring the flatter portions of the study area, and the mesophytic oak and mixed mesophytic forests preferring more rugged locations. The respective forest types dominated by red and black oak, display distributions reflecting the conspicuous patterns of those individual species discussed above.

As its name implies, the xerophytic oak species association (Figures 4.47) was composed of oak species commonly found on dry sites such as black oak, post oak and blackjack oak. This association covered 19.5% of the study area and had its largest continuous extents in the northwest corner of the study area. This forest type dominated the relatively flat portions of the extreme northwest corner; but it also followed broad ridges extending towards the center of the study area.

Quantitative analysis shows that the xerophytic oak species association occupied areas with a mean slope of 9.1º and a mean topographic roughness index value of 13.2. Analysis by slope class showed that this association had an affinity for areas of relatively low slopes with 49.6% of its distribution found on slopes of less than 10º. TRI analysis shows similar patterns with 33.2% of the xerophytic forest type's distribution falling on sites with TRI values of less than 10. Aspect analysis shows fairly even distributions among directional aspect categories with values ranging from 11.2 to 12.5%; with only 4.4% of its normalized distribution occurring on flat areas. Analysis of distribution

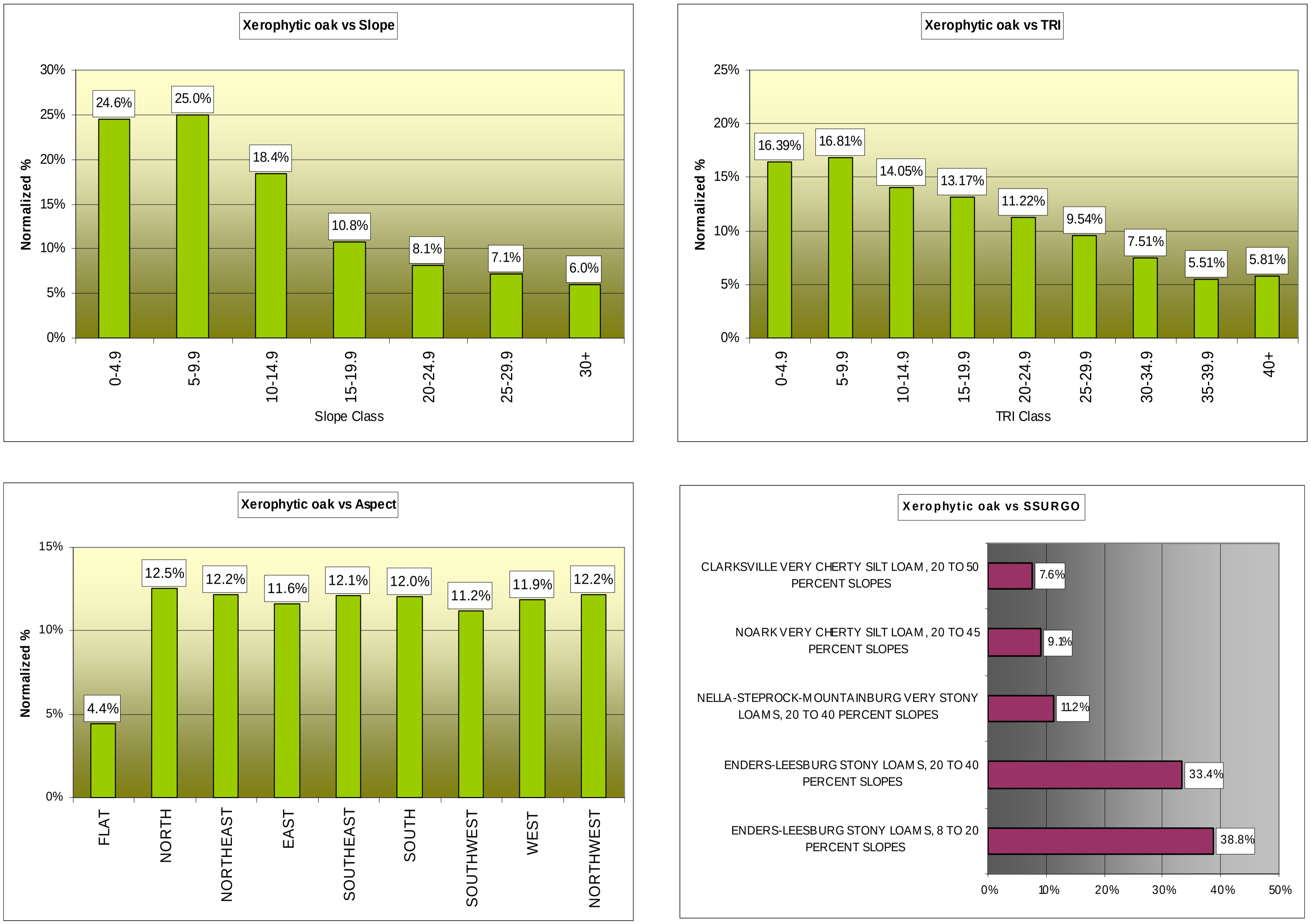


Figure 4.47. Xerophytic oak forest type site analysis.

according to soil series reveal that this association grew primarily grew on Enders-Leesburg stony loams with slopes ranging from 8 to 40 percent (72.1%).

The white oak-black oak species association (Figure 4.48) was dominated by black and white oak, but also contained Spanish oak and various hickory species. This forest type covered 9.5% of the study area and had its largest continuous extents in the west and southwest portions of the study area. Areas occupied by the white oak-black oak forest type had a mean slope of 11.3º and a mean TRI value of 16.1. Correlation to slope shows this species association's preference for areas of moderate slope, with slopes ranging from 15.1 to 19.9º containing 18.2% of its normalized distribution. TRI analysis shows an affinity for fairly rugged areas with distribution peaking at 14.0% in areas with a TRI value ranging from 30 to 34.9. The white oak-black oak species association most often fell on southwest facing slopes (12.2%) with other directional aspect categories fairly evenly distributed (10.5-11.7%). Flat sites were least preferred by this forest type with 9.3% of its normalized distribution. Analysis shows the white oak-black oak forest type most often found on Nella, Steprock, Mountainburg very stony loams with 20 to 60 percent slopes (47.3%) and Enders-Leesburg stony loams with 8 to 40 percent slopes (45.9%).

The white oak-red oak-black oak forest type (Figure 4.49) was found covering 22.1% of the study area. This species association was dominated by white oak, red oak and black oak, but also included blackgum and various hickories species. This forest type had a peculiar extent, with a broad distribution extending from the center of the study area to the northeastern corner. This pattern is directly related to the distribution of red oak along the prominent secondary extension running from the center of the study

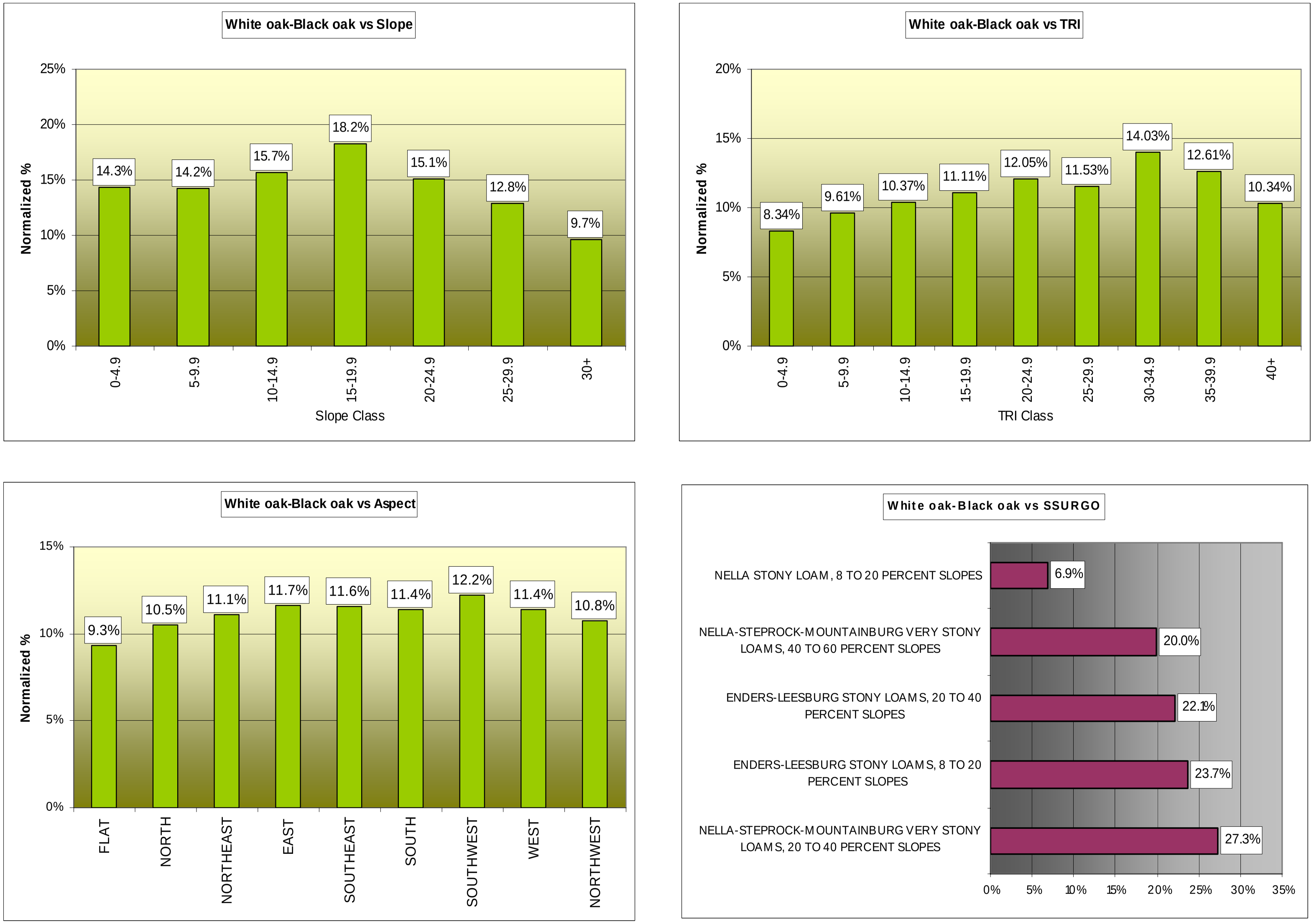


Figure 4.48. White oak-Black oak forest type site analysis.

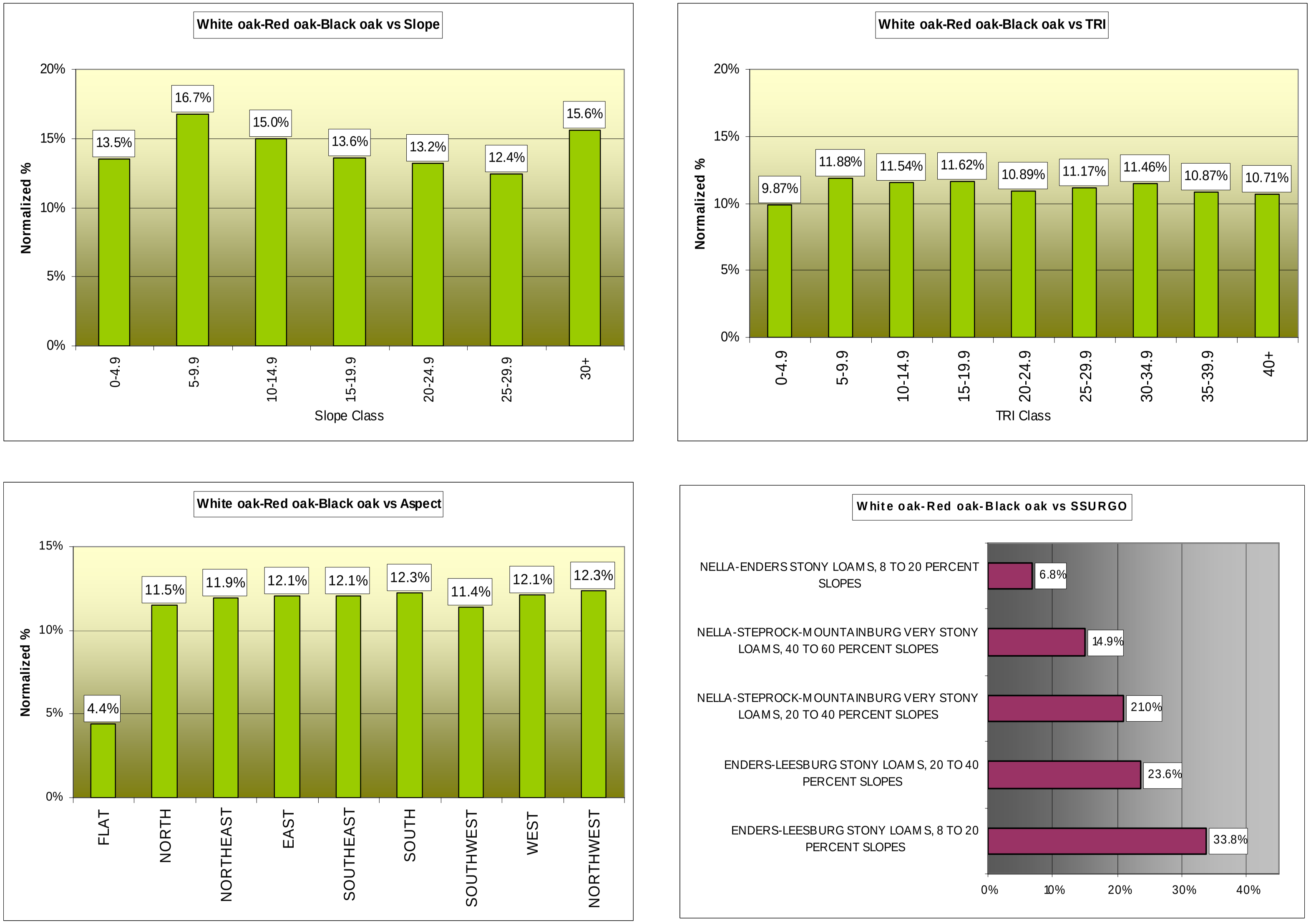


Figure 4.49. White oak-Red oak-Black oak forest type site analysis.

area to the northeast corner.

Further analysis shows that the white oak-red oak-black oak species association was found on sites with a mean slope of 10.8º and a mean TRI value of 15.2. This forest type showed a split distribution according to the classified slope values, with areas of 5-9.9º slope (16.7%) and areas of greater than 30º slope (15.6%) having the highest normalized distributions. Categorized TRI analysis shows a relatively even distribution, with the lowest TRI category of 0 to 5 having the lowest distribution with 9.9%, and all other classes ranging from 10.7% to 11.9%. Aspect analysis shows that flat sites (4.4%) were least likely to be occupied by this forest type. Directional aspects displayed an even distribution ranging from 11.4% for southwest facing slopes to 12.3% for northwest facing slopes. Analysis shows this forest type was primarily found on Enders-Leesburg stony loams with 8 to 40 percent slopes (57.4%).

Encompassing species with affinities towards fairly moist site conditions, the mesophytic oak species association (Figure 4.50) was the most widespread association, covering 38.5% of the study area. This association is dominated by white and black oak, but also includes such mesophytic species as red maple and American beech. While this forest type covered most of the southern townships, it also extended to the north where it was found in and adjacent to some of wide bottomlands.

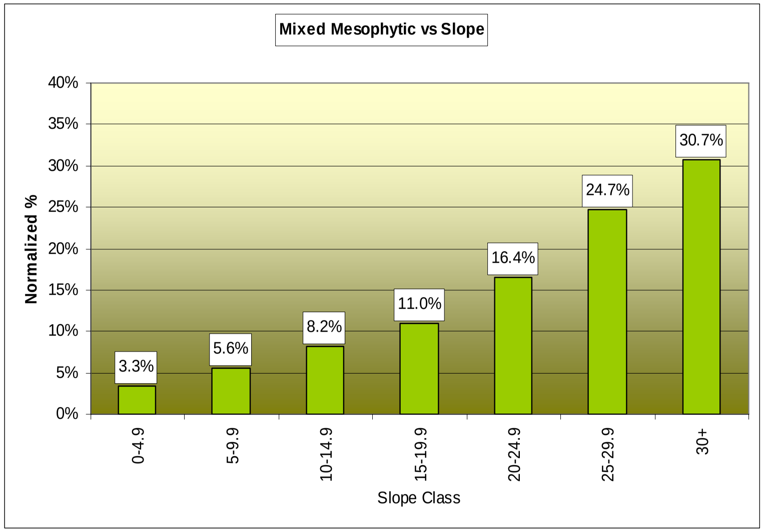
This forest type was found on sites with a mean slope of 11.8º and a mean TRI value of 15.9. Classified slope analysis shows this association fell most often on moderate slopes of 15 to 19.9º (17.2%) and 20 to 24.9º (16.8%). This forest type displays an affinity towards rugged areas with the two highest TRI classes, 35 to 39.9 and greater than 40, containing 25.3% of its normalized distribution. Like many other forest types,

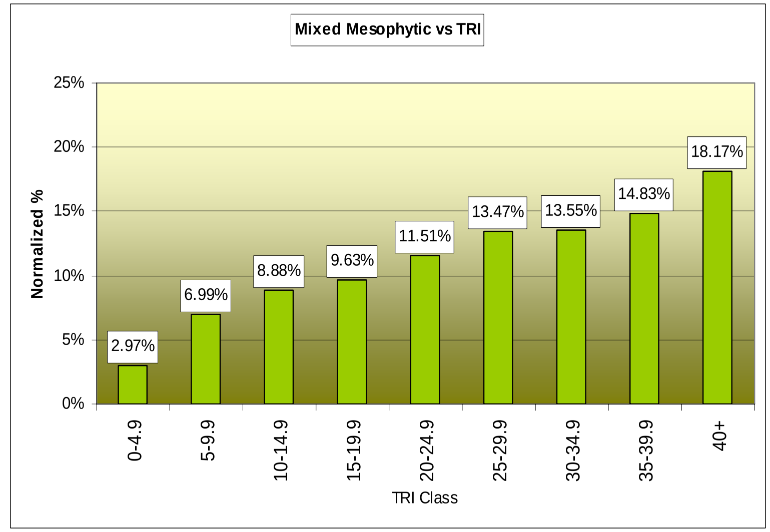
Figure 4.50. Mesophytic oak tree forest type site analysis.

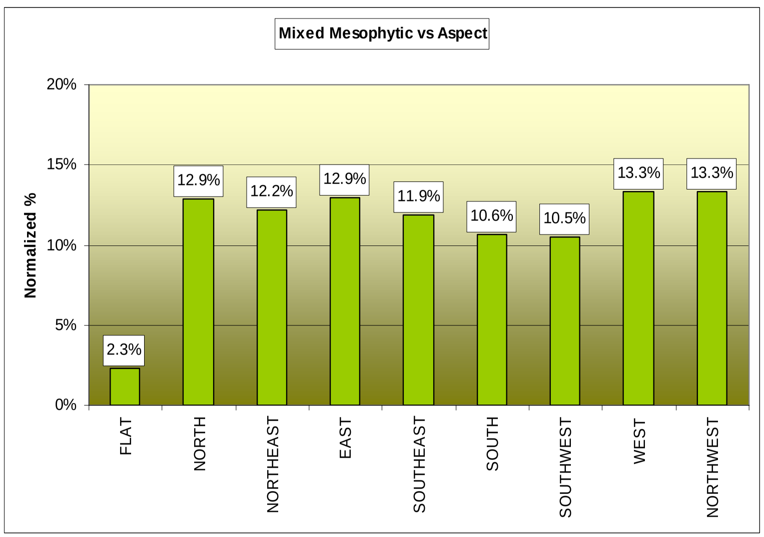
correlation to aspect found that flat areas were infrequently occupied (8.0%) by the mesophytic oak forest type. Directional aspect categories were evenly occupied, with northwest facing slopes containing 11.0% of this species association's distribution and southwest facing slopes having the highest normalized distribution at 12.2%. Analysis shows this species association most often on Nella-Steprock-Mountainburg very stony loams with 20 to 60 percent slopes (46.0%) and Enders-Leesburg stony loams with 8 to 40 percent slopes (44.3%).

The mixed mesophytic species association (Figure 4.51) contains the richest and most diverse mix of species of all the forest types identified. While this forest type was dominated by white oak and various hickory species, it contained numerous important canopy species such as Spanish oak, sugar maple, American beech, chinkapin, red oak and sweetgum. This tree species association covered 8.6% of the study area and had its largest extents in rugged parts of the eastern and southern portions of the study area. The distribution of the mixed mesophytic forest type was most effected by the prominent secondary extension running to the northeastern corner of the study area. Although it does fall in the western portions of the study area, this forest type has its largest distribution in the most rugged portions north of the primary axis and east of the secondary axis.

The mixed mesophytic forest type grew on areas with a mean slope of 14.6º and a mean TRI value 18.0. Analysis by slope category shows a clear preference for sites with steep slopes. Normalized distributions steadily increase from the lowest slope class of less than 5º with 3.3%, to the highest slope class of greater than 30º with 30.7%. Examination of distribution according to TRI classes shows a similar pattern with 3.0%







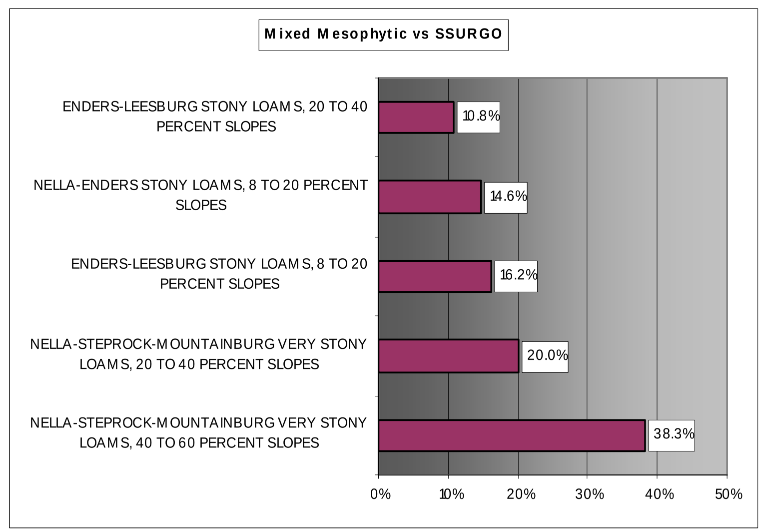


Figure 4.51. Mixed mesophytic forest type site analysis.

of this forest type's distribution falling on areas with a TRI value less than 5, and the greatest distribution of 18.2% found on sites with a TRI value of greater than 40. This species association grew most often on northwest (13.3%) and west (13.3%), east (12.9%) and north (12.9%) facing slopes. The mixed mesophytic forest type was primarily found on Nella-Steprock-Mountainburg very stony loams with 20 to 40 percent slopes (58.3%).

As mentioned above, the forest types deemed to be bottomland associations were found on less than 2% of the study area. Mapped distributions showed that all three bottomland species associations were restricted to bottomland sites, with the hackberry-elm-black oak association having the largest extent and the white oak-sycamore association with the smallest.

Because all three of these forest types were located almost exclusively on floodplain areas, they share very similar distribution patterns. All three forest types show clear preferences for low slope, topographically smooth, essentially flat land (Figures 4.52, 4.53 and 4.54). Mean slope values range from 2.0º for the hackberry-elm-black oak forest type to 2.8º for the white oak-sycamore forest type. Topographic roughness index values are also very similar, with areas occupied by the hackberry-elm-black oak association having a mean TRI value of 6.4 and the white oak-sycamore association occupying areas with a mean TRI value of 9.6. The elm bottomland association most often fell on Allen loam with 3 to 8 percent slopes (23.9%) and Arkana very cherty silt loam with 8 to 15 percent slope (24.5%). The white oak-sycamore association shows an affinity for frequently flooding Ceda cobbly fine sandy loam (25.3%) and Healing silt loam with 1 to 3 percent slope (20.7%). The hackberry-elm-black oak bottomland

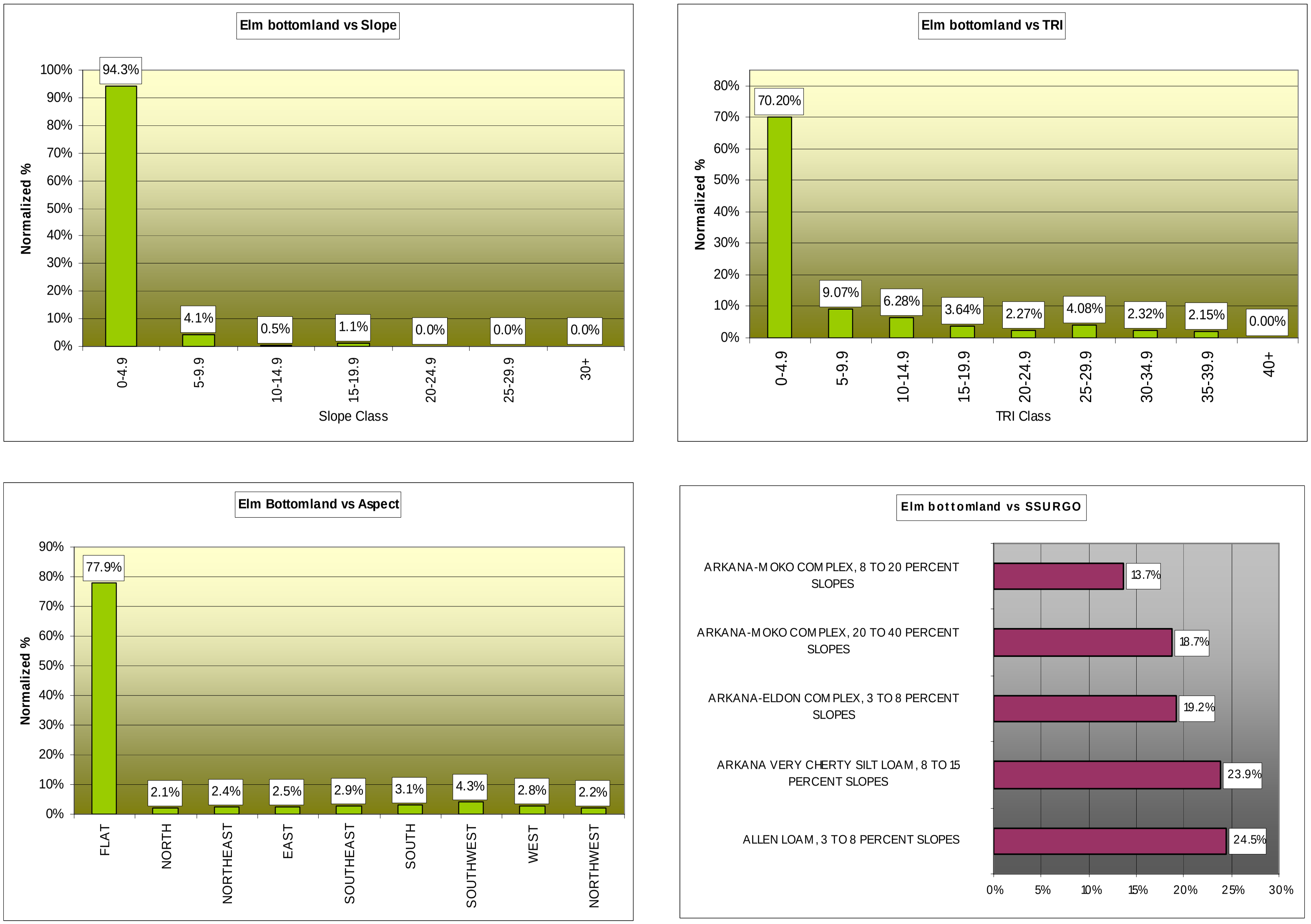


Figure 4.52. Elm bottomland forest type site analysis.

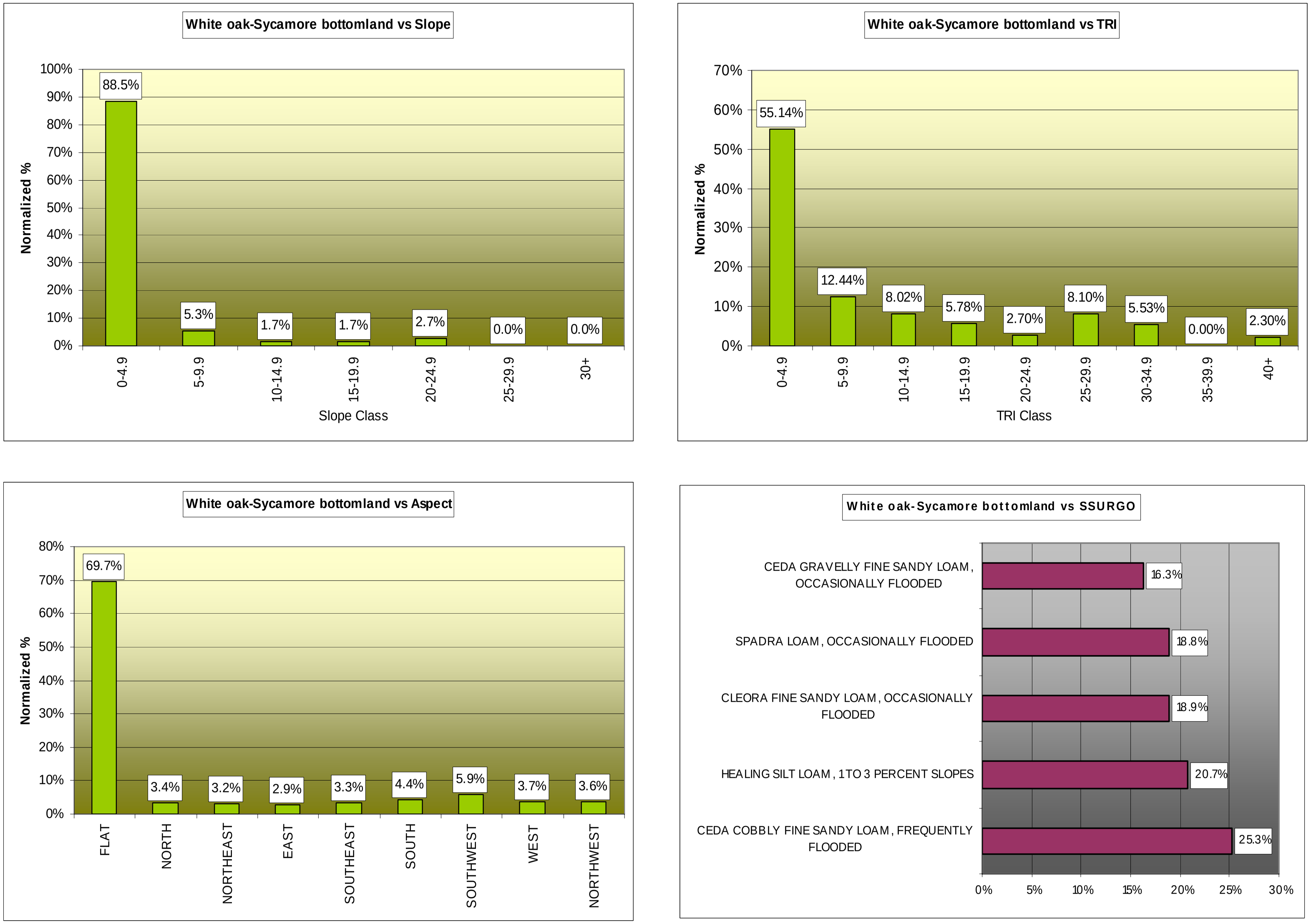


Figure 4.53. White oak-Sycamore bottomland forest type site analysis.

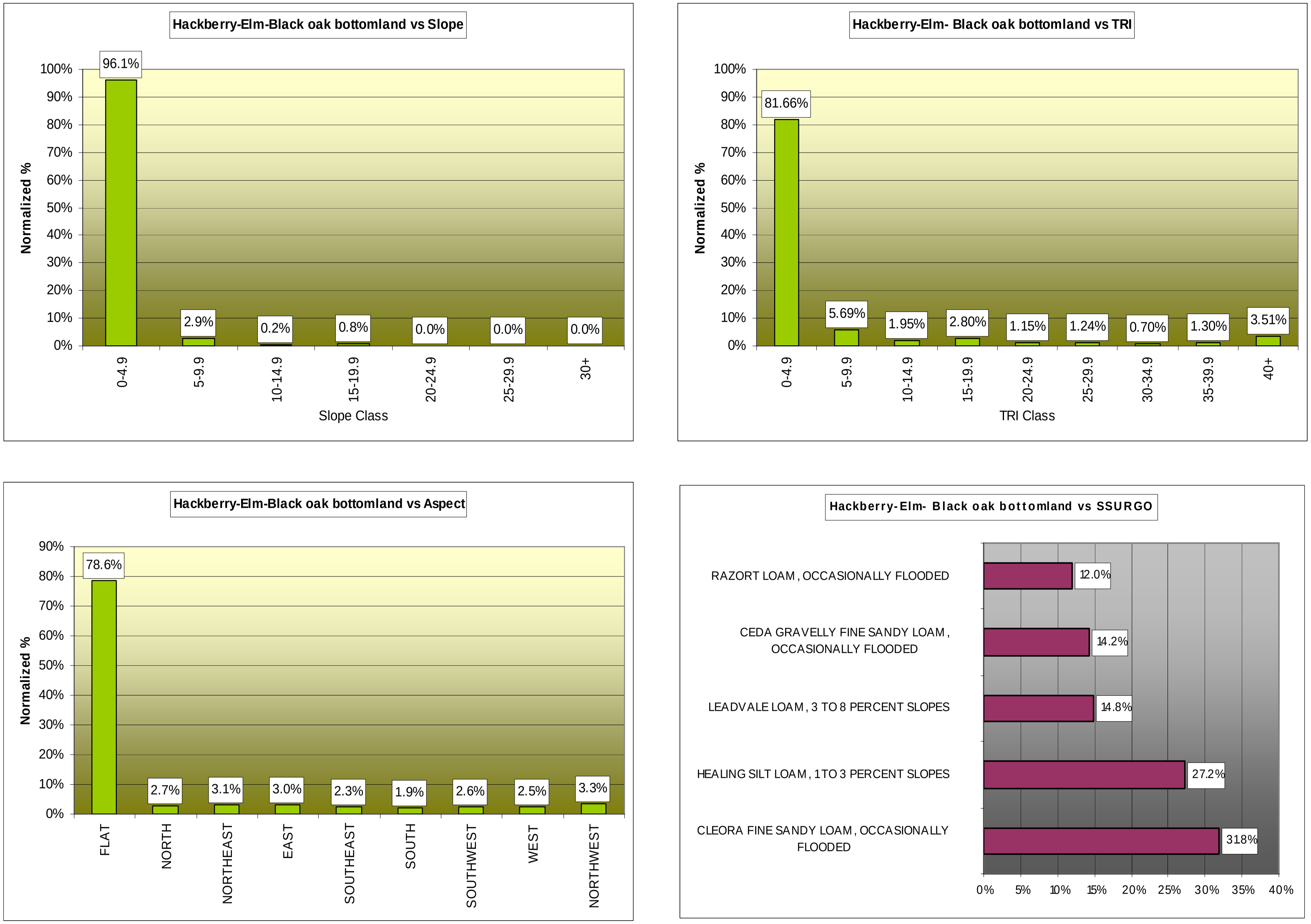


Figure 4.54. Hackberry-Elm-Black oak forest type site analysis.

species association was most commonly found on Cleora fine sandy loam that occasional floods (31.8%) and Healing silt loam with 1 to 3 percent slopes (27.2%). For specific results for each bottomland association's site preferences, please refer to their respective charts.

Summary of Vegetation Patterns

The woodlands landcover type, and was shown to be widespread and dispersed fairly regularly throughout the study area. The closed canopy forest landcover type was also distributed throughout the study area, with its largest continuous extents in the southwestern townships and its smallest extents in the northwestern corner. Open woodlands were spread throughout the study area, but were primarily found in the low hills of the northern townships. In more rugged central and southern portions of the study area, this landcover was also found on flat, elevated plateaus as well as on top of narrow ridges. Open landcover had the most restricted distribution within the study area, being primarily found in the northernmost townships.

Tree point and forest type distributions necessarily show correlated distributions throughout the study area. In the northwestern townships xerophytic species such as post oak and blackjack oak had their highest densities. Likewise, this portion of the study area was primarily covered by the xerophytic oak forest type. Red oak's conspicuous distribution in the center of the study area and along the secondary extension running to the northeast correlated with the dominance of the white oak-red oak-black oak tree species association. The white oak-black oak forest type was composed of two widespread species, but this specific forest type was identified along the edges of the study area: in the far western and southern portions of the study area.

The mesophytic oak species association was composed of a mix of relatively common oaks and hickories, as well as a constituent of more restricted mesophytic species, such as sugar maple and beech. This was shown to be the most widespread forest type, and was extensive in the fairly rugged, southern and eastern townships. The most diverse, mixed mesophytic species association was found in small patches throughout the southern portions of the study area, but had its largest extents in the highly dissected east-central townships. The extremely rugged topography found in these areas create optimal site conditions allowing a overlapping distributions of many species, including oak, hickory and elm species, as well as American beech, blackgum, sugar maple and sweetgum. All three bottomland forest types had very limited extents and were largely restricted to the broad floodplains located in the northern half of the study area. In these areas elms, hackberry, black walnut, and sycamore were common.

CHAPTER 5
DISCUSSION

The Influences of Site Conditions on Vegetation

In addition to characterizing the presettlement vegetation of the Boston Mountains, this project sought to understand how the topography of the region influenced the distribution, composition and structure of these forests. While visual patterns and quantitative analysis of general landcover allowed limited insights into the effects of topography, tree point and interpolated forest type distributions correlated strongly with physiography within the study area. This is most evident in the prominence of xerophytic species and forests types in the flatter, northern townships. In the rugged eastern and southern townships, forests contain a rich mixture of oaks and hickories, as well as more mesophytic species. The distributions of individual taxa and interpolated forest types indicate the compounding effects of site conditions due to the study area's varied topography. These environmental controls can be best explained at different scales.

Slope, aspect and topographic diversity affect conditions at both localized scales and regional scales. At a local scale, aspect influences temperature as well as exposure to light and wind, ultimately determining evaporation rates. This in turn affects air and soil moisture, decomposition of leaf litter and potentially the amount of organic matter in soils. Slope also affects solar intensity, and strongly influences soil moisture through variations in water drainage and run-off. These effects influence both canopy development and species composition by creating conditions that either restrict or promote forest growth and diversity.

The low hills and flat plateaus of the northern townships are typified by dry site conditions, resulting in sparse tree growth dominated by drought tolerant species. It is in this relatively flat, northern portion of the study area that open barrens and scrubland were most abundant. Moreover, this area was primarily occupied by the xerophytic forest types dominated by white oak, black oak and post oak. Conversely, parts of the study area with more topographic diversity provide site conditions optimal for tree grow, resulting in dense canopy development and overlapping distributions of numerous species. In the rugged eastern and southern townships, mesophytic species such as American beech and sugar maple and sweetgum have their highest frequencies. These species distributions coincide with the dominance of more mesophytic forest types.

At a regional scale, larger landforms can have a critical role in determining the extent and frequency of disturbance events. Within the study area, there is a secondary extension running from the central townships to the northeastern corner, which includes part of the Buffalo River valley (Figure 2.3). This secondary extension, as well as the primary east-to-west ridge, appear to hinder the spread of fires started in the prairies to the west and northwest. The Arkansas River Valley, located between the Boston Mountains and Ouachita Mountains, forms another important firebreak by halting fires spreading from the south. The combined effects of these features appear to result in regional firebreaks hindering the spread of fires as they are unable to burn down-slope and are potentially stopped as they reach the two river valleys.

These assumptions are supported by the dominance of species intolerant of shade, and tolerant of drought and fire in the exposed, northwestern townships. This area is dominated by white oak, black oak, post oak and blackjack oak, resulting in the prevalence of the white oak-black oak and xerophytic oak forest types. The effects of topography are more clearly seen in the extensive development of mesophytic oak and mixed mesophytic forests south of the main ridge and east of the secondary extension. These forest types are composed of many drought and fire intolerant species, some of which are primarily restricted to these protected areas of the study area. Moreover, the specific dominance of the mixed mesophytic forest type north of the main ridge and east of the secondary extension further highlights the combined effects of these two firebreaks on vegetation within the study area. This dominance of the mixed mesophytic species association identifies the portions of the study area where the highest number of mesophytic species, including ash, American beech, sweetgum and sugar maple, have overlapping distributions.

In addition to these physiographic effects, the presence of rich forest soils like those found in the southern Appalachians create conditions that allow for higher stem densities as well as numerous, overlapping tree species distributions. GIS analysis shows that both mesophytic oak and mixed mesophytic forest types are most commonly found on soils from the Nella, Enders, Leesburg, Steprock and Mountainburg series. Steprock soils, formed from residuum and colluvium weathered from sandstone, siltstone, and shale, are restricted to the Boston Mountains and Arkansas Valley and Ridges. Nella, Enders, Leesburg, and Mountainburg soil series are formed in residuum and colluvium of limestone, sandstone and shale. These four soils series have geographic extents that include both the Boston Mountains and the southern Appalachians, further highlighting similarities in environments found in these two physiographic regions (Soil Survey Staff 2006). Together, the findings of this study show that just as in the southern Appalachians, topographic and edaphic factors in the Boston Mountains combine to create site conditions enabling the development of dense, species-rich forests.

Black Oak and Red Oak Distributions

As discussed in Chapter 2, presettlement survey notes have been used with much success to reconstruct vegetation patterns prior to widespread European settlement. While GLO notes have been accepted as an important source of data that generally have high levels of fidelity, these records are not without their limitations. In addition to preferential selection of witness trees due to economic value, many studies have suggested that surveyors failed to correctly identify or differentiate tree species (Bourdo 1956, Cowell 1995, Manies and Mladenoff 2000, Schulte and Mladenoff 2001). Like other studies using GLO survey records as a source of data, the results of this study contained some patterns that could not be easily attributed to environmental factors, particularly the peculiar distributions of red oak and black oak.

Although many of the above patterns displayed in the survey records were confidently attributed to environmental factors, the peculiar distributions of northern red oak and black oak are not so easily explained. Throughout much of the study area, black oak was frequently recorded by surveyors, but is almost absent in the central and northeastern townships. In these townships, black oak seems to be replaced by red oak (Figure 5.1). While these patterns could be due to natural forces, they appear to have potentially artificial causes as well.

Of the townships in question, black oak and red oak are shown to be mutually exclusive in townships T. 15N R. 24W and T. 16N R. 22W; the former have interior section lines dominated by red oak and the latter dominated by black oak. These patterns

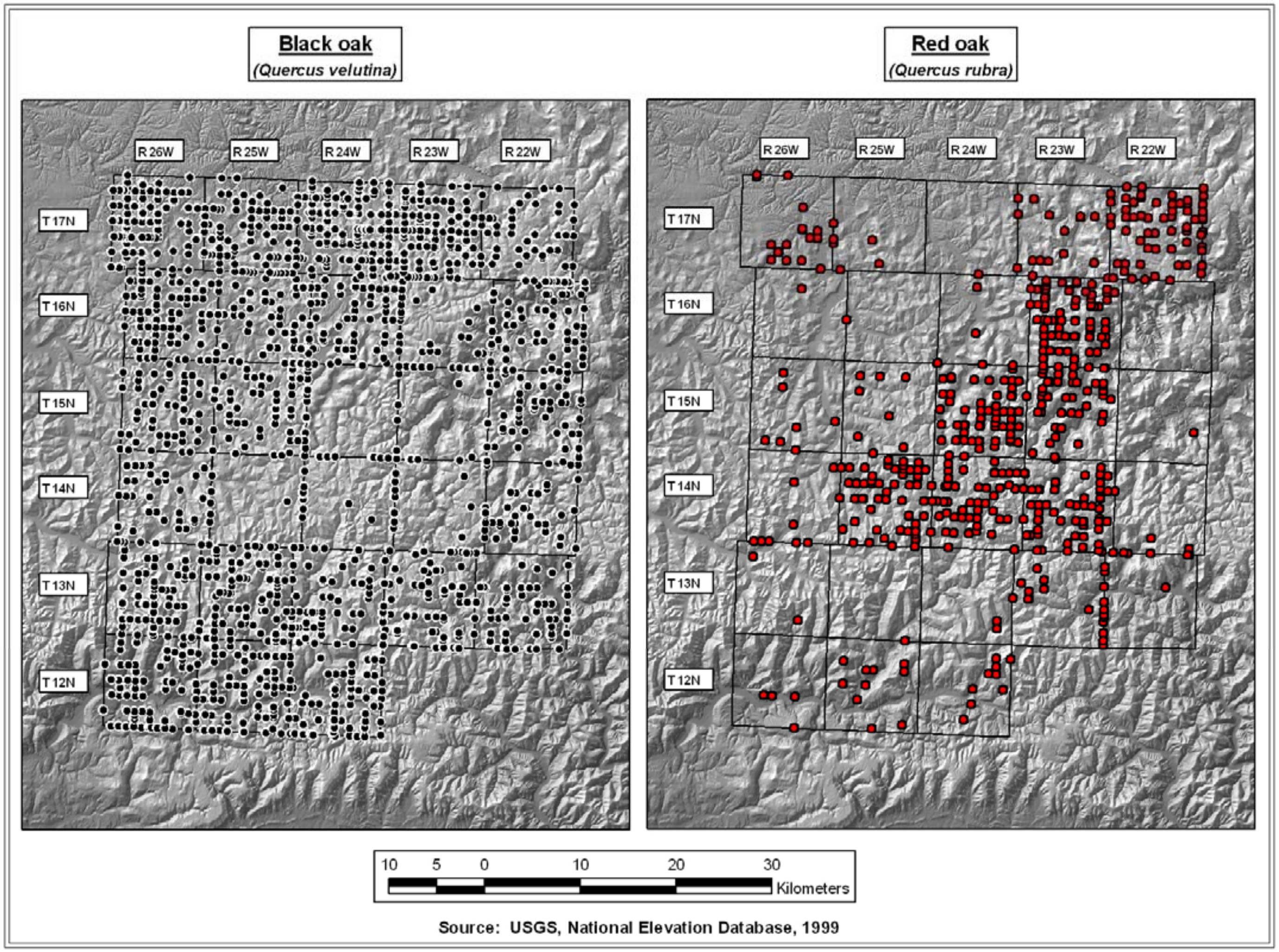


Figure 5.1. Distributions of red oak and black oak.

suggest possible misidentification of these species by surveyors. However, the two townships in question were surveyed by H.S. Lafferty and J.T. Houston, both of whom differentiated black oak and red oak stems in other townships (Figures 3.1 and 5.1). Another notable pattern was the higher densities of black oak stem along township lines than those of adjacent section lines. While the interior survey lines of T. 15N R. 24W had no black oak points, the surrounding township lines contained numerous black oak stems. These differences in black oak stem densities might be due to the township and section lines being surveyed by two separate individuals, I.M. Hudspeth and J.T. Houston respectively (Figures 3.1 and 5.1). While J.T. Houston did identify black oak stems along section lines in other portions of the study area, the densities displayed along township boundary lines surveyed by I.M. Hudspeth reflects a more regular distribution of this species. These densities are more fitting with the patterns found in the rest of the study area and may represent black oak's natural distribution.

The distributions of black oak and red oak shown in the survey records may be due to a misidentification of these species as well as Spanish oak. It is appears possible that some surveyors recorded Spanish oak, also known as southern red oak, as merely red oak. Moreover, surveyors might have confused all three species. Although their distributions do overlap throughout much of the study area, in some areas where red oak is infrequent or absent, Spanish oak is recorded in higher densities; and vice versa (Figures 4.15 and 4.19). Township T. 14N R. 23W was the only township within the study area surveyed by Jno. S. Houston and had no recorded Spanish oak stems along section lines (Figure 3.1). Because interior portions of adjacent townships did have a significant number of Spanish oak records, it may indicate that this surveyor failed to differentiate between these different red oak species. In addition, many of the townships were surveyed during winter times, possibly confounding differentiation between black oak, red oak and Spanish oak stems. These patterns possibly show that that there was some level of misidentification between these tree oak species, potentially leading to the peculiar distributions of red oak and black oak in the study area.

Cowell (1995) noted a similar phenomenon in black oak and red oak distributions in survey records for a portion of the Georgia piedmont. There too, mapped distributions of red and black oak showed little overlapping between the two species, despite comparable site preferences. In that study, the author concluded the patterns were due to surveyors failing to discriminate between the two species. While surveyor error seems to be a possible explanation, it is possible misidentification of black oak, red oak and Spanish oak all may have been involved in the resulting patterns.

Mixed Mesophytic Forests in the Boston Mountains

The primary impetus for this project was Braun's (1950) recording of species-rich forests within the Boston Mountains that she described as mixed mesophytic relics. She was struck by the southern Appalachian character of the composition and structure of forests found in two deep ravines; one near Ponca in Newton County, and another near Cass in Franklin County (Table 5.1). In both valleys, Braun noted the unique mix of species that occurred along protected north-facing slopes. While ridgetops were occupied by oak-hickory forests typical of the Ozarks, mid and lower slopes had a mix of oaks, hickories and more mesophytic species including American beech, sugar maple, northern red oak, southern red oak, white oak, American basswood, sweetgum, walnut, blackgum,

Table 5.1. Species composition of a ravine near Cass, Franklin County, Arkansas (Braun 1950).

Species	Common name	Percent Composition
Fagus grandifolia	American beech	63.4
Quercus rubra	Northern red oak	9.9
Quercus alba	White oak	8.4
Liquidambar styraciflua	Sweetgum	7.0
Nyssa sylvatica	Blackgum	5.6
Ulmus alata	Winged elm	2.8
Ulmus americana	American elm	1.4
Tilia americana	American basswood	1.4

white ash, as well as various elm species. Braun particularly described the dominance of beech and sweetgum on the lower slopes, but also noted that these species are important constituents of the upslope forests, just as in the Appalachians. Furthermore, Braun emphasized the presence of disjunct eastern species such as cucumbertree (*Magnolia acuminata*) and umbrella magnolia (*Magnolia tripetala*) as well as an Ozark chinkapin (*Castanea ozarkensis*) which is a chestnut species endemic to the region.

In addition to Braun, other authors have documented the composition of mixed mesophytic forests in the Boston Mountains. Turner's (1935) article on forests types of the Boston Mountains classified a species association comparable to Braun's mixed mesophytic forests as the White oak-Red oak-Red maple-Hard maple-Hickory association. He noted its rich but variable species composition that was often dominated by white oak, northern red oak, sugar maple, red maple and shagbark hickory. In all, Turner recorded a total of twenty-five important canopy species including black walnut, Ozark chinkapin, cucumber magnolia and American beech (Table 5.2). In his study, he described this forest type as falling primarily on "north, east and west facing mountain slopes, ravines, gullies or narrow valleys" but also on "deep, narrow south facing gullies or ravines" and "the bottoms of valleys of small mountain streams." He also noted that it was "associated with superior soil and soil moisture conditions, not with excessive but with adequate drainage" (Turner 1935).

Thompson (1975, 1977) studied the composition of forests in Lost Valley located two miles southwest of Ponca, Newton County; probably the same valley near Ponca that Braun (1950) wrote about. Generally oriented southeast, the valley floor starts at 320 meters and bluffs and slopes reach over 550 meters in elevation. Thompson identified

Table 5.2. Composition of the White oak-Red oak-Red maple-Hard maple-Hickory association (Turner 1935).

Frequency	Species	Common name
Dominant	*Quercus alba*	White oak
	Quercus rubra	Northern red oak
	Acer saccharum	Sugar maple
	Acer rubrum	Red maple
	Carya ovata	Shagbark hickory
"Very common"	*Carya tomentosa*	Mockernut hickory
	Carya cordiformis	Bitternut hickory
	Ulmus americana	American elm
	Ulmus rubra	Red elm
	Fraxinus americana	White ash
	Juglans nigra	Black walnut
"Fairly common"	*Tilia* spp.	Tilia spp.?
	Castanea ozarkensis	Ozark chinkapin
	Nyssa sylvatica	Blackgum
	Prunus serotina	Black cherry
"Less common"	*Fraxinus pennsylvanica*	Green ash
	Liquidambar styraciflua	Sweetgum
	Gymnnocladus dioicus	Kentucky coffeetree
	Platinus occidentalis	Sycamore
	Gleditsia tricanthos	Honeylocust
	Fagus grandifolia	American beech
	Magnolia acuminata	Cucumber magnolia
	Cladastris kentukea	Yellowwood
	Aesculus glabra	Ohio buckeye
	Juglans cinera	Butternut

the richest vegetation type found in “deep ravines, coves and [the] alluvial valley floor” specifically as mixed mesophytic; which he related to Turner’s (1935) White oak-Red oak-Red maple-Hard maple-Hickory species association. Thompson (1975; Table 5.3) listed the important canopy species of the mixed mesophytic forest association as American beech, sugar maple, cucumber magnolia, northern red oak, mockernut hickory, blackgum, sweetgum, white oak, chinkapin oak and white ash. He noted other important hardwood species canopy status as including shagbark hickory, American basswood, Kentucky coffeetree, bitternut hickory, red elm, sassafras and black locust.

While the records of Turner, Braun and Thompson entail a finer scale analysis of mesophytic species associations in the Boston Mountains, their in-situ observations are reflected in the composition of the mixed mesophytic forest type identified in this study of presettlement forests. Just as in these three previous studies, the findings of this project show the important role of oak and hickory species in the landscape, but most importantly they emphasize the significant mesophytic composition of forests located in protected slopes and coves in the Boston Mountains. As with Braun’s (1950) records, the upslope positions of such mesophytic species as American beech, sugar maple, sweetgum and blackgum is shown in all four information sources to be an identifying characteristic of these forests. Braun considered this mingling of typically bottomland or strongly mesophytic species with regionally dominant upland species very evocative of Appalachian mesophytic forests. While survey records only noted them in small numbers, the presence of Appalachian outliers such as black locust and cucumber magnolia serve to further highlight the disjunct character of presettlement forests the study area. The similarities in the findings of this study and the literature discussed

Table 5.3. Composition of the Mixed Mesophytic hardwood forest type in Lost Valley, Newton County, Arkansas (Thompson 1975).

Frequency	Species	Common name
Canopy dominants	*Fagus grandifolia*	American beech
	Acer saccharum	Sugar maple
	Magnolia acuminata	Cucumber magnolia
	Quercus rubra	Northern red oak
	Carya tomentosa	Mockernut hickory
	Nyssa sylvatica	Blackgum
	Liquidambar styraciflua	Sweetgum
	Quercus alba	White oak
	Quercus muehlenbergii	Chinkapin oak
	Fraxinus americana	White ash
Other Canopy spp.	*Carya ovata*	Shagbark hickory
	Tilia americana	American basswood
	Gymnocladus dioicus	Kentucky coffeetree
	Carya cordiformis	Bitternut hickory
	Ulmus rubra	Red elm
	Sassafras albidum	Sassafras
	Robinea pseudoacacia	Black locust

above provide clear evidence of presettlement forests within the Boston Mountains displaying the same Appalachian character that eventually lead Braun to label them as mixed mesophytic.

Most recently, Foti (2004) used GLO survey notes to identify the regional distribution of oak forests, pine forests, barrens and prairies within subsections of the Boston Mountains. This study only used witness and line tree points along north to south transects. In this larger scale analysis oaks and hickories comprised 78.9% of the total stems recorded, highlighting the dominance of these regionally typical species within the region. He identified mesophytic species at low densities: maples, elms, sweetgum and beech only accounted for 4.7% of the total tree points entered. Just as in this study, Foti identified the extensive tree growth of the Boston Mountains; with closed canopy forests and open forests covering 38% and 25% of the study area respectively.

Discusion of the Term "Mixed Mesophytic"

While the mixed mesophytic forest type interpolated from the presettlement survey notes resembles Braun's description of mixed mesophytic forests in the Boston Mountains, the label of mixed mesophytic is itself a topic of debate. This term was coined by Braun and was first used in her 1916 publication "The Physiographic Ecology of the Cincinnati Region." Although a widely used term, identifying its defining characteristics is a challenge. While Braun used this term to refer to a specific tree species association, the term mixed mesophytic has often been used in different and inconsistent ways (Braun 1916, Braun 1950, Parker 1987, Runkle 1996, Greenberg, McLeod and Loftis 1997, Leopold, McComb and Muller 1998, McCarthy, Small and

Rubino 2001). Though authors sometimes discuss environmental factors supporting the development of mixed mesophytic forests such as diverse topography, rich soils, and north facing slopes, it is most often the presence of certain tree species that is used to characterize this forest type. Mixed mesophytic forests are typically described as being composed of 20 to 30 canopy species, with no species displaying consistent dominance. Furthermore, in studies of eastern forests white basswood (*Tilia heterophylla*) and yellow buckeye (*Aesculus octandra*) are often identified as the most important indicator species of this forest type (Braun 1950, Greenberg, McLeod and Loftis 1997, Leopold, McComb and Muller 1998).

In Braun's (1950) own discussion of mixed mesophytic characteristics, she urged a stricter application of the term, but failed to clearly delineate a list of defining characteristics. In fact, she stated that "[b]ecause of the large number of dominants of this climax, the composition and relative abundance of the dominants vary greatly from place to place" (Braun 1950). In addition to focusing heavily on the compositional characteristics of forest types, Braun often discussed links between the development and geology of different physiographic provinces and their natural vegetation (Braun 1916, 1947, 1950).

What most confounds a standardized characterization of mixed mesophytic forests are the contentious and simply outdated principles on which Braun initially developed the concept. In reading her works, it is clear that Braun (1935, 1947, 1950) was strongly influenced by contemporary views in geomorphology and physiography, most likely due in large part to her own background in geology (in which she received her master’s degree). During the century prior to Braun’s 1950 publication *Deciduous*

Forests of Eastern North America, the field of geomorphology had risen to a place of considerable influence within geography and ecology.

Publications such as W. M. Davis' (1899) article "The Geographical Cycle," aligned geomorphology to the positivist, uniforminatarianist movements of the day, made popular by Darwin's (1859) theory of evolution. Davis' cyclical theory of landform development, through which it was though all landforms were transformed, involved the uplifting of a penneplain and its progressive dissection and erosion until it was returned to its original state of elevation and flat topography. Throughout her many works Braun (1935, 1947, 1950) extensively referenced concepts and terms from Davisian geomorphology.

These concepts pervaded early 20th century ecology, in which succession was seen as a similar process of predictable stages leading to a climax formation or terminal state (Clements 1936). The cyclic, Davisian view of landform development and the progressive, Clementsian view of vegetative succession were unified under one overarching theory proposed by Cowles (1911) and cited by Braun (1950, p 12.). This theory, which involved the interplay between climate, physiography and vegetation over time to effect an area's climax formation, ultimately appears to be the basis of Braun's classifications.

Although she did recognize that the static records contained in *Deciduous Forests of Eastern North America* do not reflect the dynamic nature of forests, Braun (1950) interprets vegetation dynamics through the use of Davisian and Clementsian climax theory. Clements' theory suggested that organisms composing a community are so tightly bound together that they essentially form a superorganism. This superorganism concept maximizes the effects of the collective and minimizes the effects of the individual organisms that comprise a community (Clements 1936).

The view more widely accepted today, originally developed by Gleason (1926), accentuates the independence of species within the community. In contrast to Clementsian ecology, this theory emphasizes the influence of continuously varying spatial and temporal conditions inherent in the natural landscape, rather than stability and uniformity. Whittaker provides an alternative view of mixed mesophytic forests more in line with Gleason. In his article "Vegetation of the Great Smoky Mountains" Whittaker (1956) described mixed mesophytic forests as occupying the transitional zone between “mesic oak forests” and “truly mesophytic cove forests,” dominated almost entirely by mesophytic species such as *Acer saccharum*, *Tilia heterophylla*, *Aesculus octandra* and *Fagus grandifolia*, rather than as a specific tree species association. Furthermore, he specifically notes that it is because of the transitional nature of mixed mesophytic forests that they contain such high levels of species diversity.

Within his article, Whitakker criticizes Braun's term mixed mesophytic because it "seems too broad and heterogeneous a grouping," and that "the Mixed Mesophytic in Braun's sense seems less a definable vegetation type than a range of stand conditions" (Whittaker 1956). Whittaker's idea of mixed mesophytic forest growth is not based primarily on species composition like Braun, but rather on the environmental variations and gradients in site conditions that cause the intermixing of more definable forest types.

In addition to referencing Davis’ views on landform development and Clements’ views on vegetative succession, Braun (1950) also relies heavily on the concept of glacial refugia in order to identify the unique character of mixed mesophytic forests, both in the southern Appalachians and the Boston Mountains. This theory attempts to explain the effects of glaciation and climate change over geologic time-scales, on tree species migration and contemporary forests patterns. The glacial refugia concept holds that certain mountainous regions of eastern North America, such as the southern Appalachians, had been continuously available for habitation through Quaternary glacial cycles. Pioneered by E.W. Berry (1914), the theory of glacial refugia was applied to an analysis of hardwood cove forests in the Smoky Mountains in an article published by Cain in 1943. Cain proposed that areas of glacial refugia, such as the southern Appalachians, contained remnants of the ancient, rich Arcto-Tertiary forest.

Just as Cain took many of the concepts developed in Berry's publications, Braun used many of the conclusions drawn by Cain to describe the formation of the deciduous forest regions of eastern North America. Braun believed that from these points of glacial refugia, most tree species dispersed across much of eastern North America to form contemporary forest patterns (Cain 1943, Braun 1947, 1950). It was the evidence of similar geologic histories, as well as the presence of tree species considered tertiary relics and eastern disjuncts, that led Braun (1950) to believe that the rich forests of the Boston Mountains were not only similar to mixed mesophytic forests of the Appalachians, but that they were indeed related as glacial refugia.

The characteristics Braun generally used to indicate the ecological importance and distinctive nature of mixed mesophytic forests of the southern Appalachians include high levels of species diversity, the presence of species with some level of endemicity and a unique stand structure. While these characteristics are found in the diverse forests of the Boston Mountains, they are present at reduced levels. By Braun's own definition, these decreased levels of diversity and complexity weaken the contention that rich forests found in the Boston Mountains are truly mixed mesophytic. Characterizing these forests from a more contemporary standpoint by applying the concepts proposed by Whitakker (1956) highlight their similarities to southern Appalachian mixed mesophytic forests. While mixed mesophytic forests within the Boston Mountains do have high levels of species diversity, they do not display the specific composition Braun described in the southern Appalachians. However, the factors behind the development of these forests are similar in the both regions.

The forests recorded by Turner (1935), Braun (1950) and Thompson (1975) all display tree species diversity atypical of the greater Ozark Plateau, and especially unique within the oak-hickory forest region. Although oak and hickory species dominate the study area as a whole, heterogeneity of site conditions within the Boston Mountains diverse topography counteracts the prevailing climate enough to enable mesophytic species to extend upslope to intermingle with xerophytic upland species; just as in the southern Appalachians.

In addition to localized site conditions, analysis indicates landforms within the area play a key role in minimizing fire frequencies in certain parts of the study area. The dominance of mixed mesophytic forests in the east-central townships is the strongest evidence of these regional firebreaks. It is in this area that the combined influences of physiography not only create site conditions required for the growth mesophytic species, but also for the reduced levels of disturbance required to allow these rich forests to develop and persist.

CHAPTER 6
CONCLUSIONS

The primary purpose of this research was to reconstruct the presettlement land cover and tree associations of a portion of the Boston Mountains. It was thought that by analyzing the distribution of landcover and forest types, as well as individual tree species distributions, it would be possible to better understand the factors behind forest development in the region; especially the species-rich mixed mesophytic forests recorded by Lucy Braun (1950).

This project entailed the digitization of 28 townships of General Land Office surveys into a Geographic Information System for the purposes of interpolation and analysis. Within the study area, this survey data mapped landcover types and eight tree species associations. These patterns, as well as distributions of 19 selected tree species and taxa, were then correlated to several environmental factors, including topography and soil type.

Results show that over 75% of the study area was covered by woodlands and closed-canopy forests. Flatter portions of the study area contained xerophytic oak-hickory forests presumably common in much of the Greater Ozarks. Within more rugged portions of the study area, forests were found to have a composition strikingly similar to the relic mixed mesophytic forests noted by Braun (1950). These forests displayed a composition and structure more akin to eastern forests, with oaks and hickories occupying upland sites alongside mesophytic species such as sugar maple, American beech and sweetgum. Supported by the conditions afforded by more mesic site conditions and decreased levels of disturbance than the surrounding landscape, the presence of such rich forests can be strongly correlated to the significant topographic diversity found in the Boston Mountains.

The similarities between the forest patterns resolved from the survey data, Braun's own notes regarding disjunct mesophytic forests in the Boston Mountains, and descriptions of mixed mesophytic forests found in the Appalachians is of significance for further research. Although the overall distribution of mixed mesophytic forests is patchy in the presettlement landscape of the Boston Mountains, their mere presence is significant. While this study only contains a small insight into the presence of such species-rich forests in the area, the findings support the need of more extensive research to determine their historical as well as present distributions.

The forests patterns of the Boston Mountains require further study to better understand them but also to potentially more effectively manage them. Over two separate field investigations into the distribution of mixed mesophytic forests, it was clear to the author that region's present forests are drastically different from those recorded by surveyors in the early nineteenth century, as well as those studied by Lucy Braun 100 years later. Over the last 150 years, forests in the Boston Mountains have been extensively logged and their current structure and composition reflect these anthropogenic impacts (Strausberg and Hough 1997, Guldin 2001). The findings of this project offer some insight into the natural extent of mesophytic forests, as well as what is assumed to be the limited role of disturbance in the development and persistence of such forests. If land managers desire to reflect the natural, presettlement patterns identified in this study, it may be necessary to adjust management techniques and harvesting rotations.

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