ABSTRACT

Title: HISTORICAL AND COMPUTATIONAL ANALYSIS OF LONG-TERM ENVIRONMENTAL CHANGE: FORESTS IN THE SHENANDOAH VALLEY OF VIRGINIA

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The increase and decrease of forests is a major factor of land cover change. This study of forest change in the Shenandoah Valley builds upon the rich historiography of the region through the analysis of generalized and spatially explicit primary and secondary sources covering the period of 1700 to 2000. Combining geo-historical and geo-computational approaches produced a more robust picture of land cover change than would be possible using only one method. Comparing modern and historical reports on the timing of forest clearance and re-growth revealed that a discrepancy existed between the spatially explicit sources and existing historical interpretations regarding the timing and location of forest clearance and re-growth. Understanding this discrepancy is important for the interpretation of forest change and its implications in the Shenandoah Valley and beyond.

Two main aspects of the study are the thorough interrogation and comparison of different data sources, and the subsequent analysis and interpretation of the data. Historic maps (1864, 1906, and c. 1945) and digital data sets derived from remotely sensed images (c. 1974 and c. 1992) were analyzed in a geographic information system (GIS) and compared to agricultural census data and published reports of land use and land cover change. Three major findings came out of this study. First, the spatially explicit sources produced values for the amount of cleared area that were within 0.5 to 2.7% of the same information derived from the agricultural census. Second, the maximum amount of forest clearance occurred 25 – 50 years later than existing published reports indicated. Third, the commonly held explanations of federal land acquisition and the abandonment of farms on steep slopes did not account for the observed patterns of forest re-growth. The documented variations in spatial and temporal patterns and reasons for the variations have impacts on our understanding of cultural and physical processes that took place in the region.

Keywords: deforestation, reforestation, land use change, geographic information systems (GIS), Shenandoah Valley

HISTORICAL AND COMPUTATIONAL ANALYSIS OF LONG-TERM ENVIRONMENTAL CHANGE: FORESTS IN THE SHENANDOAH VALLEY OF VIRGINIA

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Dedication

For my wife Lisa, my sons Wyatt and Julian,

and my parents, Mack and Nancy

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Chapter 1: Introduction

“This Neighborhood is covered with Pine; finely
watered with Branches of the Shanadore; & the Land I
am told, & by Appearance, is fertile.”
Philip Vickers Fithian, while visiting the Mossy Creek
community in the North River watershed on February
8, 1776 (Philip Vickers Fithian 1934, p. 180)

Why Study Forest Clearance and Re-Growth?

The timing, extent, and impact of forest clearance and re-growth have been studied because of their importance to many issues including timber supply, sedimentation of water bodies, carbon sequestration, climate, biodiversity, and landscape ecology (Greeley 1925; Cooper 1995; Bonan 1999; Houghton 1999; Sarmiento and Wofsy 1999, p. III; Schuler and Gillespie 2000;Hall et al. 2002). With the continued interest in long-term local to global assessments of landscape change (see Sarmiento and Wofsy 1999; Committee on Grand Challenges in Environmental Sciences National Research Council 2001; McMahon et al. 2005), a need has arisen to determine if there are “… significant variations in local to regional to continental patterns of landscape change and the communities and cultures residing in those lands” (Crews-Meyer 2002 p. 3). In addition, methodological issues about validating analysis conducted with varying types and amounts of sources and comparing studies “across scales, geographic areas and cultures, and methodological approaches” have been raised (Crews-Meyer 2002 p. 3). Because of the lack of useable, spatially explicit information for many areas, attempts to understand what has happened in a particular location over time often depend on the use of regional (multi-state) studies conducted with coarse grained or proxy information or trying to link local (county level) studies in other areas to the new study area. This case study seeks to overcome these limitations to determine the timing, extent, and other characteristics of forest clearance and re-growth in the North River watershed.

Case Study: The North River Watershed

Watersheds have been identified as an appropriate landscape unit to study human – environment interactions (Aspinall and Pearson 2000) and the North River watershed is a useful location to study the dynamics of forest change. North River is part of the headwaters of the South Fork of the Shenandoah River and flows into the Potomac River which drains into the Chesapeake Bay, making it part of the Chesapeake Bay watershed. The watershed has a relatively short history (approx. 300 years) of intense human alteration to the landscape, presently contains urban and rural areas as well as public and private lands, and straddles the border between Augusta and Rockingham Counties in Virginia, (Figure 1). In addition, the watershed is in the ridge and valley physiographic province and contains mountainous areas as well as parts of the floor of the Shenandoah Valley (Thelin and Pike c.1991).

Agriculture has been a significant part of the regional economy since European colonization in the early eighteenth century and has been identified as a significant driver of change in the conversion of forested landscapes to open landscapes (Mitchell 1977; Williams 1989). The Shenandoah Valley was called the “breadbasket of the Confederacy” and in 1997 Augusta and Rockingham Counties were rated as the top two agricultural counties in Virginia based on cash receipts (Heatwole 1998; Virginia Agricultural Statistics Service c.2000). Agricultural

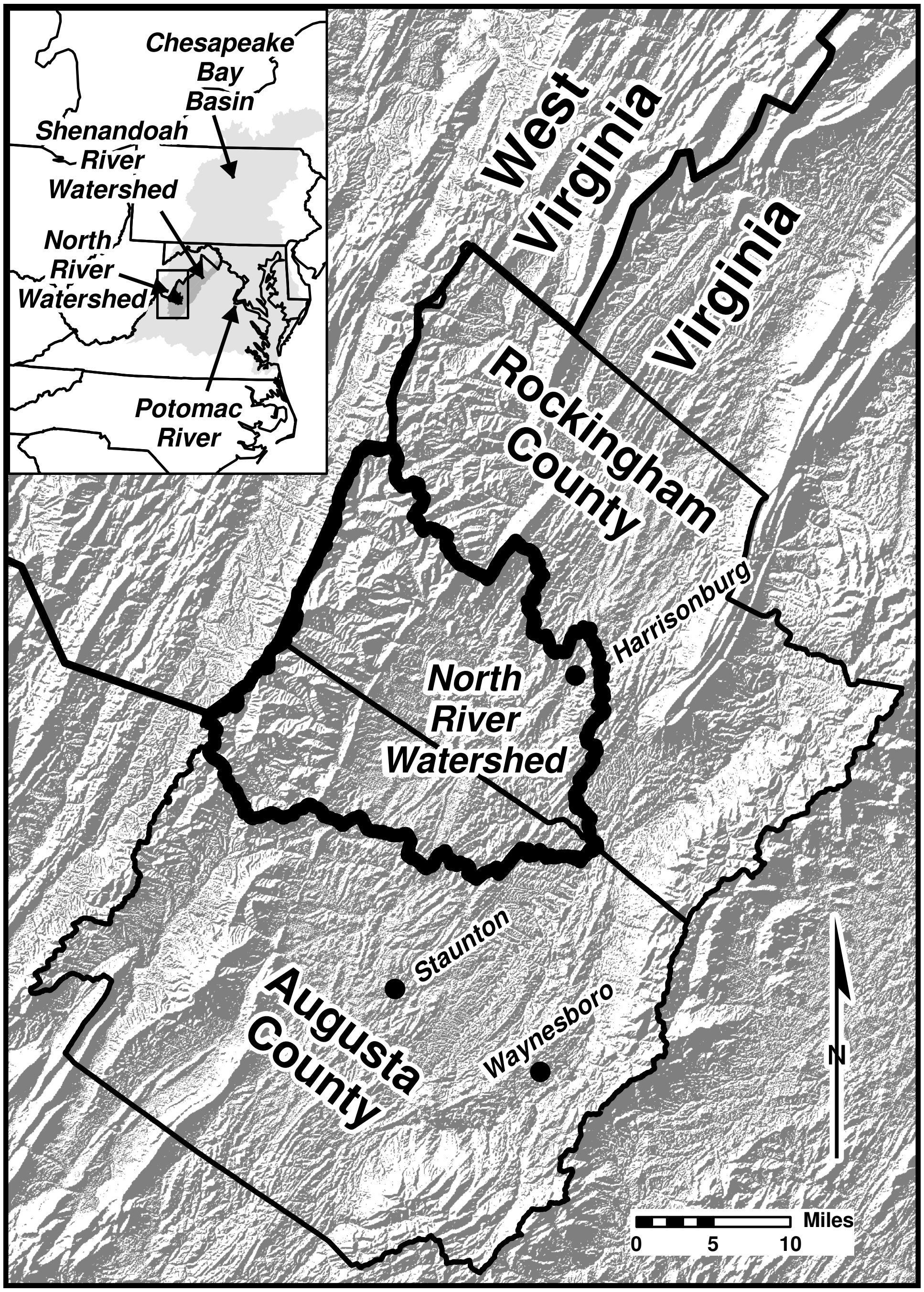

Figure 1: Location of the North River Watershed in the Shenandoah Valley of Virginia.

The North River is part of the headwaters of the Shenandoah River, which flows into the Potomac River and then the Chesapeake Bay. *Source*: (Virginia Dept. of Conservation and Recreation 1995; Chesapeake Bay Program 1999a, 1999b; United States Geological Survey 2004c, 2004a)

activities in the region have been identified as a contributor to water quality problems for the Chesapeake Bay (Preston and Brakebill 1999) and the U.S. Environmental

Protection Agency has classified the South Fork of the Shenandoah River watershed as having more than 25% of its water miles impaired, the highest category of impairment in its national assessment (United States Environmental Protection Agency 2000).

Other human activities that stem from direct exploitation of forest resources that affected the watershed include the charcoal iron industry, which was active during the eighteenth and nineteenth centuries, and the extensive exploitation of the forests in the western and mountainous portion of the watershed during the late nineteenth and early twentieth centuries for timber production and tan-bark harvesting. Conservation efforts have also been a part of the area's history. In the early twentieth century, perceptions of over exploitation and poor land use practices lead to the creation of Shenandoah National Park and Shenandoah National Forest (now known as the George Washington and Jefferson National Forest) to preserve and restore the natural beauty (Reich 2001). It should be noted that recent scholarship has called into question the degree to which portrayals of the region's residents and their activities were accurate (Horning 2000).

Much of what we currently know about forest clearance and land use in the area comes from historical and modern regional data and studies of agriculture, local case studies in other physiographic provinces such as the coastal plain, and from the analysis of sediment cores obtained in the Chesapeake Bay (see for example Hart 1968; Brush 2001; Earle and Hoffman 2001; Walsh 2001). Preliminary comparisons of forest clearance and re-growth information for the Eastern United States, Virginia, and the Upper Shenandoah Valley of Virginia indicate that regional patterns do not appear to hold true for the North River watershed and the counties that contain it. The specifics of these differences are examined with the analysis of the data in Chapter 4.

Approaches

Two approaches geographers have used to study human – environment relationships have been through historical (hereafter referred to as geo-historical) and computational (hereafter referred to as geo-computational) studies. While these approaches are not necessarily independent or at odds with one another, some general distinctions can be made. The geo-historical approach is characterized by critical evaluation and interpretation of diverse data sources including maps, the physical environment, and written documents and accounts representing people, businesses, and governments. It fills spatial and temporal gaps when spatially explicit information is not available (Conzen 1993). The geo-computational approach typically focuses on quantifiable entities and relationships and today is often associated with the use of geographic information systems (GIS), digital image processing, and computer-based process models. These tools can be used to integrate and analyze spatially explicit information and have been widely used to study recent phenomena and as a modeling tool to project trends through time (see for example Wear and Bolstad 1998; Wear et al. 1999; Wickham, O'Neil, and Jones 2000). While the possibility of gaining new insights into complex issues through the use of spatially explicit historical data in a GIS has been known for many years, only limited exploration of the possible integration of these approaches has been pursued (Marble 1990; Knowles 2000a).

The case study presented here combines geo-historical and geo-computational approaches with local and regional data to determine the timing, extent, and other characteristics of forest clearance and re-growth in the North River watershed. Two main aspects of the study are the thorough interrogation and comparison of different data sources, and the subsequent analysis and interpretation of the data. Chapter 2 provides an analysis of the existing literature regarding the geographical study of human - environment interactions and the study area. Chapter 3 examines data sources and research methods. Chapter 4 examines the results of the analysis in chronological order from approximately 1700 to 2000 AD, and provides a summary of the major activities that impacted forests and farm land in the region. Chapter 5, the conclusion, summarizes the research results over the three hundred year period, looks at the regional context, evaluates the sources and approaches, and discusses the importance of this research to future research in human – environment relationships.

Chapter 2: Literature Review

> "… the historical impulse succeeds in blazing new interpretive trails, and almost always contributes the most seasoned and durable syntheses in geography, whether in a regional or systematic vein." (Conzen 1993, p. 89-90)

Geography

Modern geography goes beyond mere description of the surface of the earth to include an explanation and evaluation of the relevance of the issue being studied (Guralnik 1974, p. 584; Rubenstein 1996, p. 5). Geography seeks to synthesize information from multiple perspectives. From the late sixteenth century until the middle of the nineteenth century, geographers synthesized the vast amounts of knowledge that had been gained through centuries of exploration and scientific inquiry. Geographical publications through this period primarily contained descriptions of the earth and the creatures and peoples who lived on it (for examples, see Malte-Brun 1827; or Humboldt 1845). As technology and scientific research developed in the late nineteenth and early twentieth centuries, specialized research came to dominate the field. Now, at the beginning of a new millennium, the need has arisen again for a renewed emphasis on synthesis of knowledge (Conzen 1993, p. 85). The need for synthesis within and between multiple fields has developed as policy makers, researchers and the general public have become increasingly concerned with economic, social and environmental issues and realize that these complex issues require input and understanding from multiple perspectives, particularly perspectives that take into account and integrate human and physical systems (Wear 1999; Golledge 2000). Geography is a discipline that has and can continue to integrate understanding of human and physical systems (Trimble 1992, xv). There has also been an increased need to focus on specific places and there is a renewed interest within geography for the development of new regional specializations (Murphy 2003).

A common theme throughout much of the history of geography has been the relationship of humanity with the environment (Pattison 1964). A major milestone in the development of the human-environment tradition took place in the middle of the nineteenth century when George P. Marsh published *Man and Nature: Or, Physical Geography as Modified by Human Action* (Marsh 1864). In this publication Marsh examines the interrelationships of human activities and the extent of their impact on the surface of the earth, though he primarily focuses on northwestern Europe and the Mediterranean. Marsh explores the impact of human activity on plants and animals (domestic and wild), the woods, the waters, and the sands. While not the first to examine such impacts, Marsh also raises concerns about the future implications of continued alterations of the environment, intended and incidental, and promotes the conservation of resources (Marsh 1864, p. 456). While Marsh challenges the notion of inexhaustible natural resources, he does not promote the elimination of their utilization (Kates, Turner, and Clark 1990, p. 3).

The next major publication in what is known by some scholars as the "man-land trilogy" is the publication edited by William Thomas, *Man's Role in Changing* *the Face of the Earth* (Thomas, Jr. and et al. 1955). This publication came out of an international symposium attended by scholars, government representatives, and business people who represented over twenty disciplines, including many of the leading geographers of the day. The symposium, referred to as a "Marsh Festival" by Carl Sauer, was designed to create an updated synthesis of humanity's impact on the earth, and became the standard text on the subject for thirty-five years (Thomas and et al. 1955, p. 49). One criticism of the book is that it is merely a collection of research and reflections of individual authors rather than a systematic and empirical investigation of the major changes wrought by humanity to the surface of the earth (Kates, Turner, and Clark 1990, p. 4). Among the important works in the volume are Carl Sauer's essay "The agency of man on the earth" and H. C. Darby's essay "The clearing of the woodland in Europe" (Darby 1955; Sauer 1955).

In contrast to *Man's Role*, the editors of the third publication in the "trilogy," *The Earth as Transformed by Human Action* (Turner, and et al. 1990), sought to develop a more systematic overview and "a third global inventory of the long-term changes wrought by humanity on the biosphere" (Turner, and et al. 1990, p. 5). As in the previous work, multiple perspectives are presented on topical and regional case studies utilizing descriptive and quantitative techniques to point out the complexities and global nature of the interactions between humanity and the biosphere. Snapshots in time and trends through time are explored, as are brief overviews of different theories of explanation. Two chapters of note are "Land Transformation" by John Richard and "Forests" by Michael Williams. Each chapter summarizes major changes to land use and forests of the world (Richards 1990; Williams 1990).

Global Change Research

In recent years research into global scale transformations of the earth have been championed by international organizations. The lead organization coordinating research into changes in the biophysical systems of the earth has been the International Geosphere – Biosphere Program (IGBP), which was created in the late 1980's (International Geosphere-Biosphere Programme: A Study of Global Change (IGBP) of the International Council of Scientific Unions (ICSU) 1990). The lead international organization coordinating research into the human aspect of global environmental change has been the International Human Dimensions Program (IHDP), which evolved soon after the IGBP. The first joint IGBP & IHDP program, the Land Use and Cover Change (LUCC) program, grew out of several initiatives including a workshop held in 1991 that was attended by global change scientists and social scientists. The results of the 1991 workshop were published as *Changes in Land Use and Land Cover: A Global Perspective* (Meyer, Turner, and University Corporation for Atmospheric Research. Office for Interdisciplinary Earth Studies. 1994). This publication gives an overview of the understanding at the time of some of the significant changes in land use and land cover (forests and tree cover, grass lands, and human settlements), environmental consequences (atmospheric chemistry and air quality, soils, hydrology and water quality), and the human driving forces (population and income, technology, political-economic institutions, culture and cultural change) of those changes. The authors of the book explore different methods of approaching research into these areas in the future, and discuss data and modeling issues.

The LUCC Implementation Strategy (Scientific Steering Committee and International Program Office of LUCC 1999) underscores the lack of full comprehension of the human role in the earth's systems. Unlike most of the other IGBP programs, the LUCC Scientific Steering Committee "…has produced an Implementation *Strategy* rather than a Plan" (Scientific Steering Committee and International Program Office of LUCC 1999, p. 7). The strategy proposes a set of specific activities and scientific networks in hopes of adding value to individual research projects based on the assumption that "…the whole will be of greater value than the sum of the parts" (Scientific Steering Committee and International Program Office of LUCC 1999, p. 10). In order to connect our understanding of human and physical aspects of land use change, the LUCC community believes it is necessary that the "understanding brought to bear from bottom-up, field-based approaches must be made spatially explicit" and include "efforts to integrate results with remote sensing information (*pixelizing the social*)." The LUCC community also feels that "remote sensing approaches that potentially increase spatial and temporal dimensions of land-use/land-cover change understanding must be pushed beyond its biophysical dimensions (*socializing the pixel*)" (Scientific Steering Committee and International Program Office of LUCC 1999, p. 25).

The LUCC community proposes models of land-use change for projecting change into the future through two methods. The first is through "empirical, diagnostic models based on an extrapolation of the patterns of change observed over the recent past, with a limited representation of driving forces." These models merely "highlight spatial and temporal associations between variables" (Scientific Steering

Committee and International Program Office of LUCC 1999, p. 9-10, 63). The patterns of change are often based on a series of remote sensing images. The driving forces are often based on generalizations of dependent variables like in the I = PAT equation, where the environmental impact (I) is a function of population (P), affluence (A), and technology (T) (Commoner 1971; Turner, Moss, and Skole 1993, p. 22). Recent attempts to utilize this approach for a small area in western North Carolina found that certain measures of population and affluence were adequate to explain greenhouse gas emissions for that area (DeHart and Soule 2000). Potential problems with utilizing such an approach at the national level and for cross-national comparisons has been described by Bilsborrow and Geores (Bilsborrow and Geores 1994). Other categories of driving forces include political economy, political structure, and attitudes and values (Turner, Moss, and Skole 1993, p. 22).

The second approach the LUCC community is pursuing is through "dynamic integrated models based on an understanding of the processes of land-use change. Diagnostic models integrate landscape variables and proximate causes of change in a data-rich spatial context. However, they can only provide short-range projections (5 to 10 years at most) due to non-stationarity in land-use change processes" (Scientific Steering Committee and International Program Office of LUCC 1999, p. 9-10). These models are often based on econometric or demographic analysis of local to regional situations. Nancy Bockstael has developed such a model for predicting changes to land use for areas in the State of Maryland under different policy scenarios (Bockstael 1996). One issue Bocksteal is grappling with is how to generalize her approach so it can be used in other areas because the model depends on parcel information that is not readily available for other states or nations. Another promising attempt at modeling recent land-use changes, this one in the southern Appalachians, is a study conducted by David Wear and Paul Bolstad. They found that topographic features and proximity to roads have significant influence on land use (Wear and Bolstad 1998).

The LUCC program starts with the premise that in order to "understand recent changes in the Earth system, the scientific community needs quantitative, spatially-explicit data on how land cover has been changed by human use over the last 300 years and how it will be changed in the next 50-100 years." The proposed approach to circumvent the lack of data is to develop a spatial sampling scheme based on a typology of "land-use situations" and through the identification of "hot spots" of change, though there is little discussion of how the validity of such an approach would be assessed. Land-use situations are likely to include scenarios like deforestation in tropical forests, or re-forestation in temperate forests of the mid-latitudes. The situations might be more refined to include biophysical variables like soils or human activities like pastoralism. Hot spots might be defined as past or present areas of rapid change, or particularly vulnerable areas (Scientific Steering Committee and International Program Office of LUCC 1999, p. 9-10). In order to build on existing research and to foster greater integration between researchers focusing on human and physical aspects of global environmental change, the LUCC program has recently been merged with other research initiatives of the IGBP & IHDP to create The Land Project. The objective of this new project is "understanding the terrestrial coupled human-environment system in order to reduce the vulnerability of the human-environment system to global environmental change and enhance sustainability of land systems" (Moran 2003).

In order to focus its efforts on historical issues, the joint IHDP and IGBP LUCC program helped coordinate a one-day workshop entitled the LUCC-PAGES-DIS Workshop on Historical Land Use/Land Cover Change in 1998 to explore the possibilities of developing a historic land use research plan. Other groups have also held workshops focusing on exploring available historic data and techniques. The International Geographical Union (IGU) Commission on Historical Monitoring of Environmental Change held a meeting in the Czech Republic in 1994 (Simmons and Mannion 1994) and the IGU Study Group on Land Use and Land Cover Change has held meetings in recent years where historic land use and land cover have been central themes (see for example Himiyama and Crissman 1997). These conferences have showcased a variety of case studies from around the world and have helped foster the development of linkages between researchers with a common interest. One result of collaboration between researchers in these communities is the production of the BIOME 300 CD-ROM, which contains a variety of population, land use, and vegetation data representing the last 300 years (Leemans, Goldewijk, and Oldfield 2000; Ramankutty et al. 2001).

Historical Geography and Environmental History

While the global change research community is relatively new and primarily focused on global-scale issues, two groups of scholars that have contributed to our understanding of human – environment interactions through time at multiple scales are historical geographers and environmental historians. These two groups have come to where they are today in this research area by different means and at different times. Environmental historians were initially concerned with tracing the development of conservation and preservation movements, but by the 1960's they had begun discussing the environment as one of the agents in historical events. The focus of most environmental historians has been to include the environment into their studies of humans and human society. In contrast to historians, geographers focus on the environment first and then look at how humans have shaped and situated themselves in the environment (Colten 1998; Baker 2003).

While the study of the natural environment and human impacts on it are almost as old as American geography, some people believe that historical geographers have been late to take up this area of research (Earle et al. 1989, p. 179). Stanley Trimble laments the lack of historical geographers' incorporation of the physical side of the human – physical environmental relationship in the 1970's and 1980's and points out that the focus of historical geography had been on cultural, social and economic theory (Trimble 1992, p. xvi, 1). As historical geographers have strived to incorporate the physical side, they have had to identify some fundamental questions to guide their research. Craig Colten and Lary Dilsaver (1992) have identified two fundamental questions that reflect on the two most important factors in environmental change over time: "(1) How have human pursuits transformed the environment? and (2) How have human social organizations controlled their environment?" They go on to say that "both questions place the environment as the object of human activity and consider humans as important forces in its alteration. Historical geographies that ask these questions are not explaining the development of cultural landscapes or the establishment of an economic system; rather, they illuminate the creation of a humanized landscape … and they examine the controlling mechanisms used to protect or plunder a territory" (Colten and Dilsaver 1992, p. 9). Historical geographers utilize a variety of techniques and critically evaluate primary data sources, including maps and written records, to weave together a narrative about a place. This ability to integrate and synthesize techniques and knowledge from multiple perspectives (within and outside of geography) is one area where historical geographers can make a contribution to the field of geography (Mitchell 1987, p. 10; Earle et al. 1989, p. 158; Conzen 1993, p. 37-38, 89-90). Historical geographers often structure their approach along common means of geographic inquiry asking questions about where, why, and how important is a particular phenomenon (Rubenstein 1996, p. 5).

Not all historical geographers agree on the purpose or approach to their research. Some view the purpose of historical inquiry or reconstruction as providing explanation to current situations and conditions. Others view the study of past periods as having legitimacy in their own right, leaving connections to contemporary geography for others to do in an "ultimate synthesis" (Mitchell 1987, p. 10; Conzen 1993, p. 83). As in other sub-fields of geography, some historical geographers focus primarily on a particular place or region for their analysis, while others take a more systematic approach looking at one or more thematic issues. Some geographers include aspects of both approaches into their work. Another issue that historical geographers differ over is whether the best approach is to do historical geography or geographical history. The primary difference between the two is whether the research focuses on issues raised by geographers or issues that are already established, and debated, in the historiographic record (Earle 1992; Conzen 1993, p. 86-87).

Another difference in approach between some (historical) geographers is whether the research should be based on, or at least emphasize, empirical or scientific methods and results. Geographers also debate whether analysis and results need to be quantifiable. Some of these issues may be dependent on the current state of knowledge about a particular location, topic, time period, or method. As new areas of inquiry are identified, or new techniques developed, or new insights become available from other fields, basic exploratory analysis is often required in order to synthesize the information and to develop new understandings. Researchers may need to start with more general questions, like those proposed by Colten & Dilsaver (see p.15), before more detailed hypotheses can be constructed. Geographers and geographical approaches are also useful for these types of studies. One such geographical method, promoted by Carville Earle, is the spatial or map method which "acquires its power by aligning the effect … in proper locational position so that potential hypotheses on the causal variables … immediately leap to mind" (Earle 1992, p. 7).

An important general historical geography that analyzes the broad cultural themes that have shaped North America through time are the first and second editions of *North America: The Historical Geography of a Changing Continent* (Mitchell and Groves 1987; McIlwraith and Muller 2001). These collections of essays are organized topically and temporally and identify the major political, economic, and cultural forces and phases that shaped North America. The individual chapters deal with regional and national scale issues in time scales of decades and centuries. While the book does provide some general discussions and overviews of the climate, physical environment, and resource exploitations in different regions at different times, it does not provide much detailed information about humanity's interaction with the environment. Another general text that does discuss the human impact on the environment of North America is a book edited by Michael Conzen, *The Making of the American Landscape* (Conzen 1990). While primarily focused on the creation of cultural landscapes rather than environmental change, the collection of essays explores the North American landscape by looking at groups of related landscape processes in a broadly historical and regional framework. Like *North America: The Historical Geography of a Changing Continent*, this book provides additional coverage of major historical processes that have affected the North American landscape, but does not provide any detailed insights into forest clearance and re-growth in the Shenandoah Valley, or any other specific locale.

Michael Williams' book, *Americans and Their Forests: A Historical Geography* (Williams 1989), presents one of the most thoroughly researched studies of the human use of and impact on the forests of the United States. Williams utilizes numerous and diverse primary and secondary sources to map and analyze the human use of (e.g. cutting wood for building fences), impact on (e.g. clearing land for agriculture), and preservation of the forests in the United States from the time of colonial settlement through the twentieth century. After describing the forests that existed when European colonists arrived, Williams determines and analyzes national trends in forest use and impacts for the colonial and ante-bellum periods. Taking into consideration the growing economic diversification in the second half of the nineteenth century, Williams shifts to regional case studies and then to thematic analysis of industrial uses of wood products and the impact of agriculture. Williams closes the book with a section on early efforts to protect forests and forest re-growth in the twentieth century. While Williams' work has been characterized as only looking at the utilization of forests from the perspective of cultural landscapes and economic development (Colten and Dilsaver 1992, p. 8), it does provide a good foundation for looking at more local impacts on forests having established broader trends and an approach for presenting topical, temporal, and spatial differences. For example, the most important activities identified by Williams that affected the forests in the Shenandoah Valley were clearing for agriculture, charcoal production in support of the iron industry in the eighteenth and nineteenth centuries, and timber production in the late nineteenth and early twentieth centuries. Williams' latest book, *Deforesting the Earth: From Prehistory to Global Crisis*, condenses the material from his earlier works on the United States and adds to it similar, but less detailed, analysis of the rest of the world (Williams 2003).

A book that looks at more than one aspect of humanity's impact on the environment is Gordon Whitney's *From Coastal Wilderness to Fruited Plain* (Whitney 1994). Whitney takes an ecological approach and not only considers humanity's impact on the forests of temperate North America, but also on other flora and fauna of the region through different types of agricultural practices and legislative measures. By incorporating ecological concepts of the reciprocal relationship between an organism and its environment, action and reaction, Whitney is able to explore how flora and fauna react to the intentional and unintentional changes in the environment wrought by humans. Regarding the forests, Whitney is able to look at how forest succession was impacted by human activities such as livestock grazing in woodlands and different timbering techniques. He also discusses the impact of human activities on soil fertility, erosion, and stream flows. Whitney does not provide any detailed analysis of the Shenandoah Valley.

Historians have also written regional studies of environmental change that provide good models of identifying, analyzing and presenting significant historical processes and their effects on the landscape. William Cronon's *Changes in the Land: Indians, Colonists, and the Ecology of New England* (Cronon 1983) is a milestone in environmental history where Cronon showed the benefits of taking a multidisciplinary approach and incorporated geographical and ecological concepts into his work. Cronon first describes the native peoples and the environment the initial European colonists would have encountered in New England. He then analyzes the impact of the colonists on the environment (and the native people) during major changes to the cultural and societal structure (e.g. from subsistence farming to more intense resource exploitation) of the colonists as their population increased. Tim Silver's *A New Face on the Countryside: Indians, colonists, and slaves in South Atlantic forests, 1500 – 1800* (Silver 1990) takes a similar approach in his study of the English settlements in the American South. Neither Cronon nor Silver's works discuss the Shenandoah Valley in any detail, and both only cover the period from initial European settlement in the New World to the close of the eighteenth century.

Appalachia and Frontier Studies

While the Shenandoah Valley is part of the ridge and valley physiographic province (see Figure 2. Physiographic divisions, provinces, and sections of the conterminous United States in Thelin andPike c.1991) and not a part of the Appalachian Mountains, it is often included in Appalachian studies. One of the themes that has permeated the historical research into North America, and particularly into Appalachia and the Shenandoah Valley, is the concept of a frontier. Much of this interest can be traced back to Frederick Jackson Turner's presentation titled "The Significance of the Frontier in American History" (Turner 1920). Turner postulated that the frontier experience, repetitively creating subsistence settlements in new areas of wilderness, was the most important fact in making America and Americans distinct. This notion has essentially been abandoned in the recent past for many reasons, including the fact that many places believed to have been isolated on the frontier in the eighteenth and early nineteenth centuries were actually well connected to more populated places and that subsistence farming in these areas lasted for only short periods of time, if at all. The term "backcountry" has become more common in the scholarly literature when referring to areas away from the more densely populated areas of eastern North America to get away from the intellectual baggage associated with the term frontier.

One of the works that helped challenge the concept of isolated farmsteads in Appalachia is the volume edited by Robert Mitchell, *Appalachian Frontiers: Settlement, Society & Development in the Preindustrial Era* (Mitchell 1991). This collection of diverse papers (e.g. chapters on Cherokee women farmers, political systems, cattle trade) gives an overview of a more complex society. While none of the chapters look explicitly at human – environment interactions, they do provide analysis of some economic, social, and political issues in the Appalachian region (including the Shenandoah Valley) during the colonial and ante-bellum periods. Some of the issues explored include studies seeking to determine if there are cultural differences in settlement systems and daily lives of different ethnic groups who settled in backcountry, particularly Germans and Scotch-Irish (Keller 1991; Kessel 1991). Variations in settlement and social systems are also explored from the perspective of competing and overlapping land policies in the northern Shenandoah Valley. Settlers in the western portion of Frederick County, mainly coming from the north, were more socially equal and intermixed than people who lived in the eastern part of the county, who were economically and socially tied to the eastern part of Virginia (Hofstra 1991). Richard MacMaster's essay on the cattle trade in western Virginia provides analysis of the location and methods of cattle raising and droving which (though unexplored in any depth by MacMaster) had a direct impact on the environment in the Shenandoah Valley (MacMaster 1991).

The *Southern Colonial Backcountry: Interdisciplinary Perspectives on Frontier Communities* (Crass et al. 1998) continues to give credence to the complexity of settlement system development in the region and contains numerous essays by authors from diverse fields. Mitchell points out in the opening chapter of the book that our knowledge of the southern colonial backcountry was still so poorly understood that the topic needed to be studied in its own terms (but not in isolation) before it could be properly understood in any broader context (Mitchell 1998). This collection also contains essays that explore the existing and possible future collaboration of multiple disciplines in researching the region. In his epilogue to the book, Warren Hofstra draws from his own research and those presented in the book to make the point that interdisciplinary study of the southern colonial backcountry requires scholars to look at place and process at multiple scales and from multiple perspectives (Crass et al. 1998; Hofstra 1998).

A more systematic overview of the settlement and development of Southern Appalachia is Wilma Dunaway's *The First American Frontier: Transition to Capitalism in Southern Appalachia, 1700 – 1860* (Dunaway 1996). Dunaway challenges the stereotypical belief that Appalachia was an isolated, backward area for generations by utilizing a world-systems framework looking at the connections and clashes of people and economies in the area with the rest of the world from the era of European settlement until 1860. Other scholarly works that describe the social and economic histories and geographies of Appalachia include Ronald Eller's *Miners, Millhands, and Mountaineers: Industrialization of the Appalachian South, 1880-1930* (Eller 1982), Karl Raitz & Richard Ulack's *Appalachia: A Regional Geography* (Raitz, Ulack, and Leinbach 1984), Paul Salstrom's *Appalachia's Path to Dependency: Rethinking a Region's Economic History 1730 – 1940* (Salstrom 1994), and *Appalachia in the Making: The Mountain South in the Nineteenth Century* by Pudup et al (Pudup, Billings, and Waller 1995). Some of the themes brought out in these works include the issues of absentee ownership of land, corporate exploitation of timber and coal resources, the growing dependency of the area on outsiders, and the marginallization of the peoples and land in Appalachia by all of these activities.

An article by Ronald Lewis in *Appalachia in the Making* is expanded in his book, *Transforming the Appalachian Countryside: Railroads, Deforestation, and Social Change in West Virginia, 1880-1920* (Lewis 1995, 1998). In these works Lewis discusses the huge impact the timber industry had on the region during their boom years, and includes some discussion of the environmental impacts of the timber activities including erosion and sedimentation. Except for Lewis' discussion about environmental impacts, the other works mentioned provide little insight into the environmental impacts of the activities described other than general descriptions of deforestation and changes in water quality.

Geoffrey Buckley's "The Environmental Transformation of an Appalachian Valley, 1850-1906" (Buckley 1998), which is derived from his doctoral thesis (Buckley 1997), gives a detailed analysis of the environmental impact of human activities in one particular Appalachian valley in western Maryland. Buckley goes beyond the presumption that coal mining will have a significant impact and also looks at other activities and participants in the community to evaluate how they are related and their impacts on multiple aspects of the environment including the forests and water resources. Buckley found that the clearing of forests to produce timber products and to make way for coal mining and other industrial developments tied to the areas natural resources, led to multiple environmental problems. People became concerned about future timber supplies and the impacts of fires that were more common in cut over areas. Increased flooding and erosion impacted nearby streams, which also became the receptacles for domestic and industrial wastes. These pollutants killed the aquatic life in the streams and contaminated the public water supply. Buckley also found that all of the regions inhabitants played a role in these environmental impacts, the large industrial concerns could not be blamed for all of the damage.

Shenandoah Valley

The Shenandoah Valley was settled by Europeans prior to the central and southern portions of the Appalachians, and provided a corridor to unsettled areas in Appalachia from the more populated North Eastern states (Mitchell 1977). Samuel Kercheval published one of the first histories of the area in 1833, *A History of the Valley of Virginia* (Kercheval 1925), approximately 100 years after the initial settlement. This history is typical of the time period and devotes most of its attention to great events (e.g. Indian raids and wars) and great people (e.g. local gentry). The book does not discuss the impact of human settlement on the local environment in any detail, but does contain appendices on the "Face of the Country" and "Natural Curiosities" which are primarily basic descriptions of the topography, town locations, springs, and caves.

One of the first significant modern analyses of the Shenandoah Valley, at least for the colonial period, is Robert Mitchell's *Commercialism and Frontier: Perspectives on the Early Shenandoah Valley* (Mitchell 1977). Mitchell presents a temporal and spatial framework for this historical geography of the region and then systematically analyses different aspects of the settlement and development of the region and its connection to other areas. Mitchell proposed that the establishment of new commercial centers on a frontier allowed people and goods to enter new areas for settlement. As settlements became established around these new centers small amounts of locally produced goods began to flow back from the frontier to the more settled areas. As the population grew and expanded out from these centers, the center would become the hub of production. Developmentally, unspecialized farming and local commercialism initially characterized the economy. Through time, there would be increasing amounts of agricultural specialization and economic diversification. Eventually agricultural production would specialize in regions and external contacts would intensify. These processes would lead to the centralization of local manufacturing and services. While Mitchell's model does not explicitly address the environmental impacts of these activities, he includes some general observations about the amount of deforestation that had likely occurred due to the expansion of agriculture and the development of extractive industries (e.g. charcoal iron production) (Mitchell 1977, p. 1-14).

Mitchell continued his research into the region and often worked with historian Warren Hofstra. Their collaborative work resulted in a series of articles about the development of the region, particularly the northern Shenandoah Valley (see for example Hofstra and Mitchell 1993; Mitchell and Hofstra 1995). Hofstra has also collaborated with archeologists to help locate and interpret early settlement and industrial sites in the northern Shenandoah Valley (Geier and Hofstra 1991; Hofstra and Geier 1992). These projects did not target environmental change as a main theme, but helped spark an interest among the researchers. Mitchell, Hofstra, and Edward Connor (an ecologist) began to address the issue of what the vegetation was like in the Shenandoah Valley at the time of initial European settlement and initial land use activities with a research project funded by the National Geographic Society.

The report on their initial research, *European settlement and land-cover change: the Shenandoah Valley of Virginia during the 18th Century* gives an overview of what is known about these issues for the Shenandoah Valley and outlines an approach to integrate multiple data sources and techniques (Mitchell, Connor, and Hofstra 1993; Mitchell 1997). One of the primary sources used by Mitchell, Hofstra and Connor were land surveys that include various environmental clues through the use of descriptions of the terrain along survey lines and with the recording of witness trees (by type) at survey corners. Other sources used by Mitchell, Hofstra, and Connor included period narratives.

Most of the recent historical and geographic research on the region during the nineteenth and twentieth centuries have been either very general overviews or focused on specific topics or short time periods. Some recent works that do explore in a limited way man's interaction with the local environment are a few case studies of specific industries and communities. Two such studies are Chris Bolgiano's *The Appalachian forest: a search for roots and renewal* and "Tanbark harvesting as an economic and environmental factor in Appalachia" which discuss people's attachment to and utilization of forests in Appalachia (including the Shenandoah Valley) (Bolgiano 1998, 1999).

Other works that shed light on environmental change in the area have been regional or national in scope. The Shenandoah River is part of the Chesapeake Bay drainage network that has seen intensive study in recent times. Regional historic land use and land cover analysis has been conducted using sediment cores from the Chesapeake Bay (Cooper and Brush 1993; Cooper 1995; Willard, Cronin, and

Verardo 2003). These studies show a correlation of sediment rates and contents of the sediment to historical activities in the region, mainly the expansion and later contraction of the amount of agricultural land and increases in industrial activities. It should be noted that not all studies of sediment cores in the region show this correlation (Defries 1986). Another study that looks at the shifting patterns of farm land in the U.S. is a chapter by Margaret Maizel, et al. in *Perspectives on the Land Use History of North America: A Context for Understanding Our Changing Environment* (Sisk 1998 (Revised September 1999)). The article, "Historical Interrelationships between Population Settlement and Farm Land in the Conterminous United States, 1790 – 1992," uses basic population and agricultural census data along with soils data to map out general trends of population density and percent of land in farm land on a county-by-county basis through time (Maizel et al. 1998 (Revised September 1999)).

Geographic Information Systems

Geo-historical research into environmental change requires the utilization of many different types of primary and secondary sources. Primary sources include written accounts of the landscape; personal, business and government records documenting human activities and environmental conditions; and maps. Secondary sources include scientific reports, popular accounts, and maps. One approach to link disparate data sources, particularly ones with a spatial component, is through the use of geographic information systems (GIS) (Crews-Meyer 2002). Jeffrey Star and John Estes define a GIS as "an information system that is designed to work with data referenced by spatial or geographic coordinates" and that it is "both a database system with specific capabilities for spatially-referenced data, as well as a set of operations for working with the data" (Star and Estes 1990 pp. 2-3). A fundamental operation for working with data in a GIS is by overlaying data visually or analytically, though overlay analysis does not require the use of a computer. The concept of overlaying information is documented as far back as the eleventh century as evidenced in etched stones at a major Khmer Empire temple, Angkor Wat, in north-west Cambodia. Louis Alexandre Berthier, a French cartographer, used hinged overlay maps at the Siege of Yorktown in 1781 and planners in the United States and Europe were using the overlay technique in the early twentieth century. In modern times, Ian McHarg is credited with demonstrating the legitimacy of using the "overlay technique for addressing environmental and social compatibility issues with land development planning" (Foresman 1998 pp. 3-4).

The advent of the computer ushered in a new era where overlay analysis could be automated and modern GIS was born. The first large-scale, computer-based GIS was developed for the Canadian government under the leadership of Dr. Roger Tomlinson in the early 1960's (Foresman 1998 pp. 4-5; Tomlinson 1998). Dr. Tomlinson later edited two volumes entitled *Geographical Data Handling* that influenced many people (Tomlinson 1972; Townshend 1998). Other avenues of development in the realm of computer applications and data storage techniques have also added to the development of modern GIS (Foresman 1998 p. 5). Until recently, the data structures and analytical capabilities available in many commercial GIS software offerings were dependent on the early applications of GIS, which were dominated by environmental applications (Thompson 1998).

Early attempts at analyzing historical material with GIS and spatial analysis are highlighted in the book, *Interpreting Space: GIS and Archeology* (Allen, Green, and Zubrow 1990). Examples in the book include the application of GIS to regional analysis of landscapes, archeological site prediction, and trade and settlement system modeling. Some of the data used in these projects include representations of topography, hydrography, vegetation, transportation networks, and the results from archeological survey records. In his essay "The potential methodological impact of geographic information systems on the social sciences" Duane Marble argues that GIS is one of those rare technological innovations that has the potential to revolutionize a field of study (Marble 1990). He further states that social scientists, including geographers, had (at that time) a very myopic view of human spatial behavior because of an inability (i.e. lack of tools) to "visualize, let alone model, the full scope of human spatial behavior" (Marble 1990, p. 18). The potential of GIS to change the social sciences is taking shape within some circles of scholars. A series of sessions at the Social Science History Association meetings in recent years have been focused on historical GIS. Papers and issues raised at the 1998 meeting were published in a special issue of Social Science History, "Historical GIS: The Spatial Turn in Social Science History" (Knowles 2000a). Anne Knowles described her reaction to the 1999 sessions as "a heady feeling to see the birth of a new generation in social science history." Knowles describes the benefit of historical GIS as "illuminating the regional and local variations of national and international phenomena, combining broad questions with the richness of localized case studies" (Knowles 2000b). Knowles notes however, that "historical applications [of GIS] are notable for their absence in leading GIS textbooks, survey articles, compendia of essays, and government-sponsored initiatives to promote GIS research" (Knowles 2000a p. 465).

Historical GIS has received more exposure and acceptance in the last few years. A recent publication by a leading GIS software vendor was put together by scholars in order to showcase some of the emerging applications of applying GIS to historical inquiry. *Past Time, Past Place: GIS for History* provides an introductory essay on historical GIS and eleven chapters on different applications of GIS, including one on the causes of the "dust bowl" in the United States during the 1930's and one on agriculture in Great Britain during the nineteenth century (Knowles 2002). Data sources used in the studies range from historic maps to topographic and soils data, to agricultural and population census information, to tax and insurance records. Other recent articles in scholarly journals have examined the nature of uncertainty in historical geographic information and methods to assess the content of historic maps (Plewe 2002; Vuorela, Alho, and Kalliola 2002; Pearson 2004). And Deryck Holdsworth points out the continued importance of doing archival fieldwork when conducting historical studies and encourages all historical geographers to "be open to the dazzling array of new ways of seeing, and imaging, the past" (Holdsworth 2003).

Chapter 3: Obtaining the Data

> "Serious difficulties were encountered from the want of precise topographical information as to the country… Correct local maps were not to be found"
> Major General George McClellan discussing the lack of good maps during the American Civil War (McClellan 1880, p. 8)

The discrepancies in the timing of maximum forest clearance identified in the introduction could reflect actual differences in what happened on the landscape, or could be artifacts of the type or scale of the data, or the approaches taken. Combining geo-historical and geo-computational approaches through "historical GIS" provides a means to bridge the gaps between the individual approaches and to bridge gaps in spatial and temporal scales. A thorough historical analysis of textual and graphic sources provides a context within which to interpret the contents of these sources, which provides a better means of understanding what is represented in the spatially explicit time-slices analyzed in a GIS and for understanding what happened in between the reconstructed time slices. In this chapter, data sources will be introduced in chronological order along with descriptions and rationales for deciding whether to utilize the source, and data preparation and analysis for the sources that were used. Issues and methods used for data harmonization and analysis trough time are presented next. Interpretations of the analysis will be presented in the next chapter.

Identifying appropriate sources can be a laborious task. Figure 2 gives a visual representation of the types of sources that may contain information about historic land use and land cover. A hypothetical trend line is overlaid on top of the potential sources to show the relationship of a trend to the availability of different sources so research into sources can be concentrated on key periods in the trend. From this diagram one can see that a variety of data sources are needed in order to reconstruct the landscape over a long period of time and numerous archives and data repositories (Table 1) were searched for potential data sources. In addition to the spatial extent covered by the source, important characteristics examined for each potential source included the contents (e.g. does it include forest information), the scale, and temporal information including the period covered and what interval exists between subsequent collections. An analysis of the methods used to produce each source and its historical purpose were also researched to aid in understanding the contents of the source and their relationship to data represented in the agricultural census. Without this analysis, the contents of the maps and digital spatial data could not be analyzed with any confidence since it would not be known whether the symbols represented specific features or were merely fanciful decorations.

"Primeval" Forest at the time of initial European settlement

The temporal focus of this study starts with the European settlement of the Shenandoah Valley in the early eighteenth century. In general, the backwoods or frontier of the New World were thought to be forested and the forests of the eastern United States have historically been portrayed as being "primeval" or in a climax state (Robison 1960, p. 117). No record exists of a systematic analysis of the vegetation of the Shenandoah Valley by any of the early European explorers who visited the area in the seventeenth and eighteenth centuries, and no account of the area's vegetation is known to exist from earlier, sporadic, native inhabitants.

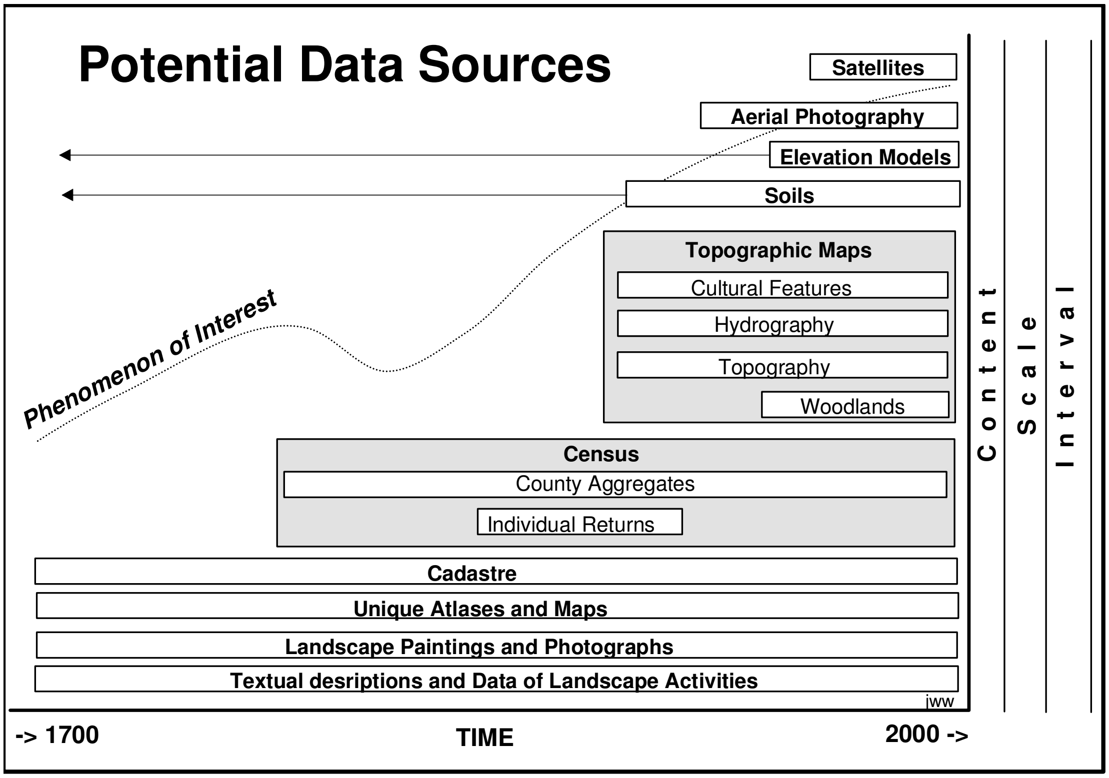

Figure 2: Schematic of Data Trends and Potential Sources.

The horizontal bars represent different types of sources of land use and land cover information available through time. A hypothetical trend line of a phenomenon of interest is overlaid on top of the sources to show the overlap between what is of interest and the types of sources that can be used to examine specific trends. The vertical columns of content, scale, and interval represent cross-cutting issues that must be examined for each potential source. *Source*: Author.

Table 1: Archives and Repositories Searched.

Archives and Repositories
Forest History Society
George Washington and Jefferson National Forest
James Madison University Library and Special Collections
Library of Congress
Library of Virginia
National Archives and Records Administration
U.S. Geological Survey (USGS)
University of Virginia Library and Archives
Virginia Department of Forestry
Virginia Division of Mines, Minerals, and Energy
Virginia Historical Society

Without detailed and thorough first-hand descriptions of the vegetation, an analysis of other sources and methods must be used to ascertain a more precise understanding of the character and extent of the forest in the area during the early eighteenth century.

Sources utilized in the next chapter to describe the vegetation at the time of European settlement include potential vegetation data sets, palynological studies, and the few written accounts that do exist from early explorers, settlers, and early histories of the area. Potential vegetation data sets have been developed for North America by examining various biophysical characteristics such as elevation and climate conditions. While the published data sets are not designed for site specific use, they do provide a generalized idea of what is likely to have existed in the region at some point in time before human alterations (see for example Baker 1936; Kuchler 1964; Defries 1999). Palynological studies examine pollen remains to develop vegetation histories for locations and some studies exist for the region (see for example Craig 1969). Some written accounts do exist and they can provide additional insight, though the author's intent and their intended audience must be evaluated carefully. These written accounts include traveler's diaries, land survey records, histories published in the nineteenth century that draw on recollections and oral histories of early settlers, and later descriptions of the landscape that describe remnants of the original landscape.

European Settlement through the American Civil War (circa 1700 – 1865)

Detailed and consistent information about land use and land cover changes for the Shenandoah Valley during the eighteenth and early nineteenth century are non-existent. Glimpses into what the landscape was like can be gleaned from occasional direct or indirect references in primary records and later histories, which will be used in the chapter on interpretation. Only a few maps were identified that had any land use or land cover information for the period prior to the American Civil War; however, these only covered very small portions of the study area and no further analysis of these sources were conducted for this study.

Witness trees

One source that has been used in other studies and is utilized in this study is witness tree data contained in land surveyor records. Witness trees are trees that were marked and recorded as defining points in a land survey (Hughes 1979; Mitchell, Hofstra, and Connor 2001). When trees were not present, natural features (e.g. a rock outcrop) or objects placed by the surveyors (e.g. a stake or a pile of rocks) were used to mark the property corners. When trees were used and recorded, they are typically identified by type and sometimes by a relative age. The information recorded about the witness trees have been analyzed in many studies in order to garner information about the landscape at the time the survey was recorded (see for example Cogbill, Burk, and Motzkin 2002). One study by Mithcell et al. that was conducted in the Northern Shenandoah Valley only looked at data for the first several decades of settlement in that region, but does give an overview of what the initial vegetative cover was like in the early part of the eighteenth century (Mitchell, Connor, and Hofstra 1993; Mitchell, Hofstra, and Connor 2001). Another analysis of witness trees was conducted by Alan Strahler who examined the historic and modern vegetation along the Fairfax Line (Strahler 1972). The line was surveyed at the request of Thomas Lord Fairfax in 1746 to demark his Northern Neck land grant in western

Virginia. At the time, the line separated Frederick and Augusta Counties, but later formed the northern boundary of Rockingham County (Wayland 1912). Another sample of surveyors' data was collected for a small area in the North River watershed in a previous study by the author and is analyzed in this current study to get a general idea of the composition of the witness trees in the watershed during the eighteenth century.

Census Data

A commonly used source for historical studies of agriculture and forests of the United States are the various censuses taken by the federal government because of the characteristics recorded in the censuses and because of the long time span covered by them. The government began taking national population censuses in 1790 and gradually broadened the scope of the census programs to include information of greater relevance to understanding land use and land cover change. While the population census often included information on the employment type for individuals which can give an idea of the types of activities going on in an area that would impact the landscape, this information can not provide details about the amount of activity taking place or specific information on the location of the activity, unless the location of individuals can be determined from other sources.

More specific information on industries from which one might infer land use activities can often be found in manufacturing censuses which were initially taken in 1810. Many problems existed in this and subsequent manufacturing census in the early nineteenth century but they can provide some useful information (Wright 1900). Like the population census, specific location information is not recorded in the census publications which are aggregated at the county or state level. While the location of specific industrial sites (e.g. saw mills) might be determined from other sources, the location of where the source materials feeding the industry (e.g. timber) came from can only be determined if other detailed records exist for the industry.

County level aggregate data is an alternative to the manuscript returns and provides the basis of many studies that look at broad changes over decades and centuries. This information is widely available for most of the United States for the years when population, manufacturing, and agricultural censuses were collected, but these aggregates have limitations in that they lack locational specifics that limit the ability to understand what is taking place on the landscape. For instance, if the amount of agricultural land was constant through time, the use of the aggregate information in the census data would not allow you to determine whether the same land is staying in agricultural production or whether land is moving in and out of agricultural production.

Beginning in 1840, the U.S. federal government conducted an agricultural census, initially every ten years. The 1840 census contained information on the quantity and value of various agricultural and forest products, but not on the amount of land devoted to the different activities and is therefore of limited value in looking at long-term land use change. Beginning with the 1850 census, new and relevant categories of information were recorded and refined through time. In particular, the inclusion of the acreage of "improved" and "unimproved" farm land in the census provides specific information relating to the landscape. Improved farm land was defined as land that was "cleared and used for grazing, grass, tillage, or which is now fallow" and unimproved farm land was to include land such as a woodlots which were owned in connection with the farm and whose timber or range was used for farm purposes (Wright 1900, p. 99 – 106, 235). These categories were modified and refined through time, but can be followed through time with the combination of different categories of data (Table 2) (Virginia Dept. of Archives and History 1965; Virginia Agricultural Statistics Service 1999a, 1999b; Geospatial and Statistical Data Center University of Virginia 2004; Virginia Agricultural Statistics Service 2004a, 2004b).

Table 2: Variables From the Agricultural Census Used to Define Improved Farm Land.

Source: (Virginia Dept. of Archives and History 1965; United States Dept. of Agriculture 1997; Virginia Agricultural Statistics Service 1999a, 1999b; Geospatial and Statistical Data Center University of Virginia 2004; Virginia Agricultural Statistics Service c.2000)

Years	Attributes
1850 - 1920	Improved farm land and subcategories
1930	Croplands, idle and fallow land, and pastures
1935 - 1997	Croplands and other pasture as published in the USDA NASS County Summary sheets

Confederate Engineer Bureau Maps

The first spatially explicit source relating to land use and land cover for the majority of the study area comes from the period of the American Civil War. While Confederate General Stonewall Jackson's famous cartographer, Jedediah Hotchkiss, lived in and mapped areas in the North River watershed, none of his maps with a woodlands symbol covered a large enough area to be used in this study. The first usable source is a series of maps (Figure 3 and Figure 25 in Appendix A) produced by the Confederate Engineer Bureau (Confederate Engineer Bureau 1863, 1864). In addition to a rendering of forest cover, these maps contain symbols for administrative boundaries, roads, rail roads, streams, topography, farms, houses, and industrial sites. Cities, towns and prominent physical features are identified by name.

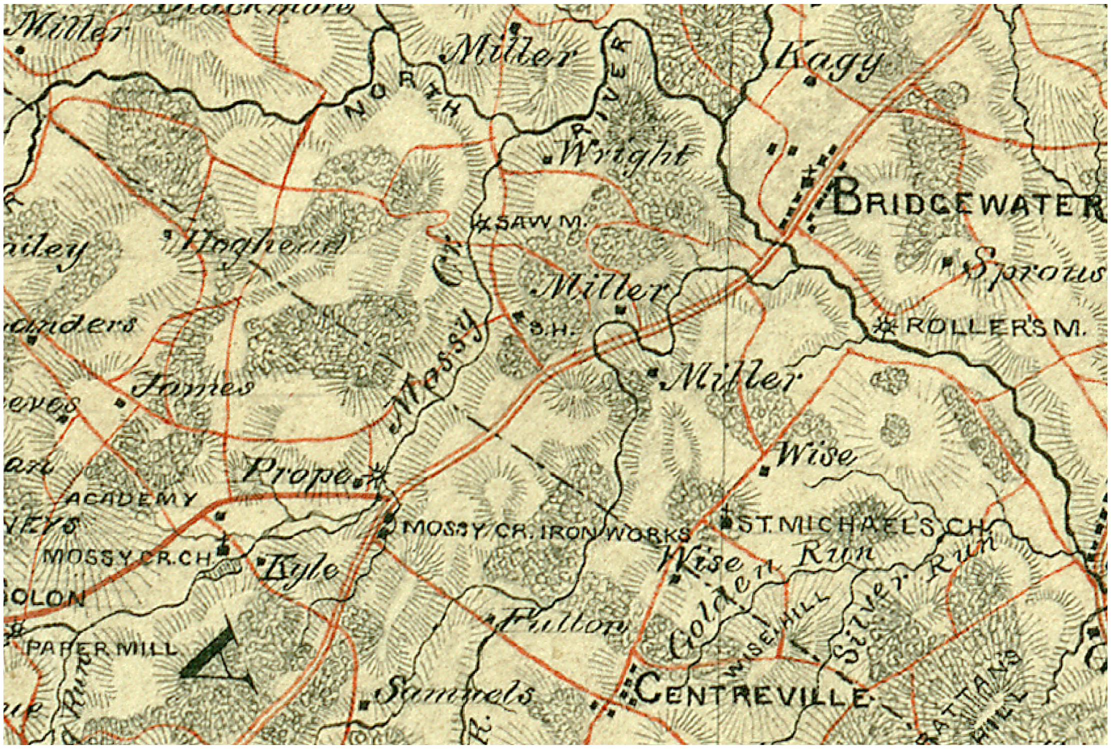

Figure 3: Details From the Confederate Engineer Bureau Map: Lower Shenandoah Valley I.

This portion of the map shows an area along the Augusta – Rockingham County border (diagonal dot-dash line running across the image). Red lines represent roads; hatchures represents slopes; dark shaded areas with squiggly lines represent woodlands; and text identifies places such as towns, residences, churches, businesses, and streams. See Figure 26 in Appendix A for an image of the entire map. *Source*: (Confederate Engineer Bureau 1864).

Georeferencing the Confederate Engineer's manuscript map presented a significant challenge. Georeferencing is the process of assigning coordinates from a known reference system to the page coordinates of an image or a planar map (Kennedy 2001). The primary map covering the study area contained some grid lines but no indication of what they represented or any other information regarding scale or projection. A second map in the collection and part of a three-map series of the Shenandoah Valley also contained grid lines and these were marked with latitude and longitude coordinates. A visual comparison of the two maps indicated that the maps were apparently designed to be used together since the content of each ended roughly where the next began, and the lines of longitude lined up with each other. A visual inspection of a modern map found close alignment with the lines of latitude and longitude and ground features. The grid lines on the historic map were determined to be spaced at ten minute intervals.

Digital copies of these maps were obtained from the Virginia Historical Society (VHS) and the Library of Virginia (LOV) in TIFF format. The LOV is in the process of scanning some of the historical societies' Civil War era maps in collaboration with the Library of Congress and the American Memory Project (American Memory from the Library of Congress 2005). The entire primary map was provided in digital form at approximately 300 dots per inch (dpi). While adequate for some uses, the forest boundary information was difficult to interpret so the LOV provided a higher resolution scan (approximately 600 dpi) of the south-western corner of the map, which covered the majority of the area needed and provided a much better base from which to interpret the wooded areas.

An initial georeferencing of the historic map using the grid lines and a first order polynomial equation produced by the "georeferencing" tools in ArcGIS version 8.2 (Environmental Systems Research Institute 2002) produced what initially appeared to be a good fit to modern grid lines, but a visual inspection found numerous cultural and natural features to be in the wrong location. The relatively good fit of the grid lines with a modern grid might be indicative of the skill of the cartographer to accurately portray the reference system. The lack of correct placement of features within the reference system may be due to the quality of the source maps, or more likely field notes because of the lack of available detailed maps, from which the cartographer produced the map. The relative locations of items may have been more important militarily than the exact location, and the availability of tools or time to accurately locate oneself in the field were lacking (for a description of field mapping techniques of the time, see Miller 1993). The errors could be acceptable for some analysis, but for this study the map needed to be more accurately aligned so that it could be overlain with more modern data sets.

In order to adjust for the unsystematic errors, a second approach was used to georeference the image of the map. A "rubber-sheeting" or "triangle-based rectification" tool in Erdas Imagine version 8.5 was used to independently move portions of the map to a more accurate location (ERDAS 1999b; 1999a, p. 360). Fifty control points were identified on the historic map and corresponding modern maps and an additional three more were "predicted" by the software to match the outer limits of the map scan. The features were predominately road intersections in named communities, but a few prominent hills were also used. Due to the scarcity of identifiable control points, all were used to georeference the map and none were used for verification purposes. A visual inspection of the resulting map indicated that it did more accurately align with modern features. The distortion of an arbitrary grid superimposed on the original scan of the map (Figure 4) to geographic space shows the distortion present in the source map (Figure 5). A small section of the full map scan (but lower resolution) was cut out and georeferenced to fill in the remainder of the North River watershed.

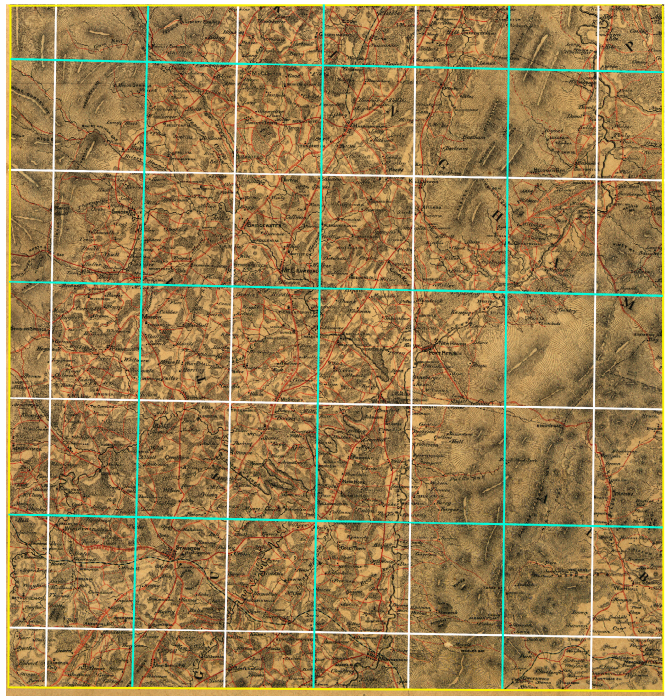

Figure 4: Geographic Distortion in the Lower Shenandoah Valley I Map – Arbitrary Grid Superimposed Over the Map Before Georeferencing.

Source: (Confederate Engineer Bureau 1864) and author.

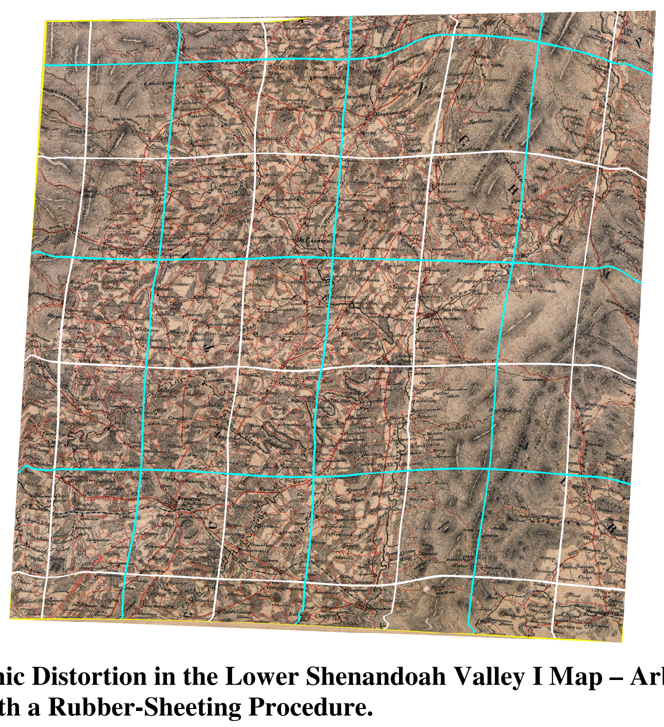

Figure 5: Geographic Distortion in the Lower Shenandoah Valley I Map – Arbitrary Grid After Georeferencing With a Rubber-Sheeting Procedure.

Source: (Confederate Engineer Bureau 1864), and author.

Woodlands were digitized from the georeferenced map using a "heads-up" technique, where items are traced on a computer screen with a mouse or other pointing device. Wooded and cleared areas were digitized primarily by tracing the woodlands symbol visible on most of the map. While no legend existed on the map, the symbol is similar to other maps of the period where a green tint is also present, and follows the convention outlined in military topographical drawing manuals from the first half of the nineteenth century (Eastman 1837; Smith 1856). In addition, the "duties of officers of engineers serving with the armies of the Confederate states" included making "reconnoissances and surveys of the sections of country occupied by our forces, and, as far as possible, of the country held by the enemy, embracing all the information that can be obtained in reference to … roads, bridges, fords, topographical, and military features, … the extent of wooded and cleared lands, … and the capacity of the country to supply the general wants of the army" (Cooper 1864). The passage of this general order has been attributed to Jeremy Francis Gilmer, the chief of the Confederate Engineer Bureau, who was likely to be familiar with the mapping standards of the day. Gilmer graduated fourth in his class from the U.S. Military Academy at West Point in 1839, was commissioned a second lieutenant of engineers, and became an assistant professor of engineering at West Point from 1839 – 1840 (Williams 1979). The 1837 manual cited above was written by a Lieutenant Seth Eastman, a teacher at West Point in the 1830's, and it became the official text for classes at West Point (Johnston 1996). The maps being discussed here were produced by Gilmer's engineering bureau and are part of a collection that

Gilmer saved when Richmond was burned during the war and are now held by the Virginia Historical Society (Virginia Historical Society 2005).

Detailed and accurate maps were important to Union and Confederate forces, but were difficult to obtain at the beginning of the war. Existing county and coastal survey maps were often copied and updated with information obtained from field reconnaissance. New maps were also created from field mapping surveys that would typically consist of drawing rough sketch maps and compiling more detailed information in a field sketchbook. Jedediah Hotchkiss recorded distances, terrain information, names of places and households, road conditions, and other details about land use and land cover in his field book (see Figure 6 for an example). Hotchkiss would ride on horseback with his leg crossed over the saddle drawing as he followed roads and trails across the countryside, counting the horse's footsteps to approximate distances. Aerial reconnaissances using tethered balloons were known to have been used by Union forces in northern and eastern Virginia, but no evidence ha been found indicating their use is western Virginia (Stephenson 1989; Miller 1993; McElfresh 1999; Jensen 2000). While the details of the methods used to produce the Lower Shenandoah Valley I map are not recorded, they were likely to be similar to the techniques employed by Hotchkiss.

The woodlands symbol was not always present in steep slope and mountainous areas of the Lower Shenandoah Valley I map. This is likely due to the mapping conventions of the time because Eastman's book on topographic mapping indicated that "care should be taken that they [woods] do not interfere with the lines indicating the slope of the ground (Eastman 1837 p. 35). When the symbol was not

Figure 6: Illustration from Jedediah Hotchkiss's Civil War Field Sketch Book.

This illustration is divided into two parts, divided by a faint line that separates the top left-hand corner. The Town of Bridgewater is in the lower left-hand corner. The main road being illustrated is the Harrisonburg to Warm Springs Turnpike, which generally runs from the north-east to the south-west. This section of the road progresses from Bridgewater in the lower left-hand corner to the upper right-hand corner, and then picks up again along the left edge of the illustration as the line coming into the Mossy Creek Iron Works. The numbers along the road are likely to be notations of distance. Blue is used to illustrate hydrological features, and brown is used to indicate terrain features and iron ore deposits. *Source*: (Hotchkiss 1862-1865).

present along the base and in the mountains bordering the Shenandoah Valley, natural and man-made breaks were used as the border. Areas on the uphill side of the feature were considered wooded but roads represented with a double line were considered cleared. Mountainous areas in the watershed that were not on the map were assumed to be wooded because later histories and reports indicate these remote areas still contained the original forest in the late nineteenth century (Hotchkiss 1876;

Stoneburner 1928). Holes in a larger wooded area were created by first creating an outer polygon for the larger area and then digitizing separate polygons for the cleared area. The cleared area polygon was then used to clip out the hole in the wooded polygon (Environmental Systems Research Institute).

1865 to 1950

Census Data

The agricultural census continued to provide the most consistent information from the end of the American Civil War until the middle of the twentieth century. While the broad categories of improved and unimproved land did not persist through the entire period, the categories that replaced them (e.g. croplands, pastures, wood lots) can be combined to approximate the original definitions of improved and unimproved land (see Table 2) (Virginia Dept. of Archives and History 1965; Virginia Agricultural Statistics Service 1999a, 1999b; Geospatial and Statistical Data Center University of Virginia 2004; Virginia Agricultural Statistics Service 2004a, 2004b). Additional sources that are used to assist in the interpretation of changes to the landscape during this period include promotional literature written to encourage the extraction and utilization of untapped natural resources in the area, governmental reports on the status of the economy and the environment, and modern histories of the area.

1906 U.S. Geological Survey Potomac River Study

The next cartographic source that contains information on the forests of the area is the map "Potomac River Drainage Basin above Washington Showing Forest

Areas and Cleared Lands" (Ashe 1907) which was included in a U.S. Geological Survey (USGS) study about the basin (Parker et al. 1907) (see Figure 27 in Appendix A). While the map was printed at 1:633,600, it is the only spatially explicit source of forest cover that encompasses the entire study area during the early twentieth century.

The report does not include any information about the mapping techniques or standards utilized, and period manuals from the USGS do not provide any guidance for the mapping of wooded areas, so the forested areas have to be accepted as is. Wooded areas in the Valley floor are portrayed with rectangles and are presumed to be generalizations of the actual wooded area. Cleared areas in larger wooded areas are also portrayed as rectangles. While these generalizations and the map scale limit the spatial accuracy, it is the best available source and is used to obtain a general idea of what areas were forested and cleared at the beginning of the twentieth century. Cleared areas were classified as being either largely in tillage or in grass, and forested areas were classified into several groups according to the degree which the humus had been damaged by fire.

Field and forest data on the Potomac drainage basin map was compiled by William W. Ashe. Ashe was a forester for the North Carolina Geological Survey from 1892 until 1905, and he also worked on special projects with the recently-formed United States Forest Service during this period. Ashe joined the U.S. Forest Service full time in 1905 and continued to work for them until his death in 1932. Ashe also served as Secretary of the National Forest Reservation Commission from 1918 until 1924, as vice-president of the Society of American Foresters in 1919, and was chairman of the Forest Service Tree Name Committee from 1930 until 1932 (Gilmour et al. 2005).

The map was scanned with a single pass on a large format scanner at 800 dpi and stored as a 24-bit color TIFF file. The image file was georeferenced in ArcGIS (Environmental Systems Research Institute 2002) based on latitude and longitude lines present on the map primarily using control points within and near Augusta and Rockingham Counties. Visual inspection confirmed a good fit with modern county boundaries. The "woodlands" information was manually digitized using a "heads-up" technique where polygons were created by tracing over the georeferenced image in ArcGIS. Digitizing was limited to areas within Augusta and Rockingham Counties and the different categories of woodlands present on the map were collapsed into a single woodlands category. The green layer on the map was not aligned properly with the polygon boundaries, which were printed in black, so the black boundaries were used to define the wooded areas (Figure 7).

1920 – 1950 USGS 15' Topographic Maps

The next representation of woodlands come from USGS 15 minute topographic maps with a scale of 1:62,500 produced from 1920 to 1950. While the USGS had started its national mapping campaign in the late nineteenth century producing 30 minute series maps, it was not until the USGS started the 15 minute map series in the twentieth century that it routinely included a woodlands symbol on its maps of the

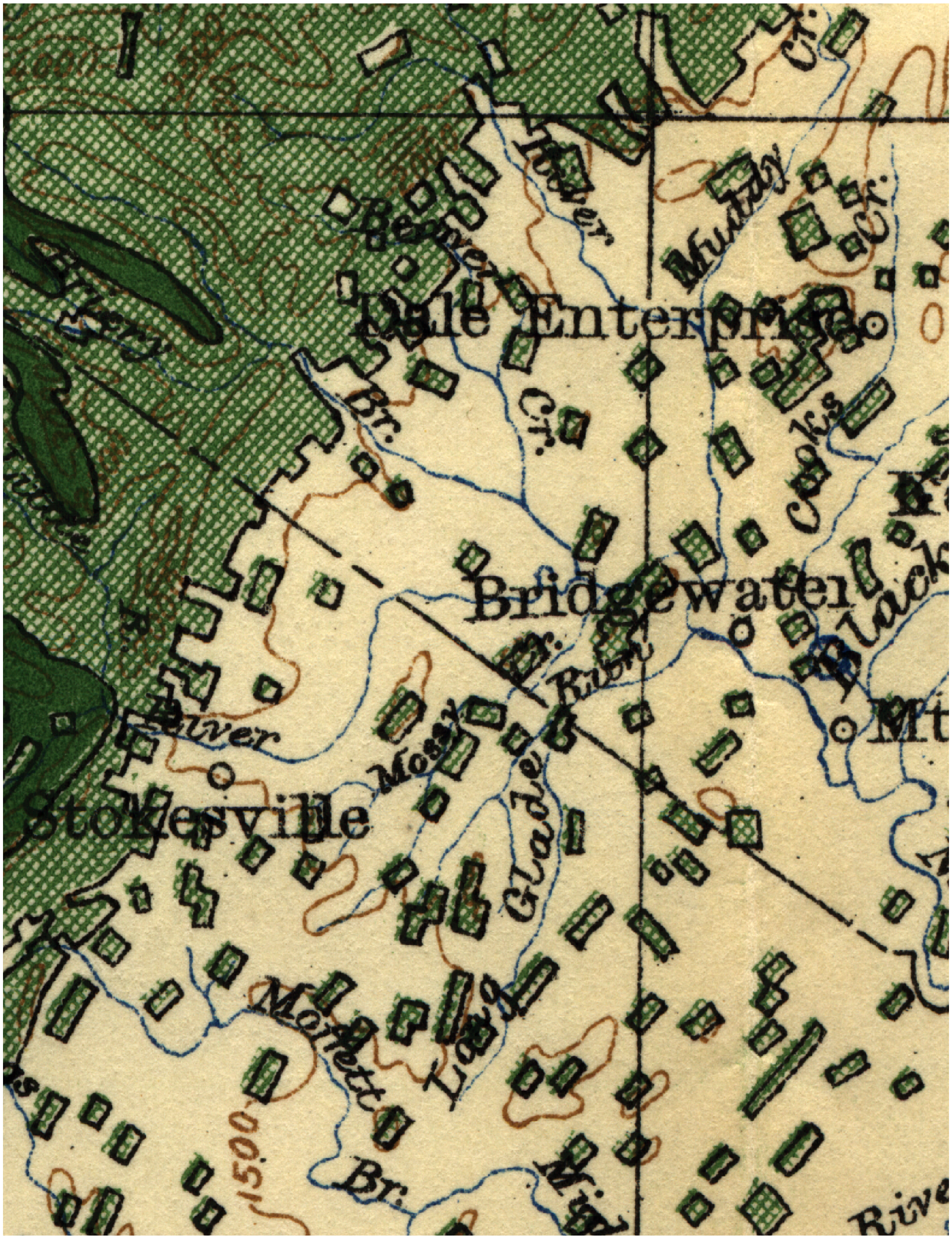

Figure 7: Details From a Section of the Potomac River Basin Map.

This section of the map shows an area along the Augusta – Rockingham County border (broken line running diagonally across the image). The different shades of green represent forested areas that were classified into several groups according to the degree which the humus had been damaged by fire. See Figure 27 in Appendix A for an image of the entire map. *Source*: (Ashe 1907) study area. Determining which maps contain a woodlands overlay requires examining each map sheet. While there are publications that list the date and name of when different maps were produced and contain maps of their geographiclocation (see for example Moffat 1985), there is no consistent catalog of which maps included a woodlands symbol, not even the records of map production at the USGS from the early twentieth century. The Historic Map Archive at the USGS is supposed to hold copies of every map produced by the USGS, but the collection is probably not complete (Lowell 2001). A manual search of the USGS Historic Map Archive identified maps for the entire study area, except one, that contained a woodlands symbol. The missing map was identified in another collection. While the maps were produced over the course of thirty years, the dates reflect multiple steps in the production of a paper map during this period of time. Up to five dates might appear on these maps. Three dates reflect different methods of collecting or verifying information: surveying, aerial photography, and field verification. The other dates represent the publication date and a reprint date if the map is reproduced at a later time. The earliest maps in this study primarily cover areas incorporated into the Shenandoah National Forest (now the George Washington and Jefferson National Forest) and Shenandoah National Park where land acquisition was taking place. The actual range of dates in field collecting and verification from the earliest to the latest is twenty-five years, about the time it might take for an abandoned field to covert to some type of forest. So the amount and location of forests and open space represented in this collection of maps will not account for any areas that were abandoned or newly cleared on the earlier maps.

The importance, definition, and techniques of mapping woodlands varied through time for the USGS. Early topographic manuals from the USGS focus on technical aspects of determining locations and elevations based on astronomic observations, base lines, triangulation, and traversing the terrain (Gannett 1906, originally published in 1893). The primary focus according to Gannet was on producing general topographic maps that could be used for many years without revision and does not mention including woodlands or trees in the features that could or should be mapped.

By the 1920's, the USGS had developed specific instructions for the inclusion of woodlands on standard maps. The 1928 USGS topographic manual contains explicit instructions for mapping woodlands. The manual states that the "outlines of woodland areas … should be mapped" and that the "accuracy in the location of woodland outlines for maps to be published on a scale of 1:62,500 will be based upon the location of the principal salient features only, the intermediate details between located points being sketched." Woodlands were defined as "all timber, woods, or brush, whether alone or mixed, of sufficient stand and height to impede ordinary travel or afford cover for small detachments or troops." In addition, "logged over or burned areas, if covered by second growth or brush, should be shown as woodland." The outlines produced in the field were later used to create the green woodlands layer on the printed map. The woodland edition of the printed map was usually limited to the first edition of the map, though the original woodlands layer could be included on later editions if it "fairly represents the condition at the time of reprint," tough it does not give any guidance on how to make this comparison (Beaman 1928, p 255-256, 344).

Eighteen 15 minute topographic maps (Figure 8) were needed to cover the two counties containing the North River watershed (United States Geological Survey 1922, 1930, 1931, 1937a, 1937b, 1939, 1941, 1943a, 1943b, 1945, 1946a, 1946b, 1947a, 1947b, 1947c, 1947d, 1949, 1950). Coverage of the entire counties was needed in order to compare calculations from the cartographic sources with the county level aggregate census data. Each map was scanned in a single pass at 800 dpi and saved as a 24-bit color TIFF file. Custom and existing automation tools were utilized to expedite the processing of the map data, without which the processing of so many maps would be impractical.

Each map (see Figure 9 and Figure 28 in Appendix A for examples) was georeferenced in ArcMap from ESRI using 12 latitude and longitude tic marks around the edge of each map using a custom point file. The point file was created by starting with the latitude and longitude values for each tic mark, which are five minutes apart. These values were converted from degrees, minutes and seconds to decimal degree values using the Microsoft Excel spreadsheet program and then saved as an ASCII text file. The text file was read into ArcMap as a table and used as X and Y source values to display points with the datum defined as North American Datum 1927. The points were saved as an ESRI Shape File and then projected to UTM coordinates (Zone 17 North, North American Datum 1927, Clarke 1866 spheroid) using ArcToolBox from ESRI. A new ArcMap session was used to display the UTM point file and georeference each raw TIFF file using the "georeferencing toolbar" in ArcMap.

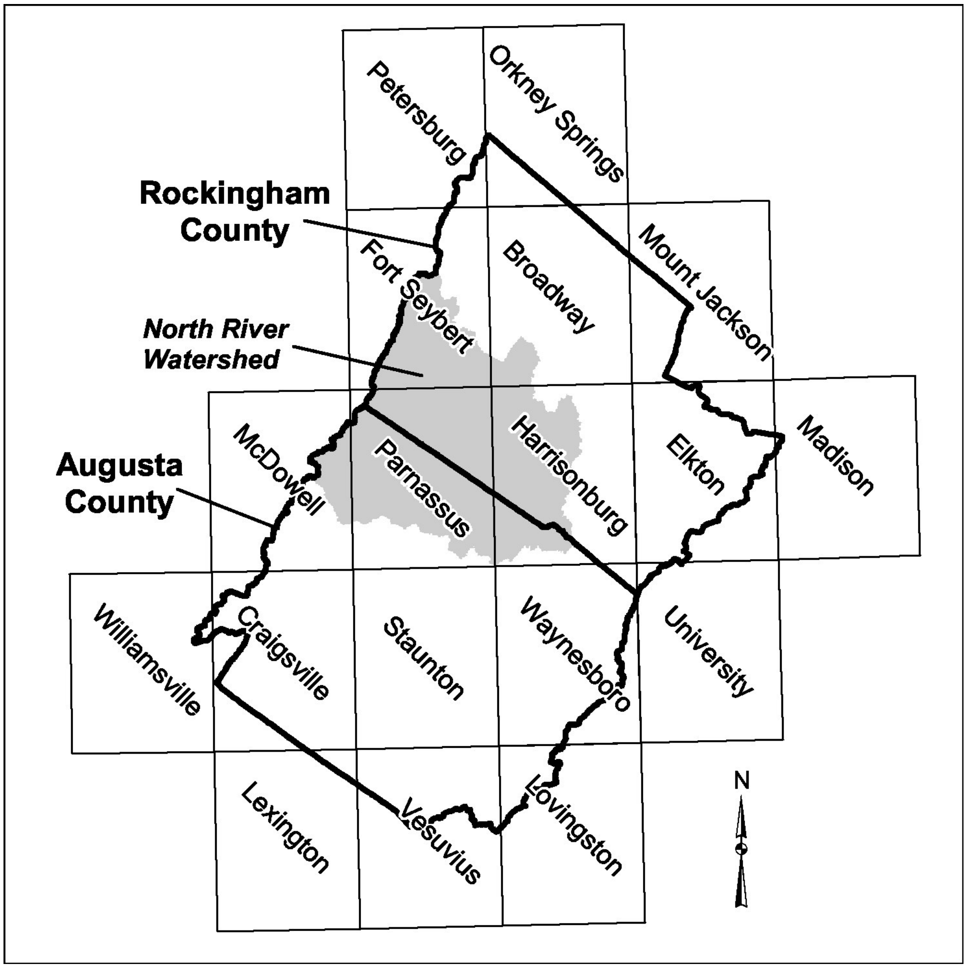

Figure 8: USGS 15 Minute Topographic Maps for Augusta and Rockingham Counties.
Source: Author.

Further processing of the images to generate a seamless woodlands data set requires the removal of the map border, or collar. Each georeferenced image was converted to an ESRI GRID stack and the collar was clipped using custom ArcInfo scripts and polygons generated to match the outer border of the map area for each map sheet (see Environmental Systems Research Institute 2002). A GRID stack was required because the TIFF files contained RGB (red, green, & blue) values and a single grid can only contain the values for one image band (red, or green, or blue). The collar was clipped from each band and then the stack was recreated.

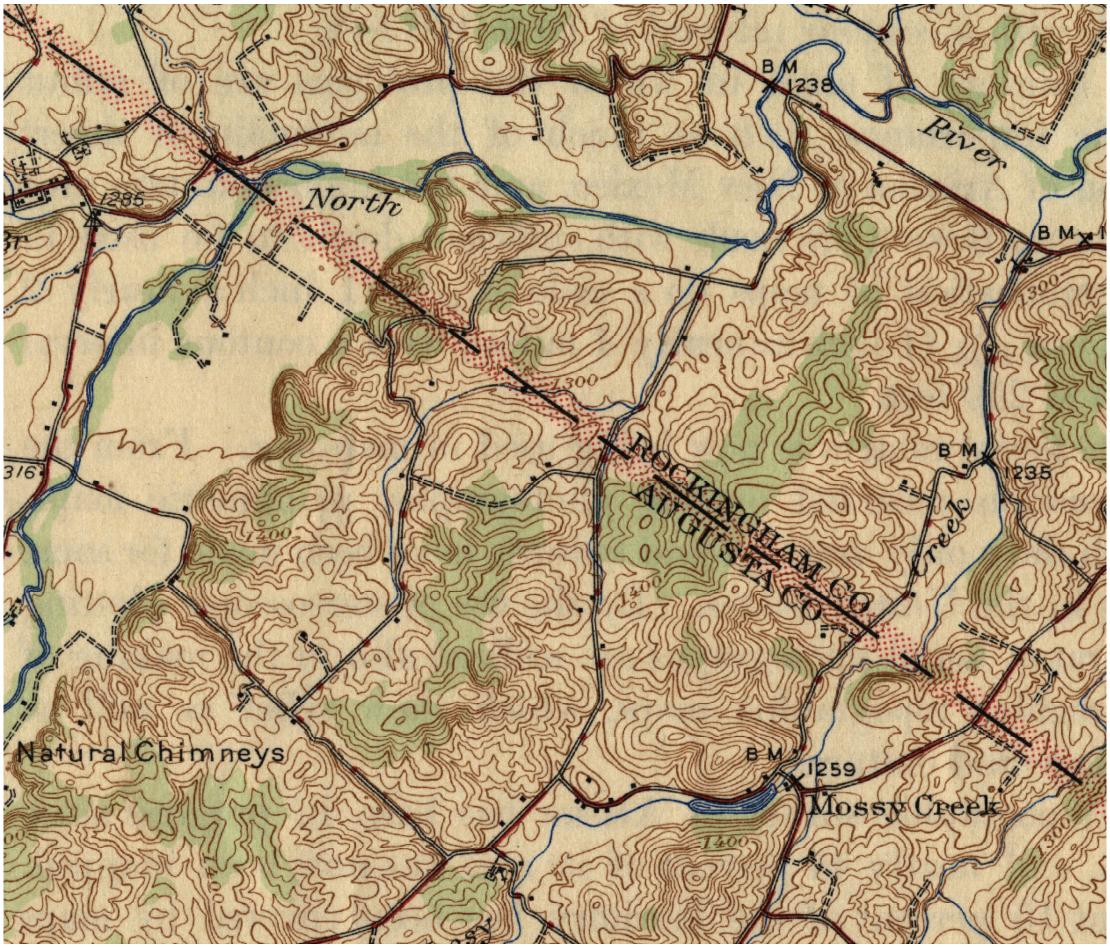

Figure 9: Details From the USGS Parnassus 15 Minute Topographic Map.

This section of the map shows an area along the Augusta – Rockingham County border. Black lines represent cultural features such as roads and political boundaries; brown lines represent contours; green areas represent woodlands; and text identifies places such as towns, and streams. See Figure 28 in Appendix A for an image of the entire map. *Source*: (United States Geological Survey 1947c)

In order to expedite the process of extracting the woodlands information from each map sheet, a commercial automated feature extraction tool was utilized. Feature Analyst uses machine learning technology to learn how to classify geographic features using examples provided by users of the program (Visual Learning Systems Inc. 2001). The program was developed with support from the National Imagery and

Mapping Agency (now the National Geospatial-Intelligence Agency) and the National Science Foundation. Simple image processing programs could have been used to extract all of the pixels with a green tint (color of woodlands symbology) from the scanned version of paper maps, but these would miss all areas that were intended to be represented by green (and the human eye would interpret as green) but were not due to the overlay of other symbols (e.g. contours) or lettering (e.g. place names) on the original paper map (see Figure 9).

Feature Analyst was trained to extract woodland areas through an iterative process to classify areas of symbol overlap the same as it would classify the green pixels by looking at the spatial pattern of the pixels. The training, done on one map, consisted of manually digitizing areas of woodlands with and without overlapping symbols, running the extraction process, and then adding and deleting areas from the initial results to identify correct and incorrect features. The learning and verification processes are repeated until the learned "model" is satisfactory. This model was developed on one map and then applied to the remaining seventeen maps. The program outputs a polygon shapefile representing the woodlands for each map sheet. The data from all 18 map sheets were merged together to create a continuous woodlands data file (Figure 10).

Potential Sources That Were Not Used

Some sources that were examined but determined to be of limited value in determining the location of forests and farm land in this study include U.S. Department of Agriculture soil survey and land classification maps, and aerial photography. A soil survey was published for Augusta County in 1932, but the descriptions associated with the map list characteristics of the soil and not what was present on the surface of the earth at the time for the survey (United States Dept. of Agriculture and Virginia Agricultural Experiment Station 1932). The land classification maps of Augusta and Rockingham Counties demarcated large areas that fit into broad generalizations of different land uses and the North River watershed

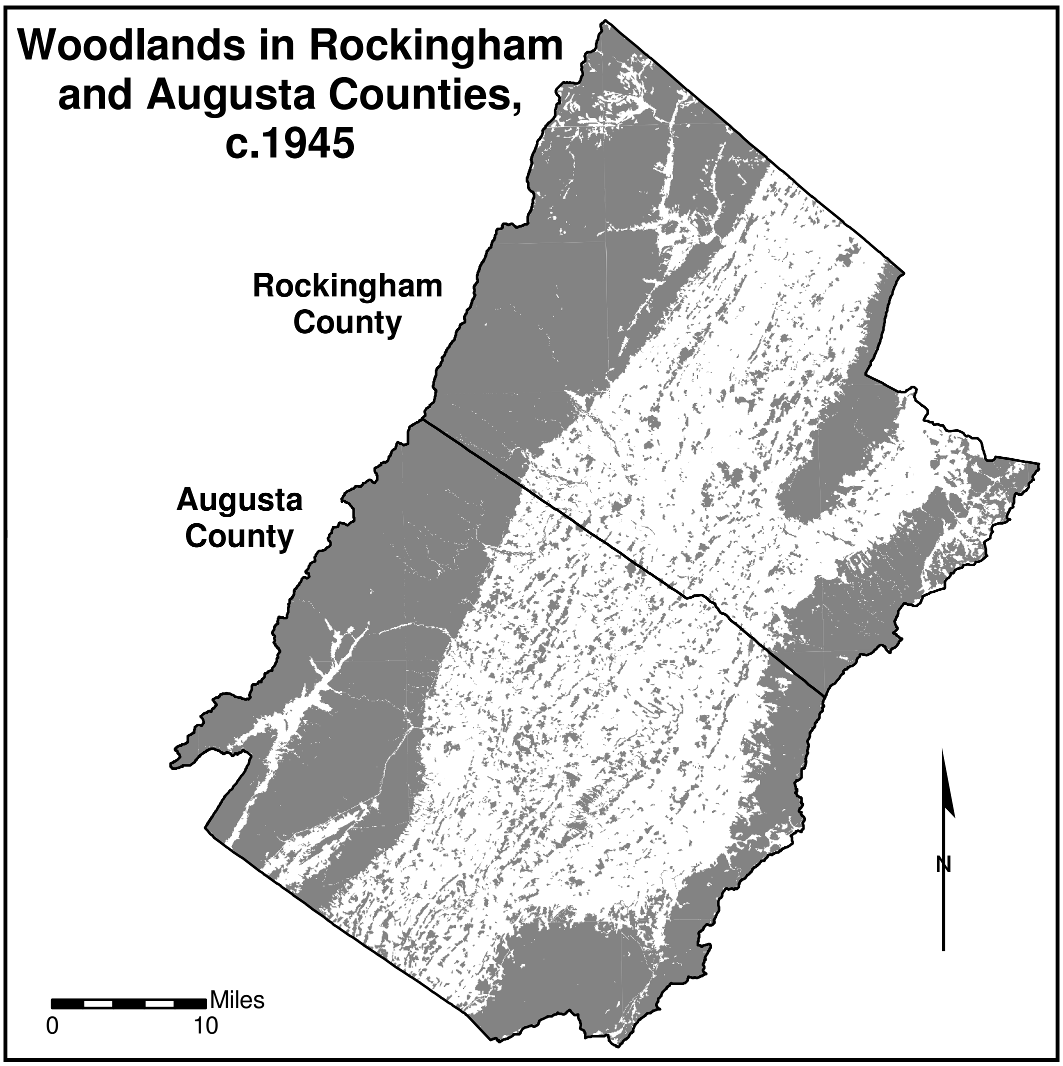

Figure 10: Woodlands in Rockingham and Augusta Counties, c. 1945.

Woodlands information was derived from eighteen USGS 15 minute topographic maps, merged together to form a continuous woodlands file, and then clipped by the county boundaries in order to compare the amount of non-wooded areas in each county with the amount of improved farm land recorded in the agricultural census for each county. *Source*: (United States Geological Survey 1922, 1930, 1931, 1937a, 1937b, 1939, 1941, 1943a, 1943b, 1945, 1946a, 1946b, 1947a, 1947b, 1947c, 1947d, 1949, 1950).

was only divided into a few discrete areas (Forest Service United States Dept. of Agriculture 1870 - 1989). While aerial photography was collected over the area several times from 1937 onward, it would take dozens if not hundreds of images to cover one or both counties for any one year(Taylor and Spurr 1973). Identifying, obtaining and processing the images for one or more years would be very expensive in time and money. Since there are other available and more easily processed data sources with suitable content and documented spatial and thematic standards, aerial photography was not utilized for comparison with the agricultural census information. A sampling of imagery could be used in the future to refine the understanding of land cover change for some small areas, but these micro-studies would not alter the interpretation of the broader trends at the county level or within the watershed.

Second-half of the Twentieth Century

Census Data

The agricultural census was collected every four to five years during the second half of the twentieth century, and statistical sampling techniques were introduced in the later part of the century. Beginning in 1964, acreage figures for pastureland and rangeland, other than cropland and woodland pastured, were only requested for farms with sales of agricultural products of $2,500 and over. Beginning in 1974, farms were defined as agricultural operations under individual management with annual sales of $1,000 or more (Virginia Agricultural Statistics Service 1999a, 1999b, 2004a, 2004b).

USGS Maps and Digital Spatial Data

The USGS produced a variety of products during the second half of the twentieth century that provided different levels of information regarding land use and land cover. Some maps representing a 1 degree by 2 degree area were produced in the 1950's and 1960's and printed at a scale of 1:250,000. The woodlands information on the maps covering the study area was a combination of data derived from the earlier 15 minute maps and aerial photography, and were deemed to be of no further use for this study. The USGS also published a detailed study and map for a small area in the western section of the study area during the 1950's. The area had been subjected to severe rainfall and flooding in 1949, one of the heaviest recorded rainfalls in the eastern U.S. at the time (Hack andGoodlett 1960). While useful for studying a sub-watershed of the study area, the report does not provide enough geographic coverage to be examined further at this time.

The next potentially useful sources from the USGS are maps produced in the continuing national mapping program. After mapping much of the United States with the 15-minute map series, the USGS moved to a 7.5-minute quadrant as the standard area of representation. 7.5 minute quad maps were produced for the study area during the 1960's and the early 1970's. A total of 47 maps are required to cover the entire study area. Some of the maps produced during this time period are already available in digital form, provided by the USGS as Digital Raster Graphic (DRG) files. The utility of these DRGs is lessoned by the fact that many of the existing files for the study area are for maps produced as photo revisions during the 1980's and 1990's, overlapping with later sources. Processing the original 7.5 minute quad maps in the same way as the earlier 15 minute maps was considered, but dropped in favor of utilizing another national source from the USGS.

A growing interest in the human alteration of the landscape and in processing data in computers drove the USGS to develop a series of land use and land cover (LULC) maps that were printed at scales of 1:250,000 and 1:100,000. Land use and land cover were derived primarily from NASA high-altitude aerial photographs, and National High-Altitude Photography (NHAP) program photographs, usually at scales smaller than l:60,000. Land use was categorized based on the Anderson Level II system. In order to provide the data in digital form, the Geographic Information Retrieval and Analysis System (GIRAS) file type was developed. These files were later converted to a more common industry supported format, the ArcInfo coverage, by the U.S. Environmental Protection Agency (Anderson 1976; United States Geological Survey 1986; United States Environmental Protection Agency 2004).

While the USGS LULC data is produced at a smaller scale (has a coarser grain) than the earlier 15 minute maps, it was determined to examine the utility of this data source for a couple of reasons. First, it is generally available in digital form for the entire U.S., and a detailed examination could prove useful for other studies. Secondly, the agricultural census from the same period showed this to be the beginning of a relatively stable period in the amount of improved agricultural land, and therefore did not warrant extensive efforts to get the best possible data. The files for the map sheets covering the study area were obtained, projected to match the other project data, and converted to shapefiles. The categories of land use and land cover were collapsed into wooded and not-wooded by adding a new attribute to the file and categorizing each existing code into one of these two more general classes.

Other Data Processing

County Boundaries

County boundaries for Augusta and Rockingham Counties were obtained from an administrative boundary file created by the Virginia Department of Conservation and Recreation (Huber 1995). The present boundaries for both counties were established in the early nineteenth century, prior to the creation of the agricultural census data analyzed in this study. The outer boundaries for both counties were used, eliminating the internal boundaries between the counties and independent cities (Harrisonburg, Staunton, Waynesboro) that exist wholly within their respective county boundary. These outer boundaries were used to clip the different temporal reconstructions of forested area in order to calculate the amount of un-forested and forested land contained in each representation for each temporal reconstruction.

1860 Census District Boundary

Since the c. 1864 Confederate Engineer's maps did not cover all of Augusta county and the original manuscript returns exist for the 1860 agricultural census, I determined to evaluate the possibility of reconstructing the census districts for 1860 in order to compare to the cartographically derived information. Boundary descriptions from the National Archives and Records Administration (NARA) were used in conjunction with an existing digital and georeferenced image of an 1870 county map in order to divide the county into the two districts used in the 1860 census (Hotchkiss 1870; United States National Archives and Records Administration 2002). The dividing line between the two districts was a series of roads that cut across the county from the east to the west. These roads were digitized from the 1870 map and intersected with the modern county boundary to create one polygon for each county district (Figure 11).

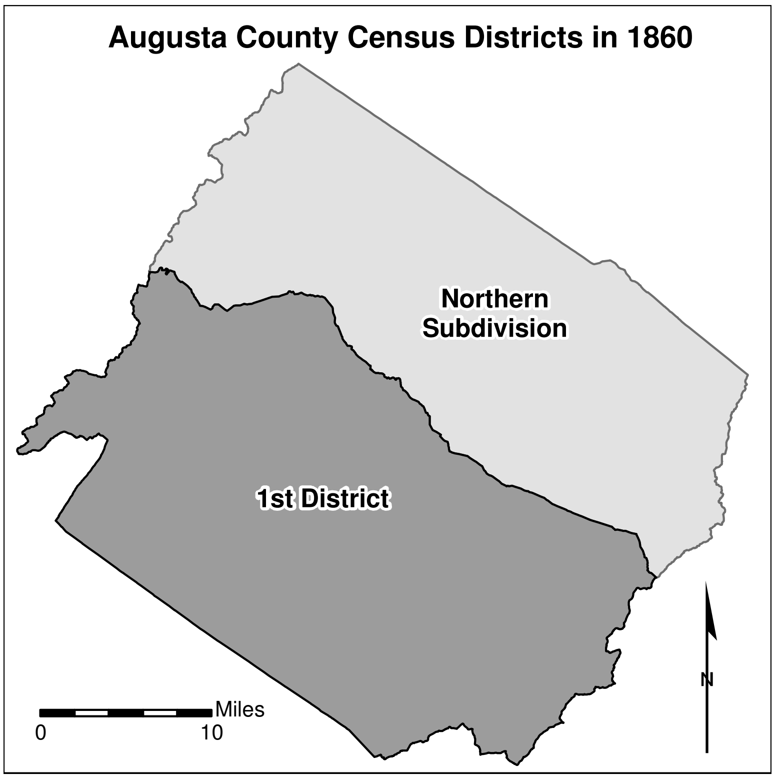

Figure 11: Augusta County Census Districts in 1860.

Federal census districts were derived from textual descriptions of the districts, a digital version of a historic atlas of Augusta County, and a modern county boundary data file. *Source*: (Hotchkiss 1870; Virginia Dept. of Conservation and Recreation 1995; United States National Archives and Records Administration 2002).

Watershed Boundary

The boundary of the North River Watershed was derived from the National Elevation and National Hydrographic Data sets using the ArcHydro tools and methods (Maidment 2002; United States Geological Survey 2004a, 2004b). Apparent sinks and other data irregularities were removed from the elevation data and then the hydrographic data was "burned" into the elevation data to form channels for water to flow into. A drainage point was identified and digitized at the confluence of the Middle and North Rivers. Then the watershed boundary was calculated based on an analysis of flow across the elevation model of the landscape above the identified point.

Mountain and Valley Designation

In order to examine the differences in landscape changes in the mountainous area versus the valley floor, a generalized soils data file was obtained and modified to differentiate between these two areas based on a visual comparison with the topography. The soils data came from the U.S. Environmental Protection Agency's "State Soil Geographic (STATSGO) Database for CONUS, Alaska, and Hawaii in BASINS" (United States Environmental Protection Agency 1998). Descriptions of the soils in the county soil surveys were analyzed in conjunction with the soils spatial data (Forest Service United States Dept. of Agriculture and Virginia Polytechnic Institute and State University 1979; Soil Conservation Service United States Dept. of Agriculture and Virginia Polytechnic Institute and State University 1982). The mountainous area was defined as being coincidental with soils formed in residual material weathered from sandstone, shale and greenstone geologic formations; and the valley was defined as being in areas where the soils were formed in residual material weathered from limestone, dolomite, and calcareous shale geologic formations.

Steep Slope Designation

Farming on steep slopes has been linked to erosion and sedimentation problems, and the abandonment of these areas has been linked to the rebounding of forest area. Areas where slopes were over 3% occurred were derived from the National Elevation Data (NED) from the USGS when the woodlands data for each time period was analyzed (described later in this chapter) with the ATtILA software. Slopes over 3% are the default value in ATtILA for determining areas on steep slopes because previous studies have indicated that soil erosion begins to increase above this point (Ebert et al. 2003; United States Geological Survey 2004a).

Public vs. Private Land

Early twentieth century federal conservation efforts, particularly through the acquisition and management of land, were targeted at protecting and improving areas deemed to have been overly exploited. In the Shenandoah Valley, the Shenandoah National Park and what is now known as the George Washington and Jefferson National Forest were both initiated in the early twentieth century, and the National Forest includes a portion of the North River watershed. A digital geospatial data set of the land owned by the National Forest was obtained from the agency and used in conjunction with the watershed boundary to determine which portions of the watershed were managed by the National Forest (George Washington and Jefferson National Forests 1999).

Comparing Census Data with Spatial Data Sources

A direct comparison of the amount of open space or agricultural land derived from the spatial data sets with the agricultural census provides a means of evaluating the content of the maps and digital spatial data sets. The amounts of open space within Augusta or Rockingham County derived from each forest reconstruction were compared to the amount of "improved" farm land contained in the most relevant census data set. Details of the comparison are presented in Chapter 4: Analysis.

Forest Changes within the North River Watershed

A direct comparison of the reconstructions at different time periods within the watershed is best conducted when the data have been harmonized to the same minimum mapping unit. Based on published standards and examination of the data sets in the GIS, I determined that the USGS LULC data had the largest threshold for the minimum area to be mapped, 40 acres (16.2 hectares), so all of the other data sets were processed to remove any polygons less than 40 acres (16.2 hectares). The smaller polygons were merged into the adjoining polygon with the largest adjoining edge (While no minimum mapping standards were published for some of the maps, these data sets were found to have multiple polygons of less than 40 acres. See Beaman 1928; United States Geological Survey 1986, 2004d; Data harmonization issues are discussed in Petit 2001). The harmonized forest data for each time period were analyzed within the watershed boundary using a landscape analysis program known as ATtILA (Ebert et al. 2003). The program was used to calculate the percent forest and the percent of non-forest for the entire watershed, on steep slopes, and in mountainous and valley areas. Pairs of reconstructions were combined to examine changes from one date to the next. The valley portions of these paired reconstructions were also analyzed to examine the shifting forest patterns within the valley portion of the watershed.

Chapter 4: Analysis

> "The Valley has nearly half its surface covered by a growth of oaks, hickories and locusts, interspersed with black and white walnuts, yellow and other pines, all having a uniform age of 150 to 200 years. This timber, while not the largest, is of the very best quality, and no well settled portion of the Union can offer a larger quantity of timber suitable for wagon, carriage, railroad car, cabinet and other work, for which hard, sound and durable woods are required."
> Jedediah Hotchkiss writing in the late nineteenth century about the forests of the Shenandoah Valley (Hotchkiss 1876).

When and Where Were Forests Cleared and Allowed to Grow Back?

Determining when and where the forests of the North River watershed (Figure 12) were cut and allowed to grow back is not a simple task. In the absence of detailed histories for the area, initial interpretations were drawn from existing regional analysis. Federal reports from the early twentieth century indicate that the maximum amount of agricultural, or cleared, land along most of the east coast likely occurred in the late nineteenth or early twentieth century. A 1917 bulletin from the U.S. Department of Agriculture looked at farm land changes between 1880 and 1910 and noted that in the Eastern States, the area of unimproved and un-wooded farm land increased over 34%, while total farm land increased less than 12%. The report also stated that in New England, the decrease in farm land was due to the abandonment of "rough, unprofitable farms." For Virginia, the report indicated that farm land as a percent of the total area decreased from 77.0% to 75.6% (Frothingham 1917 p. 11). While national in scope, the 1933 publication *A National Plan for American Forestry* continues to document the decline in farm land and indicates that there were 26,000,000 acres of abandoned farm land and an additional 22,000,000 acres of idle and fallow agricultural land that could be converted to forests through passive or active means. This report also states that the peak in farm land in Virginia was reached in 1910, though the 1917 report showed a decline from 1880 to 1910 (United States Forest Service 1933).

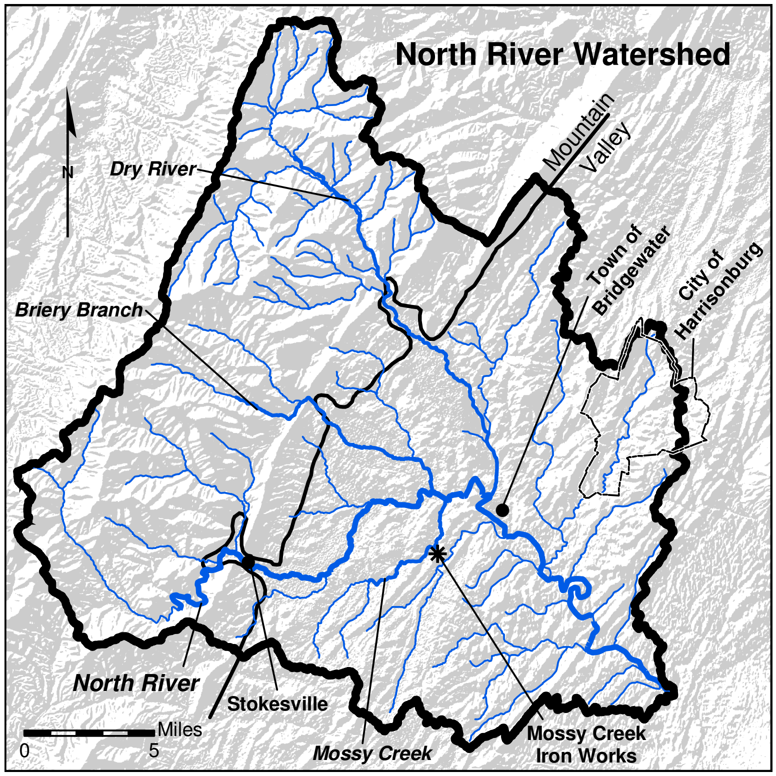

Figure 12: North River Watershed.

The North River watershed contains mountainous areas and portions of the Shenandoah Valley. The North River starts in the mountains and combines with other, smaller streams and rivers as it traverses through the Shenandoah Valley. *Source*: (Forest Service United States Dept. of Agriculture and Virginia Polytechnic Institute and State University 1979; Soil Conservation Service United States Dept. of Agriculture and Virginia Polytechnic Institute and State University 1982; United States Environmental Protection Agency 1998; United States Geological Survey 2004c, 2004a) and author.

Modern analysis of forest clearance and re-growth reinforces the notion that the maximum clearance of forests likely occurred in the late nineteenth or early twentieth century. John Fraser Hart's 1968 article and maps on the subject show the majority of the counties in the eastern United States, including the study area, as loosing farm land between 1910 and 1959 (Hart 1968). Michael Williams' 1989 publication, *American's and Their Forests: A Historical Geography*, does not provide any detailed information about the study area and makes extensive use of Hart's 1968 study and the 1933 forestry report in his chapter on "The rebirth of the forest" (Williams 1989). Williams' recent book on global deforestation adds nothing new for the study area (Williams 2003). The Chesapeake Bay Program study of trends for the entire Chesapeake Bay basin indicates the maximum clearance, or least amount of forest, occurred in the late nineteenth century (Chesapeake Bay Program 2004). A recent study based on sediment cores taken in the Chesapeake Bay also implies that the maximum amount of clearance took place around the turn of the twentieth century. The study included the analysis of pollen from *Ambrosia* (ragweed), a plant that quickly establishes itself on cleared land. The first and largest spike in *Ambrosia* pollen at multiple sampling sites is dated between 1880 and 1920, and the sample taken near the mouth of the Potomac River spiked around 1890 (Willard, Cronin, and Verardo 2003).

One of the primary sources used in the studies mentioned above is the federal agricultural census. While variations in the attributes used and the level of spatial aggregation can make comparisons problematic, comparing these published interpretations with the same data for a local area is at least a starting point in determining whether the local area underwent a similar historical development. The agricultural census data for Augusta and Rockingham Counties, which contain the North River watershed, show potential discrepancies between the regional and local trends in forest clearance and re-growth (Figure 13). Total farm land does peak in the late nineteenth and early twentieth centuries, but "improved" farm land peaks later, particularly in Augusta County (Virginia Dept. of Archives and History 1965; United States Dept. of Agriculture 1997; Geospatial and Statistical Data Center University of Virginia 2004; Virginia Agricultural Statistics Service c.2000). Hart's study looked at census data for 1910 and 1959, which in this case missed the apparent peak in improved farm land for both counties.

The drop in improved farm land in 1940 may have been caused by multiple factors. The number of farms dropped in multiple areas of the United States and the Bureau of the Census investigated why this happened. The 7th district in Virginia included the Shenandoah Valley and its supervisor wrote several letters to the Bureau's field division chief regarding this matter. According to the supervisor, the number of farms in Augusta County decreased due to some areas of the county being incorporated into Shenandoah National Park and changes in employment characteristics in the area. The supervisor wrote that "in 1935, due to economic conditions, the tendency of the people was back to the farms, as quite a lot of the industrial plants were closed down. At the present time [July 5, 1940] all of the industrial plants are running at full capacity, therefore quite a number who once were farmers are now working in industrial centers." The same supervisor sent additional letters with similar explanations for other counties in the area, but no letter for Rockingham County existed in the files (United States Bureau of the Census 1940). While the letters address the number of farms and not the amount of improved farm land, it is reasonable to conclude that the amount of land would also decrease. The increase in improved farm land in Augusta County by 1945 may reflect that these lands were only temporarily abandoned. The rebound in the amount of improved farm land in Rockingham County did not make it back to the 1935 level.

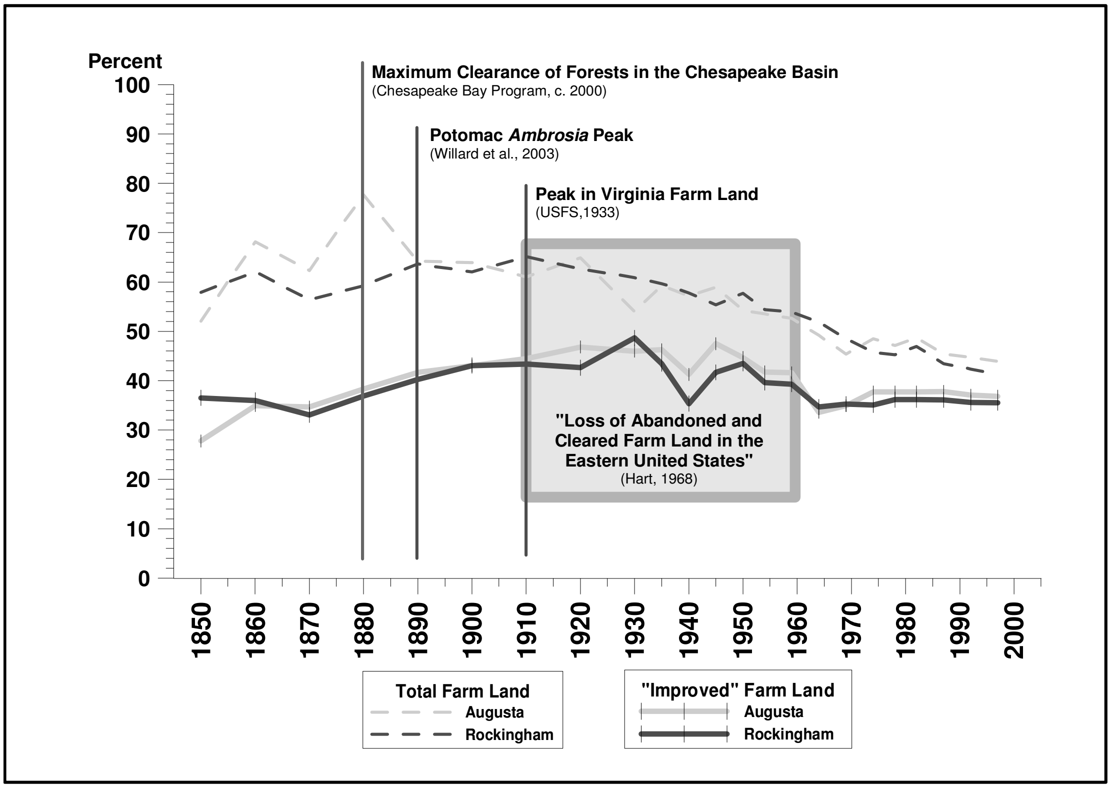

Figure 13: Farm Land - Census Data and Published Reports.

While total farm land peaks in the late nineteenth and early twentieth century for Augusta and Rockingham counties, "improved" farm land peaks later in the twentieth century. Improved farm land includes areas such as crop lands, pastures, and fallow fields. Multiple published reports reinforce the notion that maximum clearance was reached in the late nineteenth or early twentieth century: (1) the Chesapeake Bay Program indicates that maximum clearance for the entire Chesapeake Basin occurred around 1880; (2) the maximum *Ambrosia* peak at a sampling site near the mouth of the Potomac River has been dated to around 1890; (3) the U.S. Forest Service reported in 1933 that the maximum amount of farm land in Virginia was reached in 1910; and (4) John Fraser Hart found an overall decline in farm land between 1910 and 1959. Tic marks along the "improved" farm land graph line represent the year of the census. *Source:* (United States Forest Service 1933; Virginia Dept. of Archives and History 1965; Hart 1968; United States Dept. of Agriculture 1997; Virginia Agricultural Statistics Service 1999a, 1999b; Willard, Cronin, and Verardo 2003; Chesapeake Bay Program 2004; Geospatial and Statistical Data Center University of Virginia 2004; Virginia Agricultural Statistics Service c.2000)

Independent sources of information are needed in order to determine if the discrepancies found between the agricultural census data and the published reports actually reflect differences in changes on the landscape. More detailed information is also needed to examine changes within the North River watershed, since the agricultural census information is only available at the county level for the entire period being examined. A direct comparison of the amount of improved agricultural land, or open space, derived from the agricultural census with information derived from cartographic and digital spatial data sets provides one means of independently verifying these differences. If the census data and the more spatially explicit information derived from cartographic and digital spatial data sets correspond well, the latter can be used to examine changes within the watershed.

The amounts of open space within Augusta or Rockingham County derived from each forest reconstruction (1864, 1906, c. 1945, c. 1974, and c. 1992) were compared to the amount of “improved” farm land contained in the most relevant census data set. Open spaces on the maps were compared to improved agricultural land from the agricultural census for the first three sources. Since the USGS LULC and NLCD data provided more refined categories of land use and land cover, only agricultural categories were compared with the improved agricultural land from the censuses for these periods. The differences between the two types of sources for each comparison are below 3% (Table 3). The amount of non-wooded or open areas derived from the cartographic sources matches well with the census data for improved farm land, and the amount of agricultural land derived from the digital spatial data sources matches well with the agricultural census data for improved farm land.

With two independent sources of information confirming the discrepancy between local and regional timing of forest clearance and re-growth, a more detailed analysis of the area is warranted. A typical geo-historical approach can be utilized to examine the issue in some detail, but the introduction of verified spatially explicit information derived from the cartographic and digital spatial data sources allows for more localized and more detailed analysis using geo-computational methods. Both of these approaches will be utilized to trace the changes in the forests and farm land over the last three centuries.

Table 3: Comparing Cartographic and Digital Spatial Data Sources with Agricultural Census Data.

Open spaces on the maps were compared to improved agricultural land from the agricultural census for the first three sources. Since the USGS LULC and NLCD data provided more refined categories of land use and land cover, only agricultural categories were compared with the improved agricultural land from the censuses for these periods. The amount of non-wooded or open areas derived from the cartographic sources matches well with the census data for improved farm land, and the amount of agricultural land derived from the digital spatial data sources matches well with the agricultural census data for improved farm land. *Source*: (Confederate Engineer Bureau 1864; Hotchkiss 1870; Ashe 1907; United States Geological Survey 1931, 1937b, 1939, 1941, 1943a, 1945, 1946a, 1946b, 1947c, 1947d, 1949; Virginia Dept. of Archives and History 1965; United States Geological Survey 1986; Virginia Dept. of Conservation and Recreation 1995; United States Dept. of Agriculture 1997; Virginia Agricultural Statistics Service 1999a, 1999b; United States National Archives and Records Administration 2002; United States Geological Survey 2004d; Geospatial and Statistical Data Center University of Virginia 2004; Virginia Agricultural Statistics Service c.2000).

Location and area compared	Map or Digital Spatial Data			Ag. Census		Difference between sources
	Source	Date	% Open (Ag.)	Date	Improved Ag.	
Augusta Co., Northern Subdivision	Confederate Engineers' Map	1864	44.2%	1860	44.7%	0.5%
Rockingham Co.	USGS Potomac River Study	1906	45.2%	1900 1910	43.1% 43.4%	2.1% 1.8%
Augusta Co.	USGS 15' Maps	c. 1945	48.3%	1945	47.5%	0.8%
Augusta Co.	USGS LULC	c. 1974	(40.3%)	1974	37.7%	2.6%
Augusta Co.	USGS NLCD	c. 1992	(37.6%)	1992	37.1%	0.5%

"Primeval" Forest at the time of Initial European Settlement

The North River watershed was predominately forested before European settlers arrived in the area. Storms, fires, insects and diseases would have created a forest mosaic in different states of succession, and some naturally occurring clearings may have existed along streams and rivers or in areas deforested due to natural calamities. Historical and modern analysis of the natural or potential vegetation of North America indicates this area was part of the Eastern hardwood forest. The forests of the Shenandoah Valley and surrounding mountains have been variously described by different researchers as oak – chestnut, oak – hickory – pine, chestnut – chestnut oak – yellow poplar, and yellow – pine hardwoods (Robison 1960; Braun 1967; Wright 1971; Silver 1990). Pollen studies of eastern North America also suggest that the area was forested and analysis of two sites in the Shenandoah Valley provide more detailed descriptions of the forests of the region. The sites are located on the valley floor of eastern Augusta County and show a predominantly oak-pine forest persisting in the area for over a thousand years before the present. In this study, Alan Craig also produced a map of the natural vegetation present in the late twentieth century and showed the valley floor as being dominated by a oak – hickory – pine forest, the Blue Ridge Mountains as being an Appalachian Oak forest, and the first ridges on the western edge of the Shenandoah Valley as being covered with northern hardwoods (Craig 1969).

The Shenandoah Valley was occupied by Native American populations as far back as 10,000 BC, but the area is believed to have only seen periodic or seasonal use by small groups for a hundred years or more before Europeans arrived (Mitchell 1977, p. 16-22). While villages of inhabitants that practiced sedentary agriculture existed in the Shenandoah Valley, and these settlements would have required the clearing of some land, their impact would have been localized (Diamond and Giles 1987). While no comprehensive survey has been undertaken for the entire North

River watershed, no village sites have been documented in the watershed (Virginia Dept. of Historic Resources 2004).

The impact of the Native American population on the forests of the region has been debated for many years. An early nineteenth century history of the region claims that "aged informants" indicated the area was predominately a large prairie at the time of settlement, even though the area was covered with forest at the time he wrote the book. The editor of the fourth edition of Kercheval's book, Oren F. Morton, adds a note indicating that he believes the prairies were artificially produced by Indians who would burn the area at the end of hunting season to prevent the forests from regenerating. The editor goes on to say that these clearings made settlement of the area by whites fast and easy (Kercheval 1925, p. 52). Additional credence for the artificially open landscape comes from a late nineteenth century source. While not stated in the context of claiming the Valley was open at the time of settlement, an 1876 publication claims that the trees of the Valley floor were uniformly 150 – 200 years old, placing their origin to somewhere between 1676 and 1726 (Hotchkiss 1876).

The "fact" of an open valley floor has been used over and over again by later historians and researchers but not substantiated. A reference to the Valley floor being open at the time of settlement is included in an early twentieth century report on the soils and forests of the region by the Forest Service bureau of the Dept. of Agriculture (Parker et al. 1907). The idea of Indians burning the grasslands in the Valley is still being used by modern scholars. T. M. Bonnicksen includes a reference to this "fact" in his book, *America's Ancient Forests*, though it is hard to determine what he bases this on since the sources cited in the book appear to be incorrect and are duplicated from a later note in the publication dealing with the western coast of North America (Bonnicksen 2000, see notes 267 & 269).

More recent studies of the vegetational history in the area discredit these claims and suggest that some of these earlier interpretations come from careless research and inappropriate use of descriptions of areas far removed from the Shenandoah Valley (Robison 1960; Diamond and Giles 1987). Land survey records from the earliest European inhabitants also imply a limited amount of cleared area. A study of witness trees and other property boundary markings from an area encompassing over 500 square miles (1295 sq. km.) in the Northern Shenandoah Valley concluded that there were only limited amounts of open space in that area at the time of initial European settlement, stating that the "valley floor appears to have been covered with a complex forest-grassland mosaic" and "areas of open or lightly wooded grassland were caused primarily by natural processes along river and stream flood plains" (Mitchell 1998, p. 22). In addition, there were few references to "old fields", areas presumed to have been abandoned agricultural fields (Mitchell, Hofstra, and Connor 2001).

A small collection (approximately 500 points) of previously collected witness tree and other property makers recorded in the eighteenth century for an area of the earliest settlements within the North River watershed (primarily surrounding Mossy Creek), representing the survey of approximately 10,000 acres (4047 hectares, approximately 4% of the North River watershed) contained no references to "old fields" and only a couple of references to areas that might be treeless (e.g. meadows or barrens, for a general discussion of settlement in this area, see Wilson 1993). The nearly complete, if not complete, forest cover in the watershed was composed of a mixture of hardwoods and coniferous trees. The witness trees from the Mossy Creek area contained approximately 37% "pines" and the remainder were a variety of deciduous trees, though heavily dominated by white and black oaks.

European Settlement through the American Civil War (circa 1700 – 1865)

The forests in the North River watershed underwent significant changes beginning in the eighteenth century. Settlers began acquiring land in the North River basin in the first half of the eighteenth century as part of the flow of settlers coming down through the Shenandoah Valley from Pennsylvania as the colonial population expanded. The settlers were primarily of English, Scots-Irish, and German origins. Robert Mitchell has identified three levels of developmental and spatial change for backcountry settlements in the eighteenth century and the first phase is characterized by unspecialized farming and local commercialism. From Mitchell's research of settlements up to 1775 we can deduce that the earliest settlements in the North River area were dominated by Germanic and Scots-Irish groups in the areas around Long Glade and Mossy Creek, and that these ethnic groups were later joined by English settlers in the areas near the present-day City of Harrisonburg and town of Bridgewater in Rockingham County (Mitchell 1977, p. 1 - 14).

Most of the early settlements were in the Valley floor and date from the 1740's. The earliest land patents in the mountainous portions of the North River watershed date from the 1780's and 1790's (Forest Service United States Dept. of Agriculture undated). One of the early communities in the North River watershed developed along Mossy Creek, a small spring-fed stream (approximately 4% of the entire watershed) that drains into North River just west of the present-day town of Bridgewater. Previous research of the Mossy Creek area indicates that the earliest land acquired was prime farm land adjacent to the stream and areas where the stream could easily be damned to support the exploitation of water power.

Colonial laws required that settlers clear portions of land they settled; typically three out of every fifty acres (approximately 1 out of every 20 hectares) within three years. By 1760, 3083 acres (1248 hectares) had been surveyed for acquisition along Mossy Creek. Only 185 acres (75 hectares) would have been cleared by 1760 if the settlers only cleared the amount of land that was required. An additional 2259 acres (914 hectares) were surveyed by the American Revolution, 3/50th of which is 135 acres (55 hectares). So, by the American Revolution, there may have only been approximately 300 acres (121 hectares) of cleared land in the area surrounding Mossy Creek. The last quarter of the eighteenth century saw an increase of land surveys near Mossy Creek, with an additional 5291 acres (2141 hectares) being surveyed by 1800. If we assume that the amount of land cleared for agriculture continued to be 3 acres out of every 50 acres (1 out of every 20 hectares) surveyed, an additional 317 acres (128 hectares) might have been cleared in the Mossy Creek area by 1800 (Wilson 1993).

The second phase of Mitchell's frontier model is characterized by the beginnings of urbanization and increased commercialism. Staunton, the seat of Augusta County, was settled in the 1730's and formally recognized in 1761 (Catlett and Fishburne 1928). Staunton is only eight miles (13.5 kilometers) south of the southern boundary of the watershed. Harrisonburg, the future seat of Rockingham County, was founded in 1780 and is in the northeastern portion of the watershed (Wayland 1912). Both are presently independent cities and located along the old Valley Pike, which roughly follows an old Indian trail trough the Valley.

Mitchell's third phase is characterized by more intense manufacturing, growing external contacts, and agricultural regionalization. During the eighteenth century, the local, subsistence oriented economy of the Shenandoah Valley rather quickly shifted to an economy tied to the greater commercial world. Wheat became a regional specialization and a major export item from the rich agricultural lands in the region. Cattle were raised in the area and driven along the Valley Pike and other major roads to markets in Baltimore and Philadelphia. While agriculturally related commerce was important, other industries such as iron furnaces, saw and paper mills, and tanneries, sprang up to supply local and distant markets (Mitchell 1977).

The diversification of the economy and ties to distant markets are evident in the North River watershed and can be illustrated through the activities of one individual. Henry Miller grew up in Pennsylvania and began acquiring land in the North River watershed in 1774 along with his partner, Mark Byrd, the owner of the Hopewell Furnace in Pennsylvania. Jointly they created the Mossy Creek Iron Works on Mossy Creek and continued to acquire land in the area, much of it in the North River watershed. While Byrd sold his share of the business to Miller in 1779, the enterprise continued to expand until Miller's death in 1798. The iron works was in operation by 1775 and was one of the two Valley iron woks mentioned by Thomas Jefferson in his *Notes on the State of Virginia* (Wilson 1993; Jefferson and Shuffelton

1999). Miller and Bird may have acquired the initial portions of the iron works from earlier industrial entrepreneurs. John Pearse's history of iron manufacturing published in 1876 indicates that the Mossy Creek furnace was built in 1760 and burnt in 1841. Pearse also indicates that the forge was built in 1757 and rebuilt in 1767 and 1836 (Pearse 1876).

During the eighteenth century iron was smelted on the American frontier with charcoal produced through a slow and controlled process of burning of wood. Furnaces used to produce pig iron and cast iron products were called charcoal blast furnaces because of their use of charcoal and forced air to increase the heat of the fire. Limestone was used in the furnaces as a flux to assist in the removal of impurities (Mulholland 1981). According to Thomas Jefferson's *Notes on the State of Virginia*, the Mossy Creek Iron Works was producing about 150 tons (136 metric tons) of bar iron and 600 tons (544 metric tons) of pig iron annually (Jefferson and Shuffelton 1999). Similar quantities of iron were being produced at other iron works in the northern Shenandoah Valley and east of the Blue Ridge Mountains. These frontier iron communities provided goods for local and distant markets. From 1777 to 1784, Miller is known to have sold bar iron, cast products and 'specialty steel' to Col. James Madison in Orange County, which is across the Blue Ridge Mountains (Madison 1776-1817). Other products cast at the Mossy Creek Iron Works included stove plates, kettles, paper weights, and bowls (Smith 1968; Museum of Early Southern Decorative Arts 1992).

The Mossy Creek "iron works" was actually a diversified industrial plantation run by hired, indentured and slave labor. In addition to the iron furnace and forge, Miller had a maple sugar camp in the mountains of the North River watershed and grist, saw and paper mills. While in modern times paper is often made with wood fibers, rags were used in the eighteenth and early nineteenth centuries and were used at Miller' paper mill (Goodrich 1831; Miller c. 1798). Miller was also one of the largest cattle owners in Augusta County during the eighteenth century and his herd included an imported bull and an English heifer and cow, which were purchased in Baltimore County, Maryland (Mitchell 1977; Wilson 1993; Miller c. 1798).

The impact of Miller's iron woks on the forests in the region during the last quarter of the eighteenth century has been estimated to have required the cutting of 5700 – 8700 acres (2300 – 3500 hectares) of timber to produce enough charcoal to maintain the production figures mentioned by Thomas Jefferson (Wilson 1993). While records do not exist to establish if all of the charcoal came from timber in the North River watershed, the requirements of the iron works would only have required the clearing of approximately 2 – 3.3% of the watershed. In comparison, the amount of land cleared for agriculture in the Mossy Creek area in the eighteenth century has been estimated to have been approximately 600 acres (240 hectares), which is approximately 0.2% of the North River watershed.

While the Mossy Creek area was the earliest area settled in the watershed, other portions of the watershed were also settled in the eighteenth century. In order to get a rough estimate of the relative importance of the iron works and agriculture in driving the clearing of land, we can use the land clearance estimates for the entire "valley" portion of the watershed. The valley portion of the watershed is approximately 140,000 acres (56,655 hectares), which is about 52% of the entire watershed. If three of every fifty acres (1 out of every 20 hectares) were cleared in the entire area, approximately 8,000 acres (3237 hectares), or 3% of the entire watershed, would have been cleared. So the amount of land that might have been cleared for agriculture is about the same as the amount of land that would have been cut to produce charcoal for the iron works. Miller owned over 8,000 acres (3237 hectares) when he died in 1798, so it is unlikely that the land cut for charcoal production was the same land cleared by others for agriculture (Wilson 1993). While these estimates of cleared or cut-over lands are crude, they provide a rough idea of the amount of forest that would have been impacted by the end of the eighteenth century.

By the end of the eighteenth century the Shenandoah Valley had become "one of the most important wheat- and flour-producing regions of the entire South" and the nineteenth century saw the continued expansion of the population and agricultural activities in the region (Mitchell 1977, p. 175). The populations in Augusta and Rockingham counties (including the independent cities located within their boundaries) increased from 10,886 and 7,449 in 1790 to 27,749 and 23,408 in 1860 (Geospatial and Statistical Data Center University of Virginia 2004). Augusta County had been formed from Orange County in 1738 and Rockingham County had been split off from Augusta County in 1777 (Wayland 1912; Peyton 1953). While the population figures in the census represent changing geographical areas from 1790 to 1860, the overall trends are still indicative of an increase in population since the size of the counties decreased over the same time period. The city limits of Harrisonburg were expended in 1797, 1849, and 1858 (City of Harrisonburg 2003).

Additional federal censuses provide a glimpse into the local economy and activities that impacted the forests of the area in the nineteenth century. The first federal census related to manufacturing was taken in 1810, and while it is generally seen as flawed and incomplete, it does record some industries in Augusta and Rockingham Counties (Wright 1900). In Augusta County there were 3 blast furnaces, 1 trip-hammer, 3701 spinning wheels, 314 stills, 6 carding machines, 3 fulling mills, 10 tanneries, 6 flaxseed-oil mills, 1 paper mill, 3 potteries, 58 wheat mills, and 40 saw mills. In Rockingham County, there were 2 forges, 20 stills, 7 carding machines, 3 fulling mills, 14 tanneries, 4 flaxseed-oil mills, 116 distilleries, 48 wheat mills, and 44 saw mills (Coxe 1813).

The first federal agricultural census was taken in 1840, but it was not until the next census in 1850 that information on the amount of land in farms was recorded (Wright 1900). In the 1850 census farm land was recorded as either improved or unimproved. Improved farm land was defined as land that was "cleared and used for grazing, grass, tillage, or which is now fallow" and unimproved farm land was to include land such as a woodlots which were owned in connection with the farm and whose timber or range was used for farm purposes (Carroll Davidson Wright 1900, p. 99 – 106, 235). In the 1850 census (Figure 14), Augusta County had 178,695 acres (72,314 hectares, 27.8%) and Rockingham County had 203,530 acres (82,364 hectares, 36.5%) of improved farm land (De Bow 1853).

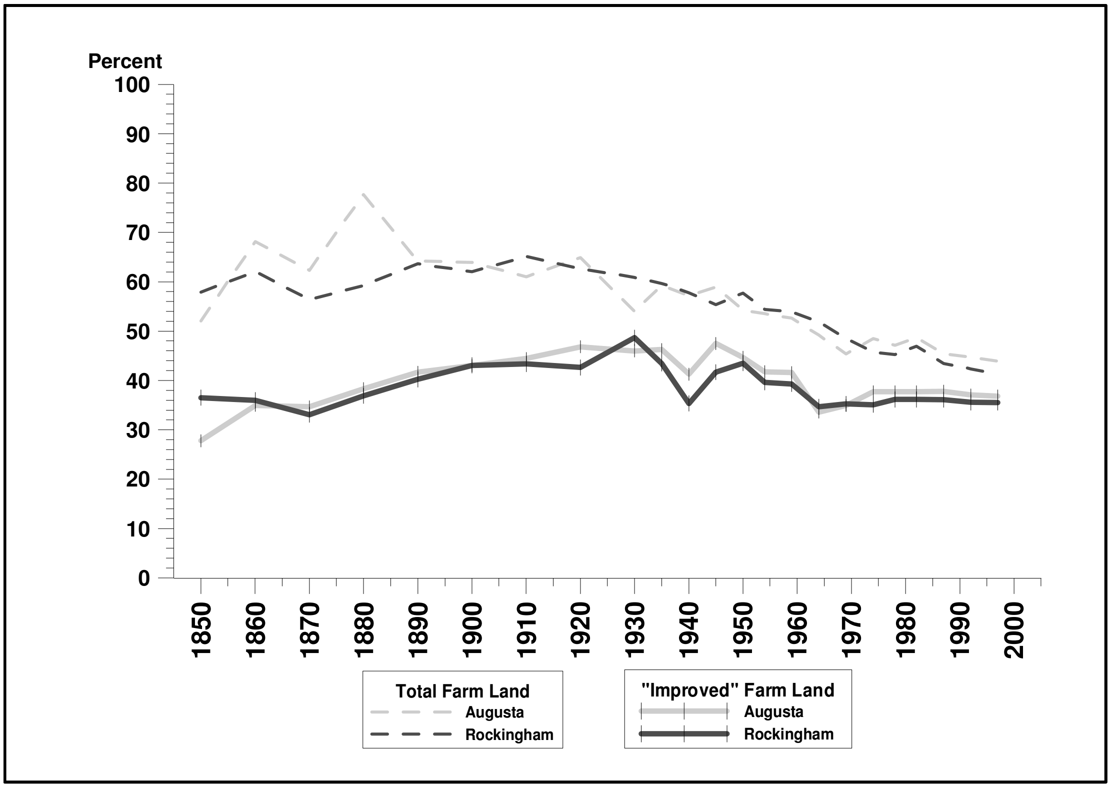

Figure 14: Farm Land in Augusta and Rockingham Counties, Virginia, 1850 – 1997.

While total farm land peaks in the late nineteenth and early twentieth century for Augusta and Rockingham counties, "improved" farm land peaks later in the twentieth century. Improved farm land includes areas such as crop lands, pastures, and fallow fields. Tic marks along the "improved" farm land graph line represent the year of the census. *Source:* (Virginia Dept. of Archives and History 1965; United States Dept. of Agriculture 1997; Virginia Agricultural Statistics Service 1999a, 1999b; Geospatial and Statistical Data Center University of Virginia 2004; Virginia Agricultural Statistics Service c.2000)

Whether it was initially cleared for farm land or for the production of charcoal, the landscape surrounding the Mossy Creek Iron Works was fairly denuded of trees by the time the 1850 census was collected. A circa 1848 sketch (Figure 15) by Jedidiah Hotchkiss shows the openness of the landscape and a grist mill situated along the creek (Hotchkiss 1848). The iron furnace, forge, and other buildings were situated to the left of the mill in the picture. Hotchkiss, who later became well know as General "Stonewall" Jackson's topographic engineer, had come to the Mossy

Creek community in the 1840's to be the tutor for an iron master's children and it was while he was in the Mossy Creek community that he taught himself the principles of map making and engineering (Hotchkiss and McDonald 1973, p. xvii).

Figure 15: Mossy Creek Landscape c. 1848.

This sketch is one of two similar sketches in Jedediah Hotchkiss's personal diary from his early years at the Mossy Creek Iron Works. Notice that the landscape is fairly denuded of trees. The Mossy Creek Mill stands in the left foreground, and other buildings associated with the iron works can also be seen in the drawing. The original furnace and forge stood within one hundred yards (91 meters) to the left of the mill. *Source*: (Hotchkiss 1848).

By 1860 improved farm land had increased in Augusta County to 224,644 acres (90,909 hectares, 34.9%) but had fallen slightly in Rockingham County to 200,803 acres (81,261 hectares, 36.0%) (Kennedy and Whitman 1864). Wheat and flour production continued to be important to the local economy and Augusta County had 62 flour and meal manufacturers and Rockingham County had 24 in the 1860 census. Other aspects of the economy showed some shifts in the number of establishments but a continuance of a diversity of enterprises. Distilling, tanning, and lumbering remained active in both counties, as did iron production; though the Mossy Creek Iron Works is generally believed to have ceased operation by the Civil War (Edmunds 1865; Pearse 1876).

The American Civil War drew men away from the region and temporarily halted the expansion of farm land (see Figure 14). While the amount of improved farm land dropped slightly by 1870, the area continued to be an important farm region during the Civil War and has been referred to as the “breadbasket of the Confederacy” (Heatwole 1998, p. 2). The agricultural significance of the region to the confederacy was underscored and ended by Sheridan’s burning campaign in 1864 where he directed his troops to burn barns, mills, and crops; and to kill or acquire livestock. “The burning” campaign spread from Staunton to the north and east, going up the Valley, and ran through the eastern portion of the North River watershed. The mill drawn by Jedediah Hotchkiss in 1848 was likely burned by federal forces that burned a mill and other buildings at the Mossy Creek Iron Works when they went through the area (Heatwole 1998, p. 42).

Protecting this agricultural base and the transportation corridor to and from the North and South was of concern to the Confederacy and the Valley saw several important military campaigns during the war. Detailed maps of the area became critically important and multiple mapping campaigns were undertaken (Brooks C. Pearson 2001). One mapping campaign was instigated in 1862, when General “Stonewall” Jackson made his famous request to his topographic engineer, Jedediah Hotchkiss, to “make me a map of the Valley” (Hotchkiss and McDonald 1973, p. 10). While the map is large (254 x 112 cm) and quite detailed, it does not contain information about the forests or cleared lands of the region (Hotchkiss 1862). The Confederate Engineer Bureau based in Richmond, Virginia also became engaged in mapping the area, and by 1864 the engineers had completed several maps of the region that included a representation of wooded areas (Confederate Engineer Bureau 1863, 1864). The Confederate Engineering Bureau maps provide the first cartographic source that can be compared to the agricultural census data to evaluate the amount and location of improved land and wooded areas. The amount of cleared land represented on the engineer's map (Figure 16) accounts for 40.6 % of the watershed (Table 4). However, almost all of the cleared land is in the valley portion of the watershed (76.6% of the valley), with less than 2% of the mountainous area cleared.

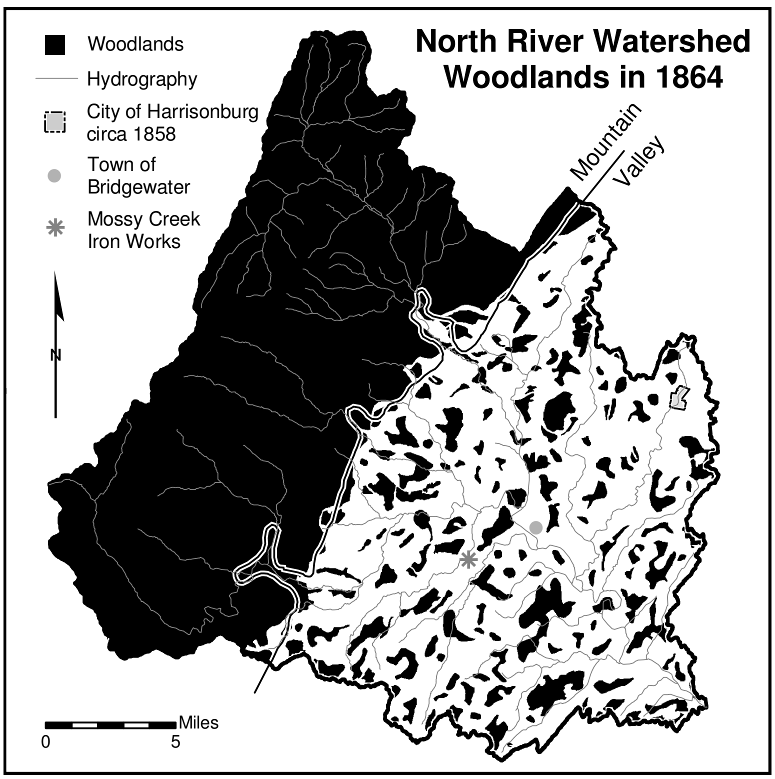

Figure 16: North River Woodlands in 1864.

The clearing of woodlands in the eighteenth and first-half of the nineteenth centuries primarily occurred in the valley portion of the watershed. *Source*: (Confederate Engineer Bureau 1864; Forest Service United States Dept. of Agriculture and Virginia Polytechnic Institute and State University 1979; Soil Conservation Service United States Dept. of Agriculture and Virginia Polytechnic Institute and State University 1982; United States Environmental Protection Agency 1998; City of Harrisonburg 2003; United States Geological Survey 2004c, 2004a) and author.

Table 4: Woodlands and Non-Woodlands in the North River Watershed.

The amount of woodlands in the watershed reached the lowest point in 1906 when the area is considered as a whole or just the mountainous area is considered; however, just like the county level analysis, the amount of woodlands in the valley portion of the watershed reached its lowest circa 1945. *Source*: (Confederate Engineer Bureau 1864; Ashe 1907; United States Geological Survey 1943a, 1946b, 1947a, 1947c, 1950, 1986, 2004d)

Date	Woodlands			Non-woodlands		
	Entire Watershed	Mountains	Valley	Entire Watershed	Mountains	Valley
1864	59.4%	98.1%	23.4%	40.6%	1.9%	76.6%
1906	50.4%	93.4%	10.7%	49.6%	6.6%	89.4%
c. 1945	52.5%	98.5%	9.9%	47.5%	1.5%	90.1%
c. 1974	54.5%	98.3%	13.9%	45.5%	1.7%	86.0%
c. 1992	56.3%	99.1%	16.7%	43.7%	0.9%	83.3%

While the quantity and location of the wooded areas is well represented by the combined census and cartographic data, the condition and type of forests or wooded areas are not. From these two sources we can not determine if the remaining trees were remnants of an original forest, or whether some or all of the forest was already cut over and what was present was from a second or third stage of growth. The type of forest, regardless of age, may not have changed much. A twentieth century analysis of the trees along the Fairfax Line, which forms part of the northern border of Rockingham County, concluded that the forest composition varied little between the witness trees recorded in the 1740's survey and trees present in the middle of the twentieth century (Strahler 1972).

The age of the forests in 1864 is more difficult to determine. Late-nineteenth and early-twentieth century sources indicate that the majority of the forests in the mountainous regions of the watershed had not been cutover by the middle of the nineteenth century and had not suffered significant fires, so the majority of the trees may have been over 150 yeas old (Hotchkiss 1876; Ashe 1907; Parker et al. 1907;

Peters and Stinespring 1924; Catlett and Fishburne 1928; Hack and Goodlett 1960). For the Valley floor, there is less definitive information. One source comes from someone very familiar with the region. After the Civil War, Jedediah Hotchkiss stayed in the Shenandoah Valley and spent many years publishing maps and writing about the natural resources of the Virginias (Hotchkiss 1876, 1880's; Hotchkiss and McDonald 1973). As previously mentioned, in 1876 Hotchkiss described the trees of the Valley floor as being uniformly 150 – 200 years old, placing their origin to somewhere between the last quarter of the seventeenth century or the first quarter of the eighteenth century (Hotchkiss 1876). While these dates slightly precede the settlement of most of the Valley, they could indicate that the trees in the Valley had been cut over at least once since settlement. It is unknown whether Hotchkiss was making an informed statement about the age of the trees or whether he was relying on earlier sources such as Kerchval's *History of the Valley* to estimate the age of what may have looked like old trees (Kercheval 1925).

1865 – 1950

The American Civil War took a heavy toll on farms in the Shenandoah Valley. Total and improved farm land decreased between 1860 and 1870 in Augusta and Rockingham Counties (Walker 1971). However, the overall changes in the local farm economy were slightly different in the two counties. In Augusta County, while the amount of improved farm land dropped less than 2000 acres (809 hectares), the number of farms increased by more than 200, suggesting that existing farms may have been broken up into smaller units. In Rockingham County, however, the decrease in improved farm land was more dramatic, with over 16,000 acres (6475 hectares) being dropped from the census. The number of farms also dropped, with 350 fewer farms being recorded in the 1870 census (Walker 1971).

The downturn in the farm economies was short lived. Kenneth Koons has shown that "wheat production in the Valley of Virginia soared during the final third of the nineteenth century and the early decades of the twentieth" (Koons 2000). The number of farms and the amount of improved farm land increased in both counties from 1870 to 1900. In Augusta County, there were 2,772 farms and 276,769 acres (112,002 hectares, 43.0%) of improved farm land in 1900. In Rockingham County, there were 3,293 farms with 240,122 acres (97,172 hectares, 43.0%) of improved farm land (Geospatial and Statistical Data Center University of Virginia 2004). The population of both counties also increased by 1900, with Augusta County having 39,659 people and Rockingham County having 33,527 people (Geospatial and Statistical Data Center University of Virginia 2004). The City limits of Harrisonburg were expanded in 1870 (City of Harrisonburg 2003).

The essentially untapped timber resources of the mountainous portions of the counties were tapped in the late nineteenth century with encouragement from economic boosters of the region such as Jedediah Hotchkiss (Hotchkiss 1880's). Timber extraction was also facilitated by the expansion of railroads in the region. Railroads had reached into the Shenandoah Valley prior to the Civil War but it was not until later that expansions were initiated to reach the mineral and timber resources in the mountainous portion of the North River watershed. The Chesapeake Western Railway, locally known as the "Crooked and Weedy," reached the Town of Bridgewater in 1895 and the North River Gap in 1902. Stokesville (see Figure 12) had been established at the North River Gap in 1901 as a company town for a major industrial complex associated with the construction of the railroad. Much of the funding for the railroad came from industrialists in New York who were interested in exploiting untapped coal deposits they had purchased (Price 1992; Geier 1998).

As the coal deposits were being explored, spur lines were built up into the headwaters of North River and the timber resources were extracted. At its peak, Stokesville contained a rail road round house, passenger and freight depots, an extract mill, a lumber mill, a stave and barrel plant, tan bark storage facilities, a school, church, many houses, and other support facilities. The boom years were short lived however, for the coal deposits did not pan out and the viable timber was quickly cut out. By 1913 the lumber mill, stave and barrel factory, and the extract plant had all left.(Price 1992; Geier 1998; Geier, Stripe, and Nash 1998).

Agriculture continued to expand in the region during the early twentieth century. By 1910, the number of farms in Augusta County had increased to 3,112 and in Rockingham County to 3,528. Improved farm land had increased to 285,841 acres (115,674 hectares, 44.5%) in Augusta County, and 241,670 acres (97,799 hectares, 43.4%) in Rockingham County. This continued expansion of agriculture and the timber extraction in the mountains did not come without a perceived cost. Problems with diseases in Washington, D.C. and the presumed linkages between disease and water quality led the federal government to study hydrographic issues and land use and land cover in the Potomac River Watershed. One of the products of that study was a map of forest and farm land in the Potomac Watershed above Washington, D.C. (Ashe 1907; Parker et al. 1907).

While the forests in the mountainous portion of the North River watershed (Figure 17) were heavily exploited, most areas appear to have been left to grow back as trees for they are shown as forested areas on Ashe's map (Ashe 1907). Farm expansion does push back the eastern boundary of the forests and encroaches into the interior as well. The amount of non-woodlands in the mountains of the watershed reached 6.6%, up from 1.9% in 1864 (Figure 18 and Table 4), and very little of the woodlands persisted from 1864 to 1906 in the valley portion of the watershed. Only 16% of the woodlands that existed in the valley in 1864 remained wooded in 1906, but these persistent woodlands made up 36% of the woodlands that existed in 1906.

Farms continued to expand in the 1920's and 1930's in Augusta and Rockingham Counties, and up to 1945 in Augusta County. The peak in the amount of improved farm land was 271,320 acres (109,797 hectares, 48.7%) for Rockingham County in 1930, and 305,453 acres (123,610 hectares, 47.5%) for Augusta County in 1945 (Virginia Agricultural Statistics Service 1999a, 1999b; Geospatial and Statistical Data Center University of Virginia 2004; Virginia Agricultural Statistics Service 2004a, 2004b). As in previous time periods, the amount of wooded area in the North River watershed (see Table 4) as derived from the U.S. Geological Survey 15 minute topographic maps (Figure 19) varied between the mountainous and valley portions of the watershed (United States Geological Survey 1943a, 1946b, 1947a, 1947c, 1950). The amount of non-woodlands in the mountains dropped from its peak in 1906 to 1.5%, indicating

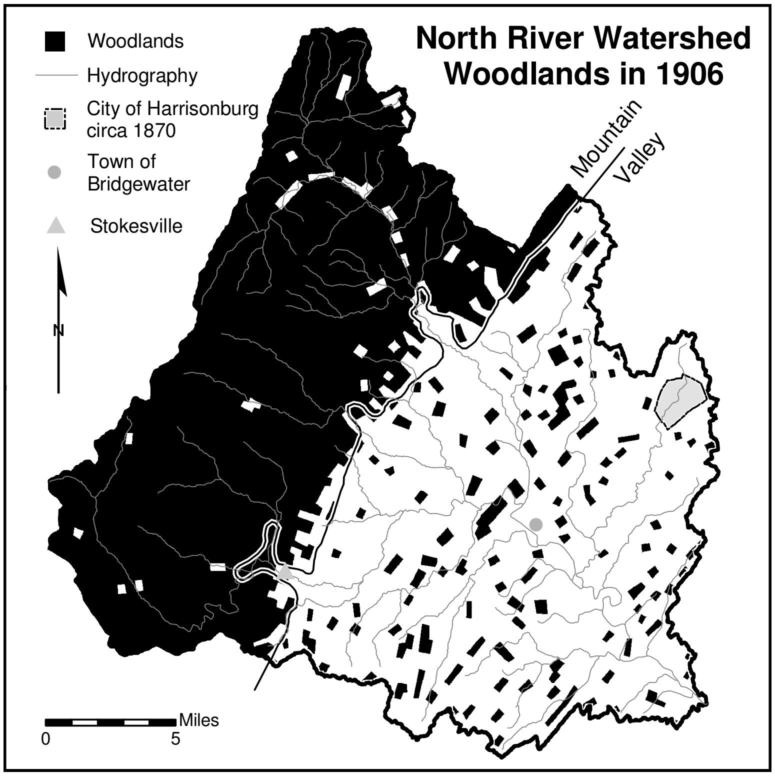

Figure 17: North River Woodlands in 1906.

The clearing of woodlands in the second-half of the nineteenth and early twentieth centuries continued in the valley and encroached into the mountainous portion of the watershed. *Source*: (Ashe 1907; Forest Service United States Dept. of Agriculture and Virginia Polytechnic Institute and State University 1979; Soil Conservation Service United States Dept. of Agriculture and Virginia Polytechnic Institute and State University 1982; United States Environmental Protection Agency 1998; City of Harrisonburg 2003; United States Geological Survey 2004c, 2004a) and author.

that much of the mountain land that had been converted to farm land between 1864 and 1906 had been abandoned as farm land by 1945. The amount of improved land increased to 90.1% in the valley (Figure 20), and the area continues to show a pattern of shifting woodlots. Only 21% of the area that was wooded in 1906 remained wooded in 1945, and these persistent wooded areas made up 23% of the wooded area in 1945.

Over exploitation of the forests in the eastern United States had led to the creation of National Forests in the early twentieth century. Much of the mountainous areas in the North River watershed were incorporated in the 1920s and 1930s into

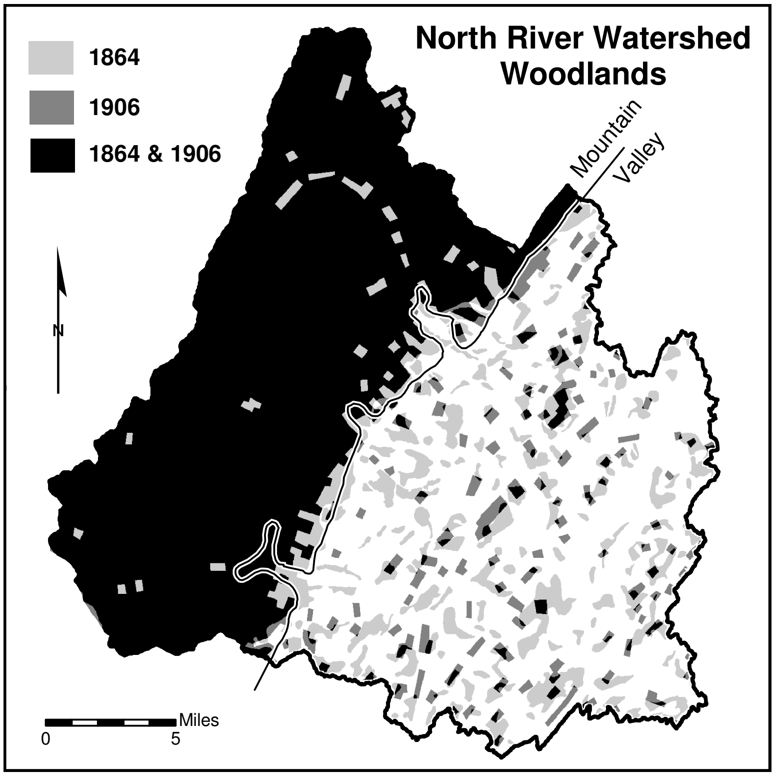

Figure 18: North River Woodlands in 1864 and 1906.

While woodlands covered most of the mountainous area at both time periods, the eastern edge and some interior areas were cleared by 1906. The valley portion of the watershed was predominately open at both time periods and the wooded areas shifted locations from one time period to the next. *Source*: (Confederate Engineer Bureau 1864; Ashe 1907; Forest Service United States Dept. of Agriculture and Virginia Polytechnic Institute and State University 1979; Soil Conservation Service United States Dept. of Agriculture and Virginia Polytechnic Institute and State University 1982; United States Environmental Protection Agency 1998; United States Geological Survey 2004c, 2004a) and author.

what is now known as the George Washington and Jefferson National Forest. While historical changes to the boundary of the national forest are not represented in the modern boundary file (Figure 21), only 38 percent of the mountainous area that was cleared by 1906 and re-forested by circa 1945 are presently included in the national forest. Soil type might be a better explanation of the abandonment of these areas since the division between mountains and valley for this study were based on soil types.

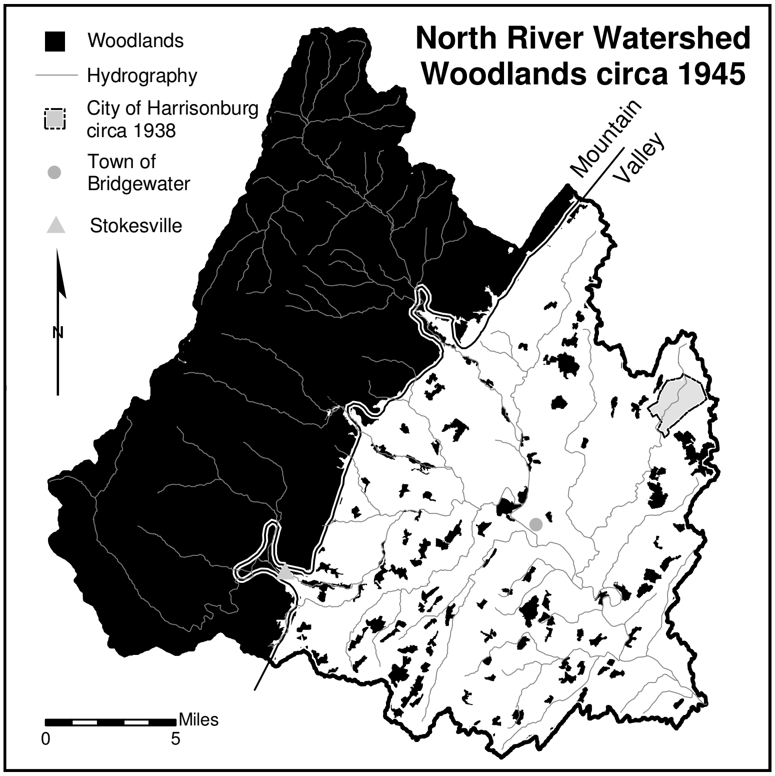

Figure 19: North River Woodlands circa 1945.

Woodlands in the valley portion of the watershed reached their lowest point by 1945. *Source*: (United States Geological Survey 1943a, 1946b, 1947a, 1947c, 1950; Forest Service United States Dept. of Agriculture and Virginia Polytechnic Institute and State University 1979; Soil Conservation Service United States Dept. of Agriculture and Virginia Polytechnic Institute and State University 1982; United States Geological Survey 1986; United States Environmental Protection Agency 1998; City of Harrisonburg 2003; United States Geological Survey 2004c, 2004a, 2004d) and author.

Another explanation for the abandonment of farm land in mountainous areas is that it is poorly suited for agriculture due to steep slopes. An examination of the non-woodland areas on slopes over 3 percent (Table 5) shows several relevant trends. First, a significant portion of the non-wooded areas in the watershed since 1864 has been on slopes over 3 percent. Second, just as the total amount of non-wooded areas for the entire watershed and the mountainous areas peaked in 1906, the amount on steep slopes also peaked in 1906. However, the amount of open space on steep slopes in the valley continued to increase between 1906 and circa 1945. This suggests that while agricultural expansion in the early twentieth century included the push onto steeper slopes and into mountainous areas, the overall expansion on to steep slopes did not cease even as the mountainous areas were abandoned in the early twentieth century.

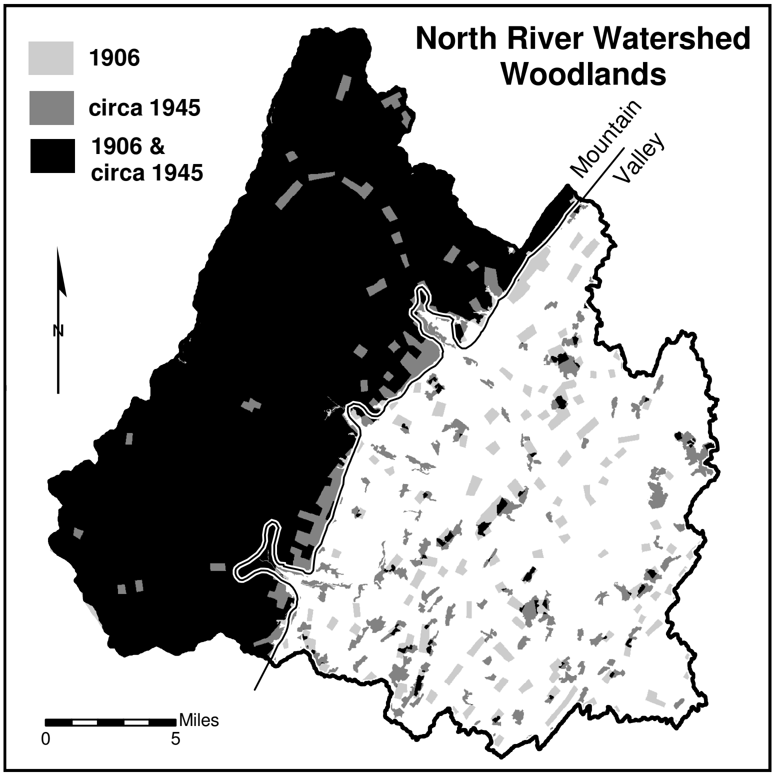

Figure 20: North River Woodlands in 1906 and circa 1945.

The mountainous area of the watershed remained predominately wooded from one time period to the next, and most of the interior and eastern areas of the mountainous portion of the watershed that had been cleared by 1906 had reverted back to woods by 1945. Wooded areas in the valley portion of the watershed continued to shift locations and declined from 1906 to c. 1945. *Source*: (Ashe 1907; United States Geological Survey 1943a, 1946b, 1947a, 1947c, 1950; Forest Service United States Dept. of Agriculture and Virginia Polytechnic Institute and State University 1979; Soil Conservation Service United States Dept. of Agriculture and Virginia Polytechnic Institute and State University 1982; United States Geological Survey 1986; United States Environmental Protection Agency 1998; United States Geological Survey 2004c, 2004a, 2004d) and author.

Table 5: North River Woodlands on Steep Slopes.

The woodlands columns show calculations of wooded areas derived from the sources after they were harmonized to a minimum mapping area of 40 acres (16.2 hectares). The least amount of wooded area in the mountainous portion of the watershed occurs in the 1906 data, while in the valley portion it occurs in the c. 1945 data. Non-woodlands on land with greater than 3 percent slope follows the same temporal pattern as the woodlands area. *Source*: (Confederate Engineer Bureau 1864; Ashe 1907; United States Geological Survey 1943a, 1946b, 1947a, 1947c, 1950, 1986, 2004a, 2004d) and author.

Date	Woodlands			Non-woodlands over 3% slope		
	Entire Watershed	Mountains	Valley	Entire Watershed	Mountains	Valley
1864	59.4%	98.1%	23.4%	33.3%	1.8%	62.4%
1906	50.4%	93.4%	10.7%	41.2%	6.3%	73.4%
c. 1945	52.5%	98.5%	9.9%	39.0%	1.4%	73.8%
c. 1974	54.5%	98.3%	13.9%	37.4%	1.5%	70.5%
c. 1992	56.3%	99.1%	16.7%	35.7%	0.8%	67.9%

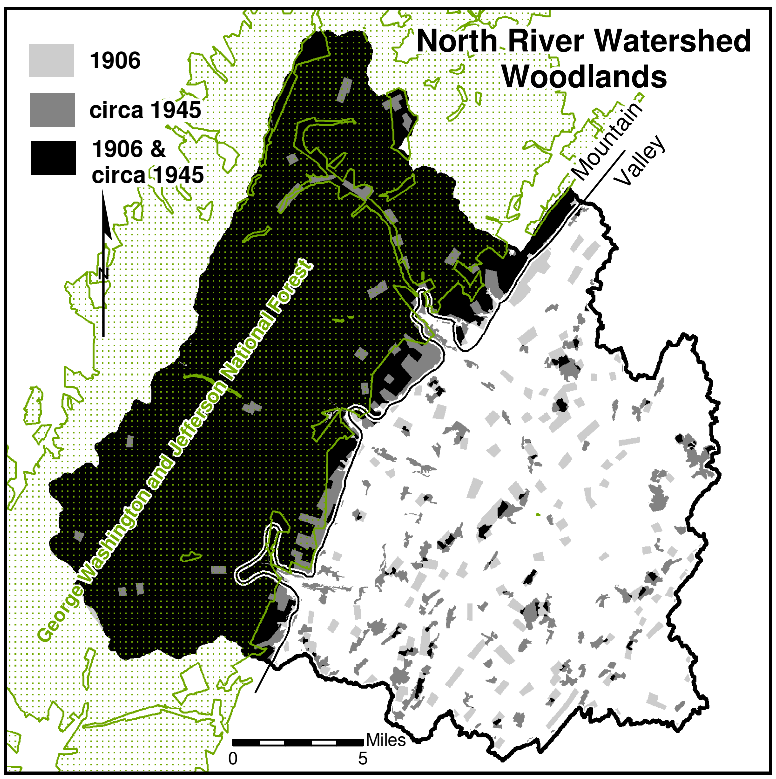

Figure 21: North River Woodlands and National Forest Ownership.

The boundary of the George Washington – Jefferson National Forest (in green) was used to analyze the amount of mountainous land that was cleared in 1906 but forest by 1945. *Source*: (Ashe 1907; United States Geological Survey 1943a, 1946b, 1947a, 1947c, 1950; Forest Service United States Dept. of Agriculture and Virginia Polytechnic Institute and State University 1979; Soil Conservation Service United States Dept. of Agriculture and Virginia Polytechnic Institute and State University 1982; United States Environmental Protection Agency 1998; George Washington and Jefferson National Forests 1999; United States Geological Survey 2004c, 2004a) and author.

Second-half of the Twentieth Century

After reaching its peak in the 1930's and 1940's, the number of farms and the amount of improved farm land declined in the 1950's and 1960's. By 1974, the number of farms had dropped to 1,540 in Augusta County and 1,967 in Rockingham County, nearly 2,000 fewer farms than the peak for each county. Improved farm land decreased to 242,560 acres (98,159 hectares, 37.7%) in Augusta County, over 60,000 acres (24,281 hectares) less than its peak. In Rockingham County, improved farm land dropped to 195,585 acres (79,149 hectares, 35.1%), over 75,000 acres (30,351 hectares) less than its peak (Virginia Agricultural Statistics Service 1999a, 1999b; Geospatial and Statistical Data Center University of Virginia 2004; Virginia Agricultural Statistics Service 2004a, 2004b). The population of both counties has also risen sharply since the middle of the twentieth century, with both counties (including their respective independent cities) having exceeded 108,000 people by the 2000 census (United States Bureau of the Census 2003).

Despite the drop in the number of farms and the total amount of improved farm land, agriculture continues to be important to both communities. Rockingham and Augusta were ranked the number one and number two agricultural counties in Virginia based on cash receipts in 1997 (Virginia Agricultural Statistics Service c.2000). The drop in farms and farm land are reflections of the intensification of agricultural enterprises such as poultry and dairy operations. The amount of agriculture on steep slopes in the valley also persists at about the same level as earlier in the century (see Table 5).

The forest components of the landscape of the North River watershed in the late twentieth century appear to be stabilizing, at least in comparison to changes in the nineteenth and early twentieth centuries. By 1974, (Figure 22) there had been a slight rebound in forested area since the low point earlier in the century, particularly in the valley (see Table 5). The amount of shifting woodlots in the valley area decreased, with more areas persisting as forest and new growth occurring around existing forested areas (Figure 23). Approximately two-thirds (69%) of the woodlands that existed in 1945 remained woodlands in 1974, and these persistent woodlands made up 49% of the woodlands that existed in 1974. By 1992, these patterns of persistent and expanding wood lots in the valley continue (Figure 24 and Figure 25). Over three-quarters (79%) of the valley woodlands that existed in 1974 continue as woodlands in 1992, making up 66% of the woodlands in 1992. While the amount of woodlands in the mountain portion of the watershed have rebounded to pre-Civil War levels, the amount of woodlands in the watershed as a whole and in the valley portion of the watershed are still lower than they were at the time of the Civil War.

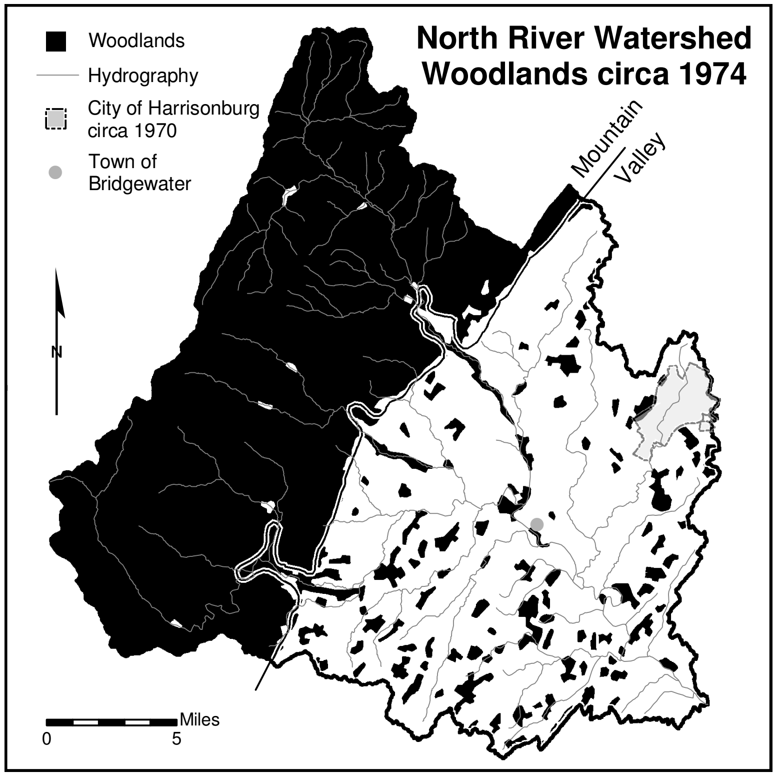

Figure 22: North River Woodlands circa 1974.

The mountainous portion of the watershed remains predominately wooded by 1974. *Source*: (Forest Service United States Dept. of Agriculture and Virginia Polytechnic Institute and State University 1979; Soil Conservation Service United States Dept. of Agriculture and Virginia Polytechnic Institute and State University 1982; United States Geological Survey 1986; United States Environmental Protection Agency 1998; City of Harrisonburg 2003; United States Geological Survey 2004c, 2004a) and author.

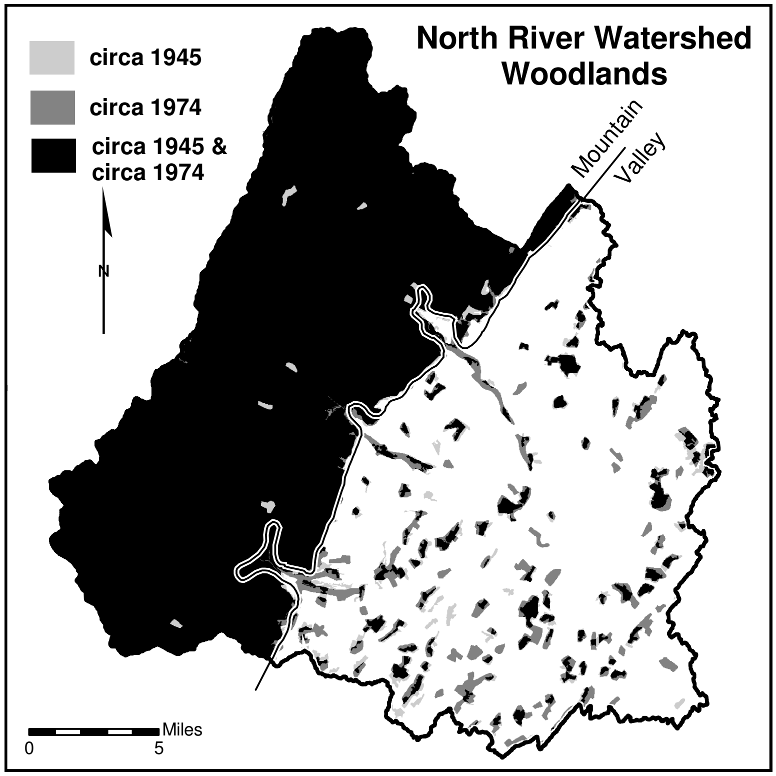

Figure 23: North River Woodlands circa 1945 and circa 1974.

The amount of woodlands increased slightly in the valley portion of the watershed between 1945 and 1974, and there is less shifting of woodlot locations than in previous time slice comparisons. The amount and location of woodlands changed very little in the mountainous portion of the watershed between 1945 and 1974. *Source*: (United States Geological Survey 1943a, 1946b, 1947a, 1947c, 1950; Forest Service United States Dept. of Agriculture and Virginia Polytechnic Institute and State University 1979; Soil Conservation Service United States Dept. of Agriculture and Virginia Polytechnic Institute and State University 1982; United States Geological Survey 1986; United States Environmental Protection Agency 1998; United States Geological Survey 2004c, 2004a) and author.

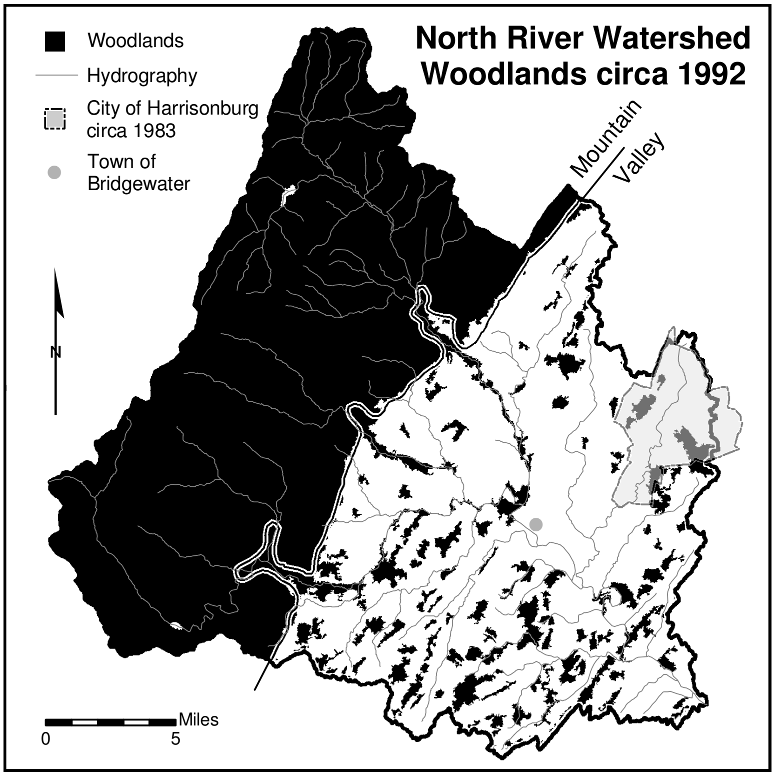

Figure 24: North River Woodlands circa 1992.

The amount of woodlands in the valley portion of the watershed continued to increase by 1992. *Source*: (Forest Service United States Dept. of Agriculture and Virginia Polytechnic Institute and State University 1979; Soil Conservation Service United States Dept. of Agriculture and Virginia Polytechnic Institute and State University 1982; United States Environmental Protection Agency 1998; City of Harrisonburg 2003; United States Geological Survey 2004c, 2004a, 2004d) and author.

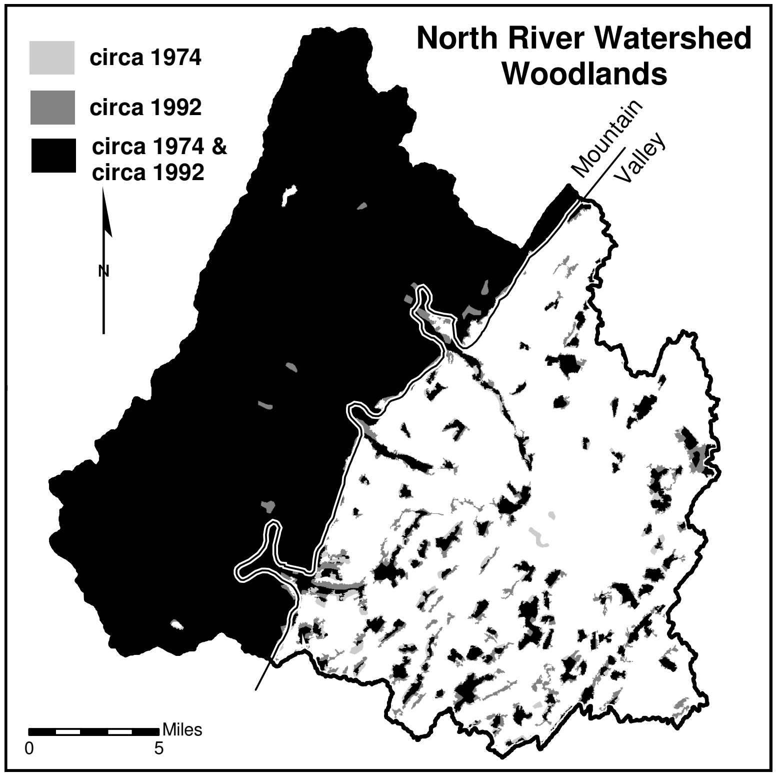

Figure 25: North River Woodlands circa 1974 and circa 1992.

As in the comparison of woodland changes from 1945 and 1974, there is little shifting of woodlot locations in the valley portion of the watershed from 1974 to 1992. *Source*: (Forest Service United States Dept. of Agriculture and Virginia Polytechnic Institute and State University 1979; Soil Conservation Service United States Dept. of Agriculture and Virginia Polytechnic Institute and State University 1982; United States Geological Survey 1986; United States Environmental Protection Agency 1998; United States Geological Survey 2004c, 2004a, 2004d) and author.

Chapter 5: Conclusion

In this study a new methodology is presented which contributes to the rich historiography about the Shenandoah Valley and to the methods used in the study of human – environment interactions. Changing spatial and temporal patterns of forest clearance and re-growth were a dynamic process that cannot be fully understood from regional analysis alone. An initial examination of published reports and agricultural census information revealed a potential discrepancy between the current understanding of what happened at the regional scale in the Eastern United States and in the Shenandoah Valley of Virginia. The published reports indicated that the maximum clearance of forests likely occurred in the late-nineteenth century or very early in the twentieth century. The improved farm land data in the agricultural census indicates that the maximum clearance occurred in 1930 for Rockingham County and 1945 for Augusta County. These variations were corroborated through the use of multiple and independent sources of information and multiple approaches.

The methodological contribution of this study comes from the combination of geo-historical and geo-computational approaches to examine modern and historical data regarding the landscape. Both generalized or aggregated information and spatially explicit sources were examined. The research presented here included the identification and interrogation of written accounts about the landscape, historical mapping practices, and cartographic and digital spatial data sets of the Shenandoah Valley. The utilization of only the geo-historical or the geo-computational approach or one type of data would not lead to the same conclusions presented in this study.

Archival research identified multiple maps of the study area that contained some form of woodlands information. The first was produced by the Confederate Engineer Bureau in 1864 and research into historical mapping practices verified that woodlands were an important military feature that Union and Confederate engineers incorporated on some of their maps. The second map was produced by the USGS in 1906 and was explicitly targeted at mapping forested and agricultural areas. The last cartographic sources were a series of maps produced by the USGS from the 1920's through the 1950's. Two digital spatial data sets developed by the USGS in the late twentieth century (c. 1974 and c. 1992) provided the remaining geographical sources of woodlands information.

A geo-computational approach was used to analyze the spatial data derived from the cartographic sources and the digital spatial data sets. A GIS was used to analyze and quantify the woodlands and open space information at the county, watershed, and sub-watershed (e.g. mountains vs. valley, steep slopes) levels. The amount of open space (i.e. improved farm land and other areas without trees) derived from the geographical sources and the agricultural census differ by only 0.5 to 2.7 percent for each time slice. Even with this slight variation in the amount of open space or improved farm land being interpreted from the different sources, the two types of data correspond well enough to support the general timing of the maximum clearance as revealed in the improved farm land census data at the county level. Since the timing of maximum clearance at the county level and in the valley portion of the watershed are later than the larger region, previous explanations of why the maximum clearance occurred when it did, and why forest re-growth took place, are inadequate. Without detailed accounts for this specific location, textual and aggregate records such as the census data cannot provide adequate descriptions or explanations. With the increased level of confidence in the evaluation of the spatial data, the GIS can be used to assist in seeking a better understanding of what happened in this watershed.

The historical contribution of this study is the identification that the commonly held explanation of the expansion, and later abandonment, of agriculture in poorly suited areas such as the mountains and areas with steep slopes does not coincide with the maximum clearance of forested areas and subsequent regeneration. Instead, within this watershed we see that an increasing portion of the non-wooded areas in the watershed since 1864 have been on slopes over 3 percent. In addition, the amount of open space in general and on steep slopes in the valley in particular continued to increase after the mountainous areas were abandoned after 1906. This study has also shown that the acquisition of mountainous land by the federal government did not account for the majority of the area that was abandoned, since most of the land remained in private hands.

In the Shenandoah Valley the variations in the timing of maximum clearance and the continued utilization of steep slopes may have been due to the continued importance of agriculture to the local economy and culture. As technologies and commercial viability changed through time, the agricultural base has shifted from subsistence farming to various specializations. While wheat farming was important in the eighteenth century and nineteenth centuries; beef cattle and more intensive activities including dairying and poultry have come to dominate the agricultural sector of the economy. The continued utilization of steeply sloped areas could be due to cultural and physical aspects. With the long tradition of farming, people may choose to continue their way of life and adapt the specifics of their operations to what is economically feasible. The intensification of some activities such as poultry farming may have allowed the rolling hills of the Shenandoah Valley to continue being utilized for pasturing cattle, providing diversification of the farming activities and keeping the land in farms. It should be noted that many aspects of these agricultural practices are embraced by both modern sectors of society and the more traditional Mennonite communities.

The documented variations in landscape change have both cultural and physical implications. The commonly held explanations for when and where deforestation and forest re-growth took place are inadequate. This study offers alternative or more refined explanations that are important for many reasons. Since the Shenandoah Valley is the focus of extensive studies on frontier and backcountry communities, a proper understanding of its continued development is important for other scholars who look to the area as a model of how these communities developed. The Shenandoah Valley is also used as the basis for public education about the human impact on the environment for the extensive number of people who visit Shenandoah National Park and stop at interpretive signs along Skyline Drive. The Shenandoah Valley is also seeing the development of new and extensive regional interpretations as part of the development of the recently formed Shenandoah Valley Battlefields National Historic District. While this organization is primarily focused on the

American Civil War, the story of what happened in the area before and after the war puts the conflict into context.

The documented variations in landscape change also had an impact on the physical environment. While not addressed directly in this study, the differences in the age of trees based on when they were cut and allowed to grow back would directly impact the carbon cycle. Global and regional assessments have not been able to adequately account for variations in the carbon cycle, and detailed reconstructions like the one described here can be used to refine models and our understanding of the carbon cycle. These detailed reconstructions also have the potential to assist in developing better understandings of sediment and nutrient flows into the Chesapeake Bay. Agricultural run-off has been identified as a major contributor to pollution problems in the Chesapeake Bay and sediment cores have been extensively studied to infer the impacts of its tributaries. Data from stream gauges and hydrological models can be used in combination with the historical reconstructions developed in this study to develop a better understanding of how much the Valley has contributed to the sediment being studied.

This study forms a foundation upon which to expand the research by conducting comparative studies in other locations using similar approaches and data sources. The agricultural census data for the entire United States have been digitized and linked with a GIS by the USGS (see Waisanen and Bliss 2002). Unfortunately, the public version of the data uses a combination of census variables that may not suit the study of forest changes since it uses improved farm land and croplands. The study reported here confirms John Fraser Hart's (Hart 1968) earlier assertion that improved farm land is a better variable to use. The USGS data has the original breakdown of variables, so they could be recombined to create a more consistent improved farm land variable, but licensing restrictions prohibit easy access to the information. If access issues can be worked out, an assessment of the amount of variation in total farm land vs. improved farm land could be conducted, providing a better understanding of the amount of variation found across the nation through time. This national data set could be used to target other areas where more detailed analysis would be useful, and to identify what time periods should be examined.

Other data sets used in this study are also available for other areas. The digital spatial data from the late twentieth century are part of national data sets, so they could easily be utilized for additional studies. The 15-minute topographic maps were also part of a national mapping campaign, so they are available for many areas in the United States. The 1906 map was part of a special study of the Potomac watershed, so it could be used of other areas within the watershed. Similar special purpose maps may have been produced for other areas, so archival research would need to be done to identify maps for this period if they are needed for other areas. The map from the Civil War was just one of many produced by the Confederate Engineer Bureau. The bureau also produced many county maps that also contained woodlands information, so they could be utilized for other areas. The Union forces also produced many maps of the eastern United States that could be used. Due to the popularity of the Civil War, many organizations such as the Library of Congress and the Library of Virginia are scanning maps from this period to make them available for researchers and the general public, so they are becoming more accessible than they have been in the past.

Coastal Survey maps were also produced for many areas of the United States in the nineteenth century and could provide additional geographic coverage.

The study reported on here also provides more general information that can guide similar studies. The study shows that textual (e.g. county-level census data) and spatially explicit (e.g. maps and digital spatial data) sources of different scales can be integrated through a combined geo-historical and geo-computational approach to assess the content and value of each source and of regional trends. These combined sources and approaches can provide more detailed and accurate information about local areas and can also provide a bridge between local and regional studies since long-term regional studies are often based on county level data. The study also provides the background for analyzing the content of similar maps, and can serve as an example of how to research the content of other types of maps. This study also provides background on the care that needs to be taken when scanning, georeferencing, and extracting information from historic maps so that they can be utilized in a GIS.

Appendix A: Cartographic Sources

The cartographic sources used in this study are not as commonly used as the digital spatial data sources used in this study, and are therefore illustrated below to provide the reader with a better idea of the types of sources that might be available for other studies. The Confederate Engineer Bureau map (Figure 26) and the USGS Potomac River basin map (Figure 27) are shown in their entirety. Only one of the eighteen USGS 15 minute topographic maps (Figure 28) is shown as an example.

Figure 26: Lower Shenandoah Valley I Map by the Confederate Engineer Bureau, 1864.

This map is one of a series of maps of the Shenandoah Valley and western Virginia produced by the Confederate Engineer Bureau. The map is oriented with North being at the top. The feature running from the bottom-center of the map to the north and east is the Blue Ridge Mountains. Running parallel to that and to the west is the Massanutten Mountain range, and the eastern edge of the Allegheny Mountains along the western edge of the map. Augusta County is in the lower left corner of the map and Rockingham County is to the north, encompassing a portion of the area between the Alleghenies and the Blue Ridge, and including the southern portion of Massanutten Mountain. See Figure 3 for an enlargement of a section of this map. *Source*: (Confederate Engineer Bureau 1864).

Figure 27: Potomac River Drainage Basin Above Washington Showing Forest Areas and Cleared Lands, 1906.

This map was produced as part of special study of the water resources of Washington, D.C., which is located at the center of the right edge of the map. North is at the top of the map. The Shenandoah Valley is the speckled area that runs roughly through the center of the map from the south-west to the north-east, with the Blue Ridge Mountains running along the eastern edge and Massanutten Mountain running down the middle. The different shades of green represent forested areas with different levels of disturbed humus and some areas that were predominately grasses. See Figure 7 for an enlargement of a section of this map. *Source*: (Ashe 1907).

Figure 28: USGS Parnassus 15 Minute Topographic Map, 1947.

This map is typical of the other USGS 15 minute topographic maps used in this study and available for many areas in the United States. The map represents a section along the Augusta and Rockingham County border (see Figure 8 for location of this map sheet) that encompasses portions of the mountainous and valley areas. North is at the top and the green symbol is the woodlands overlay. See Figure 9 for an enlargement of a section of this map. *Source*: (United States Geological Survey 1947c).

Glossary

Arc/Info Coverage	A file format developed by ESRI for topological spatial data
ASCII	American Standard Code for Information Interchange
DPI	Dots Per Inch
DRG	Digital Raster Graphic, a digital file format used by the USGS to store scanned versions of USGS topographic maps.
ESRI	Environmental Systems Research Institute
Farm Land	Land as defined in the agricultural census of the United States as being part of a farm
Forested	Areas where the predominant vegetation is trees.
Georeference	Assigning real-world coordinates to the page or map coordinates of an image or a planar map.
GIRAS	Geographic Information Retrieval and Analysis System, a digital file format used by the USGS to distribute land use and land cover data from the 1970's and 1980's.
GIS	Geographic Information System
GRID	A raster data format developed by ESRI.
GRID Stack	A method of referencing multiple GRIDs at once.
Improved Farm Land	Farm land categorized as being improved in the United States agricultural census (e.g. crop land, pasture).
LU/LC	Land Use and Land Cover
Non-Woodlands	Any area not categorized as being wooded or forested on the cartographic or digital spatial data used in this research.
Quad Map	Quadrangle Map, common name for USGS topographic maps.
Shape File	A file format developed by ESRI for non-topological spatial data.
TIFF	Tag Information File Format

USGS	United States Geological Survey
Woodlands	Any area mapped or categorized as being wooded or forested on the cartographic or digital spatial data used in this research.

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