ABSTRACT

Title of dissertation: ANALYZING FOREST CHANGE AND POLICY IN WASHINGTON, DC SUBURBAN COUNTIES

Claire A. Jantz, Doctor of Philosophy, 2005

Dissertation directed by: Professor Martha Geores
Department of Geography

Geographical approaches for landscape studies have emphasized the interpretation of landscape change as a cultural phenomenon, but often have neglected modern geographic techniques, such as remote sensing observations and quantitative spatial analysis, to characterize and understand landscape change. This study attempts to bridge these gaps by integrating a socio-cultural analysis of land use policy formation and quantitative assessments of land cover change to demonstrate how policy decisions can influence forest landscape patterns in suburban areas. Historical data from Montgomery County, MD and Fairfax County, VA, two counties adjacent to the Washington, DC urban core that have different governmental structures, were assembled and analyzed.

A policy database was developed and analyzed using qualitative techniques, such as grounded theory and content analysis, to address questions related to policy formation and trends. Key findings included the identification of a strong link between land use policies and the broader environmental discourse, demonstrating that dominant cultural

values are institutionalized in the development of land use policy. Furthermore, many policies related to forest management and preservation, particularly in recent decades, had a strong focus on protecting riparian forests.

Land cover change between the late 1930s and 1998 was studied for local case study areas using time series of aerial photographs, and between 1990 and 2000 across both counties using satellite-derived land cover maps. Using a statistical technique, weights of evidence, the processes of new development, deforestation, and forest persistence were modeled. The results highlighted the role of biophysical variables, such as steep slopes and the presence of poorly drained soils, in constraining new development and enhancing forest persistence. However, the role of land use policies was also evident in enhancing forest persistence through the establishment of protected areas and riparian protection policies.

This study demonstrated the impact that land use regulations can have on the evolution of forested landscape patterns within the built environment. The links between socio-cultural values and policy formation highlighted the institutional and cultural barriers that prevent rapid shifts in policy orientation, despite social and environmental problems that arise within a rapidly changing landscape.

ANALYZING FOREST CHANGE AND POLICY IN WASHINGTON, DC SUBURBAN ENVIRONMENTS

by

Claire A. Jantz

Dissertation submitted to the Faculty of the Graduate School of the University of Maryland, College Park in partial fulfillment of the requirements for the degree of Doctor of Philosophy
2005

Advisory Committee:

Professor Martha Geores, Chair
Professor Robert Gardner
Dr. Scott Goetz
Professor Michael Paolisso
Professor John Townshend

ACKNOWLEDGEMENTS

The successful completion of a dissertation represents a scholarly milestone, and one that cannot be achieved without the support and advice of a broad network of individuals. I am indebted to all of my committee members, particularly Drs. Martha Geores and Scott Goetz, who have been my strongest mentors. I would also like to thank Dr. Stephen Prince for encouraging my early research directions into land use and land cover change issues in the Chesapeake Bay region. I have benefited from lively discussions with planners and professionals at the Chesapeake Bay Program, the Chesapeake Bay Foundation, the U.S. Geological Survey in Reston Virginia, the Maryland Department of Natural Resources, and the Maryland-National Capital Parks and Planning Commission. Individuals in these and other organizations provided very relevant linkages between my research pursuits and the real world. Likewise, discussions with Dr. Nancy Bockstael provided me with a great deal of insight into the economic processes influencing land use change and land use policies. It is a privilege to be affiliated with the Geography Department at the University of Maryland, a program that provides a stimulating, diverse, and supportive environment for scholarly research and development. I would like to thank several of my fellow graduate students, many of whom are now alumni, for their friendship, technical assistance and support: Jenny Hewson, Robb Wright, Andrew Smith, James Wilson, Jason Drake, Peter Hyde, Colleen Joyce, Cheryl Stauffer, Ronald Luna, Barbara Kearney and many others. Thanks should also go to Robert Crossgrove, Wilhelmina Johnson and Vivre Bell, without whom no graduate student would ever succeed. I am also indebted to Dr. Joseph Cirrincione and Dr. Eugene Kinerney for fostering my commitment to undergraduate education, and to my advisees and students, who enriched my experience at the University. Archivists and library personnel at the National Archives in College Park, the Fairfax County library system, the Maryland-National Capital Park and Planning archives in Silver Spring, and the Maryland Room at the University of Maryland were extremely helpful in locating key data sources. I would like to thank my father, Richard Jantz, my stepmother Lee Jantz, and all of my brothers and sisters for their continual support, wisdom and humor; and my mother, Martha Jantz, who I hope would be proud of me. Finally, I must thank John Wah and his family—my second family—for their friendship and encouragement.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1: INTRODUCTION

1.1 Resource Definition in Suburban Landscapes

On the rapidly suburbanizing east coast of the United States, forests are a dominant component of the suburban landscape. In the mid-Atlantic region, environmentalists, policy makers, and residents value urban and suburban forests as quality of life amenities and for the ecosystem functions they provide. As development pressures in the mid-Atlantic have continued to increase, the question of forest preservation has evolved into a multi-dimensional environmental policy issue, encompassing aspects of ecologic restoration, natural resource management, resource definition, and quality of life. Underlying many of the debates concerning forest preservation and management is a question of how this natural resource is defined, and how it is being redefined, in the context of rapid land use and land cover change.

Suburban areas offer an excellent opportunity to consider the reciprocal relationships between land use and land cover change, resource definition, and environmental policy formation. Many areas have experienced a rapid shift in land use: over the past half-century, the once rural counties surrounding urban centers have become increasingly dominated by residential and commercial land uses. This shift in land use has coincided with a shift in the definition of forest resources, from an economic or utilitarian focus to a more complicated view of forests as being unique and vital ecosystems, recreational areas, wildlife habitat and suburban amenities. Suburban areas also tend to be highly regulated environments, with multiple stakeholder groups participating and competing in the discourse surrounding environmental policy formation.

Using forest policy as a focal point, this research explores the institutionalization of resource definition through policy formation, and examines how institutional structures and patterns of organizational interactions across scales influence forest resource definition and management. Using geographic information systems, the spatial consequences of forest policies will be examined by linking policy decisions to the spatial patterns of forests in the suburban landscapes of the Washington, DC. Broadly, this study addresses two main questions: 1) how forest resources in suburban environments are defined through policy, and 2) how policy influences forest patterns.

1.2 Study Area Background

The Washington, DC metropolitan area in many ways exemplifies the modern North American urban system, reflecting a complex mosaic of land cover and land use patterns as well as a diversity of demographic and socio-economic patterns (Knox 1993). For most of its history, the city of Washington, DC was sparsely populated and the surrounding region was primarily agricultural. Between the late 1800s and the 1940s, the role of the counties surrounding Washington, DC evolved from agricultural and forestry districts serving the growing city center to become residential locations for the more affluent, primarily white suburbanites (Hiebert and MacMaster 1976; Netherton and Sweig 1978; Denny 1997). After World War II, the accumulation of wealth by the middle class, the advent of the automobile as a way of life, and increasing population pressures and social problems within the city prompted many people to move out of the urban center in a nationwide process of suburbanization (Macionis and Parrillo 1998).

These suburbs have since become increasingly diverse, both economically and demographically.

The suburban counties of Montgomery, Maryland and Fairfax, Virginia are adjacent to one another and to the metropolitan core of Washington, DC, Arlington, VA and Alexandria, VA (Figure 1.1). While the counties share a geographic proximity to a major urban core, they differ in terms of their pre-suburban land use histories. At the turn of the twentieth century, Montgomery County was dominated by agriculture, particularly livestock and dairy activities (Setright 1954; Hiebert and MacMaster 1976), while timber products dominated the agricultural economy in Fairfax County (Hall, et al. 1907; Fairfax County Chamber of Commerce 1928; Netherton and Sweig 1978). These land use histories are still apparent in the contemporary suburban landscapes and have a significant influence on the current patterns and extent of forested land within the two counties (Jantz 2000).

Figure 1.1 Map of study counties (dark gray) located in Chesapeake Bay watershed (outlined in dark blue).

Despite different land use histories, the two counties are demographically similar, with residents who are highly educated and wealthy. They have also experienced similar levels of rapid population growth over the past several decades (Figure 1.2). In 2000, the population within each county was approaching one million, although Fairfax is more densely settled. Both counties experienced their highest growth rates between 1950 and 1960, when Montgomery County's population grew over 100% and the population in Fairfax County increased by nearly 180%. Their institutional structures differ, however, particularly in terms of the level of control county governments have over land use decisions. Maryland is a home rule state, where local governments can perform any function that is not prohibited by the state or that is not in conflict with the state constitution or statutes; Montgomery County adopted a home rule charter in 1948 (Hiebert and MacMaster 1976). Virginia, in contrast, is a Dillon rule state, where local governments possess only the powers explicitly granted to them by the state legislature. The differing institutional contexts create different constraints and opportunities for the development of county-level policies that target forest resource preservation and management (Weiland 1999).

The fact that both Maryland and Virginia are voluntary participants in a major federally funded regional restoration effort of the Chesapeake Bay estuary adds another set of important institutional interactions that has influenced the development of forest policies since the 1980s, particularly at the state level. The US Environmental Protection Agency (EPA) funds the Chesapeake Bay Program (hereafter referred to as the Bay Program) that is governed by an executive council consisting of representatives of the signatories of Chesapeake 2000, an agreement that outlines a coordinated effort to address the declining water quality of the Chesapeake Bay (Chesapeake Bay Program 2000). In addition to Maryland and Virginia, the state of Pennsylvania and the District of Columbia also participate in the Bay Program. The Bay Program is internationally recognized as a model in watershed restoration, and has provided over 280 million US Dollars in funding towards this effort since its inception in 1984 (Ernst 2003).

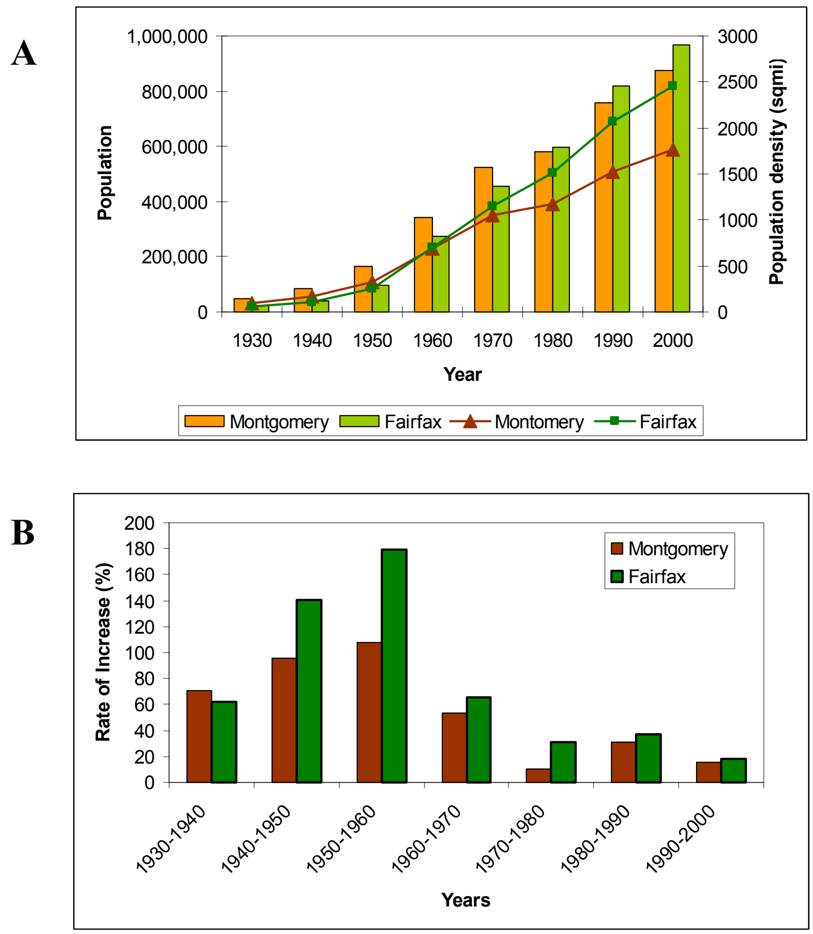


Figure 1.2 Increase population and population density (people per square mile) in Montgomery and Fairfax counties, 1930-2000 (A) and rate of decadal population increase (B). Source: GeoLytics Inc. 1996; GeoLytics Inc. 2001.

Because of the emphasis on water quality improvement, and because of the significant role that forests play in maintaining water quality, the Bay Program has advocated forest preservation strategies that conserve and promote forest cover in riparian areas. Chesapeake 2000 sets specific goals of riparian forest restoration--2,010 miles of forested riparian buffers restored by 2010--as well as overall goals of protecting natural resource lands from development, and developing the sustainable use of forest resources (Chesapeake Bay Program 2000). While the Bay Program is not a regulatory body itself, the signatory states are expected to make progress towards the commonly defined goals stated in Chesapeake 2000. The Bay Program and other organizations, such as the Chesapeake Bay Foundation, a non-profit environmental advocacy and education organization, monitor relevant policy developments and implementation efforts and regularly issue publicly available progress reports (e.g. The Chesapeake Bay Program 2004). The presence of the Bay Program and the high-profile restoration activities associated with the Chesapeake Bay estuary influence the institutional definition of forest resources through policy formation in Maryland and Virginia.

1.3 Theoretical Overview

The interdisciplinary nature of this research necessitates a broad theoretical base that intersects geographical landscape studies, political ecological assessments of institutional structures and landscape ecological approaches to analyzing land use change. An underlying assumption of this research and much of the literature discussed below is the idea that nature is socially constructed. This social constructivist orientation allows a differentiation of what is "real" and "reality." *Reality* embodies the knowledge and perception of the *real* physical world, and is time and space specific (Hajer 1995). Environmental perception is influenced by cultural and societal values (Bertolas 1998; Kempton, et al. 1995; Lutz and Simpson-Housley 1999), and attitudes towards the natural environment can be reflected in governmental structure, scientific research, and natural resource policy (Wallace, et al. 1996).

1.3.1 The Cultural Landscape

Since the publication of Sauer's essay "The Morphology of Landscape" in 1925, there has been a proliferation of cultural landscape studies. The approaches, frameworks and content of these studies are now so varied that contemporary evaluations of cultural landscape studies acknowledge that a rigorous definition of "cultural landscape" is difficult to determine. Schein (1997) notes that landscapes can be defined in numerous ways: as symbolic, as representative, as metaphors, as class-based and politicized. Rowntree (1996) also struggles to develop an organizational scheme for contemporary landscape studies and presents nine different approaches in which he attempts to capture the full range of the literature.

Social constructivist approaches to analyzing landscapes provide a framework for understanding how landscapes are constitutive of social relations (Peet 1996). This approach attempts to bridge the ontological gap between traditional morphological studies of landscapes and studies that treat the landscape as "text." In the case of the former, the landscape is treated only as a material phenomenon and it is understood that there is a physical reality that exists independent of human senses and social constructs. This was the view of landscape developed by (Sauer 1969 (1925); Sauer 1969 (1956)), and which many subsequent cultural geographers implicitly adopted (Duncan 1980). The idealist "landscape-as-text" school holds that there is no pre-interpreted reality; reality is created through human interpretation (Walton 1995). In contrast to these two extremes, the idea that reality is socially constructed relies on the assumption that the nonhuman world exists independent of human knowledge of it, and that human reality is constructed through the interpretation, perception and experience of the physical world. Wilderness, for example, is a human imposed category, with a particular geography and history, which is applied to a particular physical landscape (Duncan and Duncan 2001).

Although the constructivist approach rejects the idealist point of view, cultural landscapes studies informed by the assumption of socially constructed nature frequently treat the landscape as a "text" for analytical purposes, with the notion that "the landscape is our unwitting autobiography" (Lewis 1979). In this sense, the physical landscape is the product of human activity that occurs within a socio-cultural framework and which reflects societal values, although it should not be implied that the landscape is a passive agent. Rather, the cultural landscape as a material phenomenon can serve to reinforce or recreate societal values and codes of behavior by providing a context and a space within which human activity and interactions take place (Schein 1997). The meanings within landscapes are generally interpreted using discourse analysis, which provides a framework to relate the representation of reality as manifested on the landscape to the social processes generating them (Eder 1996). Discourses represent shared meanings, ideologies and assumptions that are communicated, interpreted, and contested by actors who share a common social framework (Duncan 1990).

By positioning the cultural landscape within a discursive framework, the landscape is interpreted as the materialization of social discourse. Discourse surrounding landscape management or production becomes materialized when action results in a tangible landscape element, such as zoning or architectural design patterns. Several discourses can be identified in the American suburban landscape: landscape architecture, zoning, historic preservation, neighborhood associations, and consumption (Schein 1997). Likewise, the idealistic spatial vision of the suburban landscape is realized and preserved through political discourse and action by organizations such as homeowners' associations (Purcell 2001). By arguing that natural landscapes can become a form of cultural capital, cultural landscapes can also reveal social power relations (Duncan and Duncan 1997; Duncan and Duncan 2001). This form of commodification of the natural landscape is subtle, since its creation and maintenance can be framed in a very positive light. For example, the formation of environmental protection policies, open space preservation, restrictive zoning and historic preservation regulations are presented as positive social and environmental goals, yet can result in negative geographic externalities, such as property values and rents that exclude moderate and low income populations (Duncan and Duncan 2001).

Although these studies represent an important and productive departure from traditional landscape studies, the emphasis on ideologies and social constructs has unfortunately resulted in a neglect of the physical landscape (Mitchell 1996). The constructivist approach acknowledges the reciprocal relationship between society and nature, yet the emphasis is typically placed on the role of landscape as a medium through which social relations are negotiated and reproduced. The landscape as a material phenomenon, with the potential to enable or constrain particular social constructions of nature, is not treated with the same rigorous attention. Attempts to relate social and political discourse to the physical landscape frequently fail to incorporate appropriate empirical evidence of actual landscape patterns, which weakens the apparent relationship. Quantitative analyses of the landscape or landscape patterns are not presented, rather these studies rely on anecdotal observations. There is seldom a discussion of the physical environment serving to facilitate or constrain the development of a particular cultural landscape. Exceptions to this latter criticism include recent work that takes into account the ecological or biophysical characteristics of a natural resource, such as timber (Prudham 1998; Prudham 2003) or copper (Bridge 2000), when examining the institutional and regulatory dynamics of the industries that depend on them.

1.3.2 Political Ecology

These latter studies mentioned above draw heavily on political ecological approaches. Political ecology seeks to incorporate political and cultural activity into ecosystem studies, recognizing that many ecosystems have components that are wholly or partially socially constructed (Greenberg and Park 1994). Political ecology is built upon traditions developed in ecology, such as evolutionary theory and systems theory, and the social sciences, which has extended ideas of ecology to investigate the interactions between human society, economics, politics and the biophysical environment. Unlike cultural ecology, however, political ecology also draws heavily from political economy, which has a broad scale emphasis on theorizing the flows of capital, production and labor at the global or regional level. Traditionally, political economy has not adequately addressed the interactions between the environment and political and economic systems, and cultural ecology has tended to focus on local scale cultural-environmental dynamics. Political ecology attempts to bridge the scales between the local and the global, while addressing the interactions between socio-cultural systems and the biophysical environment (Greenberg and Park 1994).

Geographical studies incorporating political ecological approaches are Marxist or neo-Marxist in orientation, drawing on re-readings of Marx's texts concerning the relationship between nature and capital, or the integration of nature into the capitalist system (Smith 1984). In these examples, social values informed by capitalist societies are incorporated into definitions applied to nature, a natural resource or ecosystem. Natural resources become "resources" through a process of social appraisal, which is historically and geographically situated, and are materially appropriated through human labor (Castree 1997). The industrial Douglas-fir reforestation in western Oregon and Washington is a compelling example of this, where a shift from timber extraction to timber cultivation takes advantage of the reproductive biology of trees as a source of capitalist production, redefining and physically remaking the material landscape (Prudham 2003). Duncan and Duncan's (2001) work, where certain landscapes are viewed as forms of social capital, provides a more nuanced implementation of neo-Marxist ideology.

The strength of the political ecological approach hinges on i) the analysis of political institutions and structural interactions and ii) a historic perspective, which is key to understanding the evolution of the relationships between physical and human systems. Recent studies reflect this tradition. For example, forest management policies in northern Mexico have failed to develop sustainable forestry practices (Weaver 2000), despite the development of new comprehensive policies, and the creation or restructuring of forestry agencies since the 1960s. This failure can be linked to multiple factors, such as the corruption of local officials, federal institutional changes, structural changes imposed by the World Bank, and lack of funding to support large scale development of the forest resources in northern Mexico. In this case, the complex set of factors influencing the success or failure of forest management was discovered through historical research, which allowed the identification of causal factors related to the formation, implementation, and outcome of key forest policies.

1.3.3 Landscape Ecology

A relatively young discipline, landscape ecology emphasizes spatial patterns of land use and land cover, the causes and consequences of spatial heterogeneity, and the effects of changes in scale on the relationship between landscape pattern and process (Wiens 1992; Wiens 1999; Turner, et al. 2001). In the United States, the study of landscape ecology is typified by a strongly positivistic, biophysical approach that views humans as agents of land use and environmental change and a focus on landscape patterns in environments dominated by humans. For example, Forman (1999) discusses the role of large and small forest patches in suburbia and how roads may negatively impact the ecological functioning of these patches. Loss of connectivity (Taylor, et al. 1993; Green 1994; With, et al. 1997) and species response to human-caused landscape change (Bender, et al. 1998) are other issues that have been addressed by landscape ecologists.

While Wiens (1999) maintains that a broadening of the field to address socio-cultural considerations would weaken the discipline, Risser (1999) argues that the traditional focus of landscape ecology on species and habitat distributions is insufficient to address real management issues, which occur in complex social and environmental circumstances. He encourages the inclusion of economics, politics, cultural anthropology, geography and other social sciences into landscape ecological studies to develop a "hardened analysis of political systems operating against a complex ecological, geographical, and cultural background" (p. 8). Several examples that attempt to relate landscape patterns to specific human processes exist, most notably the influence of land tenure on landscape patterns (Turner 1990; Turner, et al. 1996), historic analyses of the impacts of human land use on current landscape patterns (e.g. Krummel, et al. 1987; Axelsson, et al. 2002), the use of economics to link land development to spatial patterns of fragmentation (Wickham, et al. 2000), and the influence of landscape pattern on the formation of landscape values (Zube 1987).

One of the strengths of the landscape ecological approach is an explicit acknowledgement that scale matters (Wiens 1989; Obeysekera and Rutchey 1997). The scale of observation can influence the observation of underlying processes that drive land use patterns, and relationships established at one spatial scale may not translate to another spatial scale in a linear fashion (Gardner, et al. 1989; Jenerette and Wu 2001; Kok and Veldkamp 2001). Landscape ecology has also pioneered techniques of analyzing landscape patterns, particularly the development and application of descriptive landscape pattern metrics (O'Neill, et al. 1988; McGarigal and Marks 1994; Gardner 1999), some of which are being applied in novel ways, such as the analysis of urban form (Harold, et al. 2003). Landscape modeling techniques (Gardner, et al. 1987; Verburg, et al. 2001; Soares-Filho, et al. 2002) provide quantitative frameworks for linking pattern to process. Finally, landscape ecology, like political ecology, frequently relies on historic analyses of land use change to discover linkages between landscape patterns and the human or biophysical processes creating them.

Despite these significant contributions of landscape ecology to landscape studies and studies of human-induced land use change, the links between ecology and politics, culture, and economics that Risser (1999) argue for remain weak. While political ecology and geographical landscape studies frequently fail to incorporate sufficient treatments of the biophysical environment, landscape ecological studies often present unproblematic associations between human activity and landscape patterns. For example, Turner, et al. (1996) present land tenure as an explanatory variable for forest fragmentation patterns, but do not put forward a discussion regarding the social structures or institutions that produced and maintain the existing system of land ownership. This may be a key insight required to address relevant management issues.

A true synthesis of these approaches requires a multidisciplinary, collaborative approach that fosters mutual understanding of the theory, approaches, and methods of the relevant disciplines (Machlis and Force 1997). This research provides an example of the knowledge that can be gained through an interdisciplinary, historical approach that couples socio-cultural analyses with land use change research.

1.4 Analytical Framework

In broad terms, this research focuses on the interaction between biophysical and human systems. In developed landscapes, however, interactions between humans and the natural environment are frequently mediated by institutional arrangements so that direct causal relationships are difficult to discover. Understanding land use and land cover patterns within human-altered landscapes requires a consideration of multiple biophysical and social factors, such soils, biota, topography, economics, demographics, culture and legal institutions (Platt 1991). In suburban and urban environments, the role of policy as an agent of landscape morphology becomes particularly important. Institutional arrangements concerning land use, such as zoning, create specific landscape patterns and must therefore be considered in landscape interpretation (Schein 1997). Socio-cultural influences on policy must also be acknowledged. Conservationist ideals, for example, have informed the politics of natural resource management since the beginning of the twentieth century, resulting in a legacy of national and state policies that have focused almost exclusively on maximizing the economic value of natural resources (Cortner and Moote 1999). Only in recent decades has the environmental discourse begun to shift away from a strictly economic focus, resulting in policy orientations such as ecosystem management (Cortner and Moote 1999) and ecosystem restoration (Gobster 2000), which incorporate holistic ideas of biotic integrity, systems theory, quality of life and the intrinsic value of natural resources.

The relationships between the biophysical environment, policy and human behavioral systems can be conceptualized with a model of policy-landscape interactions (Figure 1.3). The physical system consists of biotic and abiotic elements (soil, water, climate, topography, biota); the regulatory system consists of the institutions, administrative bodies, and set of land use regulations that define resource management, which includes regulatory control of land use change; the human action system refers to the behavior of human or organizational agents whose utilization of a natural resource is constrained by the regulatory environment.

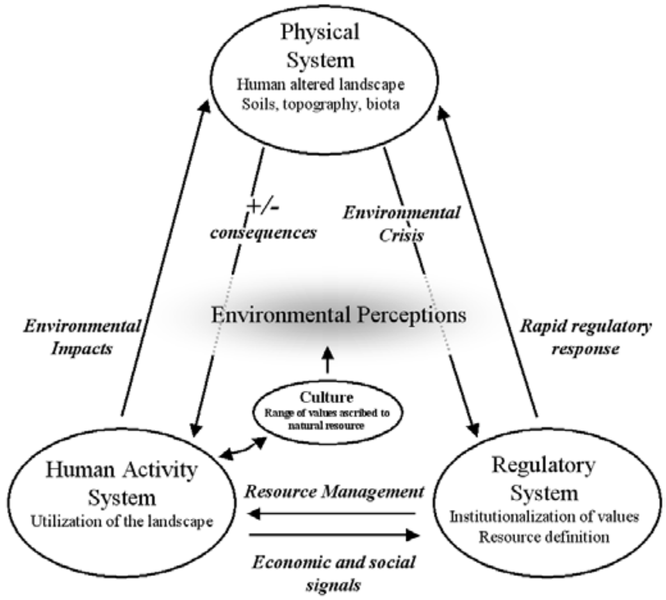


Figure 1.3 Interactions between physical, regulatory and human behavioral systems, modified from Platt 1991.

Interactions between the physical system and human systems are mediated through the lens of environmental perception. Several empirical studies confirm that environmental perceptions are strongly influenced by culture. Different cultural values and practices between groups can result in different perceptions of a natural resource, such as a forest (Bertolas 1998). The perception of something like "wilderness" is nuanced, so that, for example, urban and rural residents place similar values on wilderness but do not perceive it the same way (Lutz and Simpson-Housley 1999).

The value ascribed to natural resources is culturally informed; the cultural framework influences the issues that people perceive to be important and affects subsequent actions taken on those issues (Kempton, et al. 1995). The perception that forests in the Mid-Atlantic are threatened is informed by several factors: scientific studies documenting the loss and fragmentation of forests (e.g. Jones, et al. 1997; Jantz, et al. In press), declines in stream health as a result of development and degradation of vegetated riparian buffers (Goetz, et al. 2003; Goetz, et al. 2004), rapidly changing landscapes in which suburban residents personally experience the loss of local forested areas, and public discourse where environmental awareness is high (Kempton, et al. 1995). The idea that forests are an important resource is a cultural phenomenon that has evolved over time. For example, early Euro-American attitudes towards the forest were quite different. While forests were valued for fuel and construction materials, they were also seen as a barrier to the "improvement" of the land for agricultural use (Williams 1989). By the early twentieth century, forests were viewed as a valuable economic resource for timber and timber products (Williams 1989; Cortner and Moote 1999), and are now viewed as important ecosystem components that provide wildlife habitat, contribute to clean air and water, and provide access to nature for suburban residents.

1.5 Research Questions and Methodological Summary

1.5.1 How are forest resources in suburban environments defined through policy?

The nature of the first broad research question is largely qualitative and requires a multi-scale, multi-temporal analysis. For this study, the time period that I will focus on is roughly 1930-present, which adequately captures pre-suburban (circa 1930-1950), suburbanizing (circa 1950-1970), and suburbanized conditions. Specific research questions related to this broad problem are:

1. How has the definition of forest resources, as stated in policy documents, changed over time in Maryland and Virginia, and can these changes be linked to broader shifts in environmental awareness?

2. How has the involvement of Maryland and Virginia in the Chesapeake Bay Program influenced the development of policies related to forest preservation and management in suburban areas in recent decades?
3. How have the differing administrative structures of Maryland and Virginia impacted the implementation and development of county level policies targeting forest resource in Montgomery and Fairfax counties?

These questions are addressed in Chapter 2, with a review of historical and contemporary policy documents related to forest preservation and management and general land use planning. A policy database that was developed as part of this research will be used to document the formation of policies and their goals at all administrative scales. The first question requires an evaluation of policy and management goals at the state level through time, and an interpretive analysis to link these goals to broader scale environmental politics and national environmental policies. The second question addresses the institutional and political relationships between the states and the Chesapeake Bay Program, a regional, non-regulatory organization. Finally, the interactions between the state organizational structures and policies and the study counties will be based on a comparison of enabling legislation at the state level and the types of policy tools developed and implemented at the county scale.

1.5.2 How does policy influence forest patterns?

In contrast to the qualitative approaches outlined above, addressing this second problem requires a quantitative assessment of land cover change. Specific questions that will be addressed in this analysis are:

1. What are the patterns of land use and land cover change in the suburbs of Montgomery and Fairfax counties?
2. How have policy decisions influenced the spatial patterns of forest?

Chapter 3 presents a multi-scale analysis, over both time and space, that was performed to describe patterns of land use and land cover change. Local case studies were chosen to track land cover and land use change between the 1930s and 1998 using a roughly decadal time series of fine scale (1:20,000) aerial photographs. Two study sites in each county were chosen within which detailed data collection occurred: Olney and Rockville in Montgomery County, MD and Herndon and Burke in Fairfax County, VA. These study sites are located in what are now the outer suburbs of Washington, DC and experienced suburban development at roughly the same time, in the 1960s and 1970s. Rockville, MD and Burke, VA are historic centers of settlement, while Olney, MD and Herndon, VA are newer suburban centers. Although the geographic extent of these areas is limited, the patterns of change can be linked to broader regional trends. Fine scale analyses also provide insight into local factors related to development activities, which can inform broader scale studies.

Using coarser scale maps derived from Landsat satellite imagery, land cover changes due to urbanization that occurred between 1990 and 2000 can be described across both counties. Although this is a much shorter time scale, analysis of recent changes can be informed by the local case studies and in light of longer term policy trends.

Given the presence of multiple drivers of land use change, relating policy decisions directly to observed forest patterns presents a methodological challenge. A

Bayesian method, weights of evidence (Bonham-Carter 1997), was used to separate the influence of environmental constraints, land use history, and other factors from policy impacts. Weights of evidence can be used to quantify the spatial association between an "event," such as deforestation, and "evidence" maps, which can consist of biophysical factors, such as soils or topography, or policy factors, such as parks or zoning. Weights are calculated for each evidence theme independently and then combined to form a probability surface that describes the likelihood of the event occurring across the landscape. As discussed in Chapter 3, multiple change events were considered at both the local and county scales, including forest loss, forest persistence and urbanization, and explanatory variables were chosen for their links to either biophysical or policy measures that would enable or constrain each type of change.

Understanding how policy can influence landscape patterns is one potential contribution of this research. However, a more valuable contribution may come from a better understanding of how forests are valued and how those values are institutionalized through policy formation. This goes beyond a straightforward and unproblematic interpretation of the landscape and analyses of policy goals. Rather, I emphasize how societal values institutionalized in policy can have unintended impacts on the long term evolution of developed landscapes. In Chapter 4, the findings in Chapters 2 and 3 are synthesized in light of the multiple drivers of land cover change and the institutional values placed on different landscape.

1.6 Summary of Research Findings

The analysis of policies related to forest management revealed the complexity of the institutionalization of resource definition, which was found to be influenced by multiple factors: environmental discourses at the macro- and micro-scales, patterns of institutional interactions across administrative scales, institutional history and regional and local land use change. The focus on the Chesapeake Bay estuary holds a dominant position in the regional environmental discourse that was found to have a significant influence on state and local policies. A crosscutting institutional emphasis on forest management, water-quality related best management practices and forest conservation in environmentally sensitive areas was identified. It was also found that regulatory policies tended to emerge at the local scale, with state and federal policies providing the enabling legislation, funding sources, and political support that facilitated or, in some cases, constrained local government activity.

The analysis of land cover change showed that the abundance of forests within landscapes is linked to land use history, and the occurrence of development produces marked patterns of fragmentation. The application of the weights of evidence statistical model confirmed many of the hypotheses regarding the role of biophysical variables, such as slope and poorly drained soils, in determining patterns of development, deforestation and forest persistence. Protected lands are associated with forest persistence and current forest distribution, and deforestation rarely happens in these areas. These results also indicate an association between forests and stream proximity. It was also noted that the rate of forest loss in watersheds that are already highly developed indicate that these remaining urban forest patches are under considerable pressure from development, and the fact that outlying watersheds are experiencing high growth rates indicate that forest loss and fragmentation is becoming more widespread. The lack of strong urban forestry programs at the state or local levels indicates that unprotected, non-riparian forested areas within highly developed landscapes are likely to decline.

The future of forests in rapidly developing counties in Maryland and Virginia can be discussed in light of the above policy and land cover change analyses. Given the differences between Maryland's and Virginia's resource management approaches, the capacity of local governments to address issues related to rapid land cover and land use change can be evaluated. In Virginia, for example, there is evidence that indicates a strong state commitment to protect private property rights. Given this institutional culture, local governmental autonomy is frequently preempted by the state, potentially inhibiting the responsiveness of local government and creating a positive environment real estate interests. Maryland, in contrast, provides a more supportive institutional environment for local government control, "smart growth" initiatives, and forest conservation. Program Open Space, for example, provides a dedicated source of state funding for land acquisition, and the Forest Conservation Act is a statewide law that requires mitigation of deforestation that occurs during the development process. Despite these initiatives, however, forests in Montgomery County, MD still show significant losses.

In addition to these institutional constraints to forest preservation and land use management, there are cultural factors that influence policy formation. The fact that policies related to riparian areas influence forest patterns is a reflection of the environmental value that is currently ascribed to forests in these rapidly developing landscapes. Because of the link between institutional definitions of forests and the broader environmental discourse, the development of policies and funding mechanisms to promote forest persistence more broadly within highly developed landscapes would need to be predicated on shifts in societal attitudes.

CHAPTER 2: FOREST MANAGEMENT POLICIES

2.1 The Institutional Perspective

Despite the acknowledgement that nature and society are parts of an interdependent whole (Smith 1984; Harvey 1996; Peet and Watts 1996), much land cover and land use change research has tended to focus on the physical and socio-economic factors related to land use and land cover change (e.g. Blaikie and Brookfield 1987; Kaimowitz and Angelsen 1998). While behavioral economic models of land use/land cover change have evolved to include the spatial perspective (e.g. Landis 1995; Bockstael 1996) and have been continually refined to effectively model the economic decisions of land owners, this approach has failed to address fundamental criticisms, namely the fact that theories of profit maximization or economic efficiency do not adequately account for the influence of socio-cultural values (Bromley 1982), social structure or the actions of higher-order (e.g. bureaucratic) agency (Walker and Solecki 2004). These limitations become pronounced when considering long time scales and broad spatial scales. The institutional perspective, in contrast, is principally concerned with the process of value determination that occurs when policies related to natural resource management are debated, contested, and institutionalized (Bromley 1982).

The role of higher-order organizations, such as governments or governmental agencies, is of particular importance (Johnston, et al. 1995), especially in highly regulated environments. Indeed, Escobar (1996) argues that the state is an interface between capital and nature, between human beings and space. Landscapes can reflect the tension and interaction between regulations and political institutions and local adaptations to physical and cultural circumstances (Jackson 1984). Understanding current institutional arrangements and regulatory structures often requires an understanding of how such structures evolved and how they relate to changes in the natural environment. Extreme pressure on a natural resource that leads to an environmental crisis or resource scarcity, for example, can initiate regulatory changes (Thompson, et al. 1992; Ernst 2003). Likewise, the social definition of a natural resource can change, leading to new management schemes or land use patterns. The system linkages modeled in Figure 1.3 must therefore be considered to be dynamic over space and time.

The evolution of the forested landscape embedded in the present-day suburbs surrounding Washington, DC and many similar suburban landscapes throughout the mid-Atlantic region can be understood, in part, through the examination of the historic and political context within which land cover and land use change has occurred. The management orientations of agencies such as the state forestry departments are rooted in their respective organizational histories. It is evident that, while signals from the natural and social environment may be similar over space, the response of governments has been influenced by their institutional histories. In addition, regulations and guidelines to protect, preserve or enhance forests and trees during the development process are the result of an environmental discourse that is time and place specific. In many cases, changes in regulatory structures or institutional arrangements are precipitated by environmental change, a perception of resource degradation or a shift in resource definition.

This chapter seeks to address the question of how forests in suburban environments are defined through policy and how this definition has changed over time. While the spatial scale of the land use change data is limited to study sites within two counties (see Chapter 3), the scale for policy analysis is broader, since policies that originate at the state or regional level operate on the ground at a local level, or have provided the impetus for policy formation at the county scale (Figure 2.1). The state as a principal originator of land use policy, as the source of the county government's power to regulate land use, and as the mediator between federal/regional and county governmental policy will be a primary object of analysis. In this study, the opportunity to contrast the approaches of Maryland and Virginia exists due to their differing administrative structures, home rule in the case of Maryland and Dillon rule in the case of Virginia. Furthermore, the participation of both states in the regional Chesapeake Bay Program has played an important role in the formation of land use policies at all administrative scales, particularly since the 1980s.

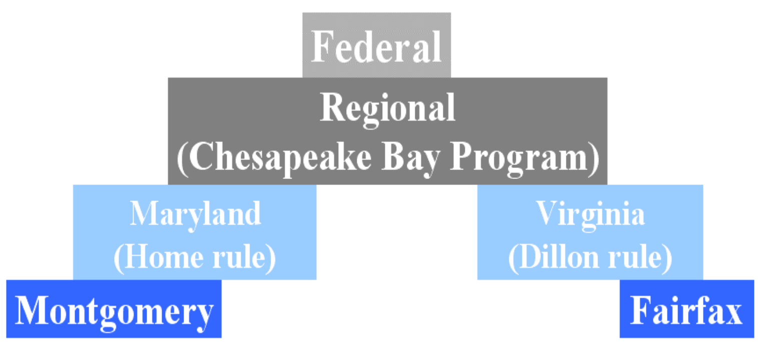


Figure 2.1 Administrative scales incorporated into this analysis, presented hierarchically. At the federal level, organizations such as the Environmental Protection Agency, Department of Agriculture, and the Forest Service act as higher-level land use change agents. Analogous agencies can be found at the state and county level. At the regional level, the primary agent is the Chesapeake Bay Program, although other organizations, such as the Chesapeake Bay Foundation, are also influential.

2.2 Data and Methods

Addressing the question of forest definition necessitated the adoption of a qualitative research paradigm that utilized methods of historiography, grounded theory and content analysis. The identification of relationships among issues in the past that continue to influence the present is necessary to understand contemporary institutional conditions and to fully appreciate the challenges faced by resource managers (Bromley 1982; Berg 2001). A database was developed that identified forest policies and principal agencies and organizations concerned with land use or natural resource management at the federal, regional, state and local level. Temporally, the database captures the pre-suburban era (pre-1950) to the present. This database served as the primary resource to identify trends in forest policy through time and across scales.

2.2.1 The Policy Database

Over 130 policies and organizations were identified and reviewed, spanning a time period from 1881 to the present (see Appendix A). While a complete inventory of all policies and organizations was not possible, particularly for the earlier time period (pre-1950), this database captures the primary agencies involved with forest management or land use decisions that could impact forests, their objectives, and the policies that were developed to implement these objectives. There are several examples of policies that do not have forest management or forest conservation implications as their central focus, such as storm water management or wetland preservation. These policy items nevertheless contain explicit references to or guidelines for vegetation preservation, including forests, and have therefore been included in the database.

Development of the database entailed extensive archival and web-based research. The World Wide Web was a valuable resource for current policy documents, including items such as mission statements, institutional histories, reports, and the text of regulations and guidelines. Furthermore, state and county annotated codes are available on the Internet in searchable format. Government codes were searched for policies related to the environment in general and forest management or preservation in particular, including tree planting programs and urban forestry. Annotations included the date that a particular ordinance or code was adopted, as well as the dates of changes to the code. State, university, and institutional archives were also searched for documents related to forest or land use management; archival research was particularly important for uncovering primary historic sources, such as documents published by land use management agencies (e.g. the federal or state departments of forestry, or state and local planning agencies). Internal validity of the database was confirmed by several key sources that provided contemporary summaries of the policies in place at a certain time, such as the Commission to Study the Forestry Conditions of Virginia (1932), the State Department of Forestry (1932), the Chesapeake Bay Commission (1995), and McElfish and Wilkonson (2000).

For each policy or organization, the database contains a description and information regarding the objective (e.g. land acquisition, planning, forest management), the approach (e.g. regulatory, incentive-based), the year of formation, and any elements that are explicitly spatial in nature. Multiple techniques were used in the analysis of the data. First, policy objectives were categorized using grounded theory (Bernard 2002). This approach is inherently inductive, allowing the researcher to evaluate the data set as a whole and identify common themes or in this case, policy objectives. Based on the generalized objectives that emerged, each policy item in the database was categorized accordingly, allowing for the identification of trends in policy objectives across scales and through time. These policy objectives are a reflection of the social construction of the forest resource across space and time, yet are also constitutive of the particular institutional context of the author organization or agency (Hajer 1995; Paehlke 1997).

In addition to the identification of objectives, the approach utilized by each policy or organization was identified. Four categories were defined *a priori*:

1. *Regulatory policies* refer to enforceable and compulsory policies that restrict or otherwise dictate the behavior of individuals, organizations or private landowners. Examples of regulatory policies include the seed tree laws in Maryland (Maryland Department of Natural Resources 2004c) and Virginia (Virginia Department of Forestry 2004), which require timber harvesters to reserve mature trees for seed production or to reforest the stand after harvest.
2. *Non-regulatory policies* refer to policies or agencies that provide voluntary or incentive-based programs to preserve forests, trees, or open space, including easement programs and tax incentives.
3. *Acquisition* refers to policies or institutions that focus on the acquisition of land in order to protect or preserve forest resources, such as Maryland's Program Open Space (Maryland Department of Natural Resources 2004d).
4. Several policies or institutions focus on *education, outreach, decision support or advocacy*. Virginia's Urban Forest Council (Trees Virginia 2004), which provides training and education about urban forestry, is an example of an institution

providing education and outreach; the Chesapeake Bay Foundation is an example of an advocacy group that also has education and outreach functions.

This content analysis (Bernard 2002) was performed primarily to test the hypothesis that the approaches to land use management at the county scale in Maryland and Virginia would be different due to the differences in their regulatory structure. In Maryland, a home rule state, it was hypothesized that land use management would rely more heavily on regulatory approaches, while in Virginia, a Dillon rule state, approaches to land use management would be voluntary or incentive-based. While this analysis proved valuable to identify and evaluate these differences between the states and between the two counties, it was also useful to apply the same analysis across all scales.

2.3 Results

2.3.1 Policy Objectives

Seventeen policy objectives were identified in the database (Table 2.1), encompassing goals such as planning and growth management, open space preservation, erosion control, and forest management.

Considering the total number of policy items in the database, the most common policy objective is forest management, including policies related to forest harvesting practices, the creation of forest management plans, reforestation, seed tree laws, and thinning (Figure 2.2). This is clearly a "top-down" objective, being heavily dominated by federal and state level policies.

Table 2.1 Policy objectives

POLICY OBJECTIVE	DEFINITION
Planning	Policies or institutions that mandate or support land use planning
Growth management	Policies or institutions that mandate or provide incentives for growth management and redevelopment.
Park fund	Policies or institutions that allow donations from private citizens to finance park operations or land acquisitions
Urban forestry	Policies or institutions that support urban forestry activities
Outreach/decision support	Policies or institutions that provide outreach services, including education, extension services, and advocacy, and/or decision support services.
Open space preservation	Policies or institutions that support open space preservation, primarily through easements.
Farmland preservation	Policies or institutions that support farmland preservation, primarily through easements.
Land acquisition	Policies or institutions that focus on the acquisition of land to be held and managed by public institutions.
Land preservation	Policies or institutions that support land preservation or conservation, including farmland, forestland, wetlands, wildlife habitat, etc.
Erosion control	Policies or institutions that mandate or provide incentives for the use of practices that will minimize erosion during land disturbing activities.
Best management practices (BMPs)	Policies or institutions that mandate or provide incentives for agricultural and forestry BMPs, including establishing riparian buffers, that will improve water quality.
Environmental preservation	Policies or institutions that mandate or support the protection of environmentally sensitive lands, such as highly erodable soils, wetlands, or important wildlife habitat.
Forest management	Policies or institutions that mandate or support forest management, including the creation of forest management plans, reforestation, seed tree laws, and thinning.
Tree planting/preservation	Policies or institutions that focus on tree planting and tree or forest conservation or preservation. These include site-level policies that mandate or encourage forest preservation during subdivision development and tree planting initiatives.
Wetlands	Policies or institutions that mandate or provide incentives specifically for wetland preservation.
Chesapeake Bay restoration	Policies or institutions that broadly focus on Chesapeake Bay restoration.
Water quality	Policies or institutions that mandate or provide incentives specifically to address water quality.

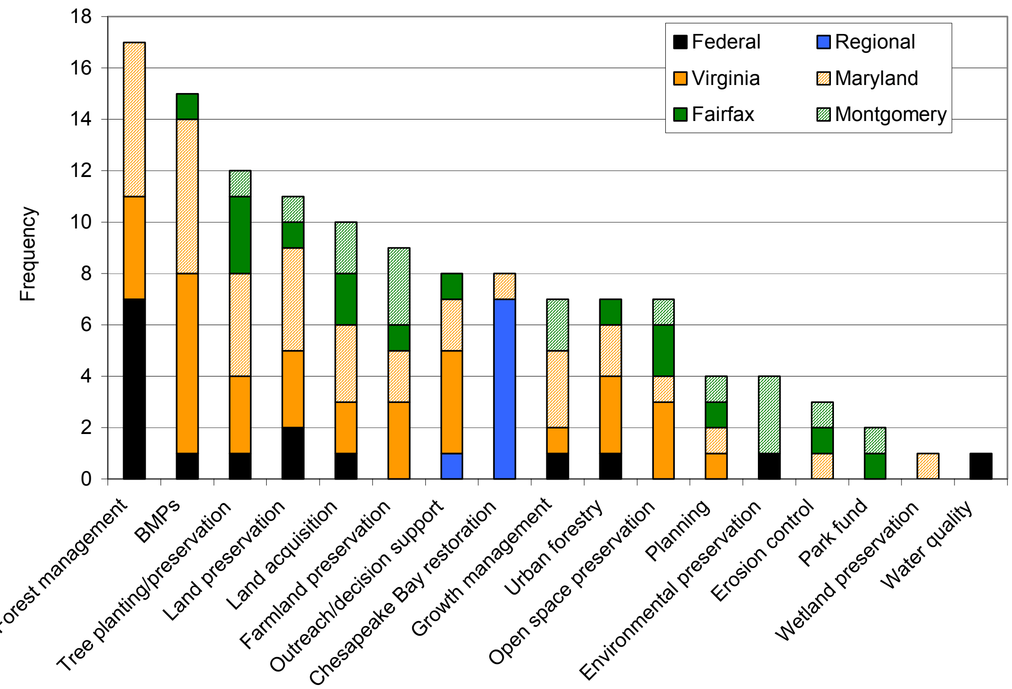


Figure 2.2 Frequency of different policy objectives at the federal, regional, state and county level.

The second most common objective is related to the implementation of best management practices (BMPs). BMPs are methods of land management that are almost exclusively focused on improving or preserving water quality, such as the creation or retention of vegetated riparian buffers. Like forest management, the implementation of BMPs is a meso-scale objective, with disproportionate representation by the state governments. Tree planting and preservation is also a common policy objective, although this particular policy goal has more representation by the state and county governments rather than the federal government. These policies include those related to street tree planting and maintenance, reforestation or forest preservation during development, and the establishment and maintenance of state tree nurseries.

Other trends across administrative scales can be identified. In addition to being focused on tree planting and preservation objectives, the objectives of the county governments are also centered on open space preservation, farmland preservation and land acquisition. States' objectives focus on forest management, BMP implementation, and tree planting and preservation, but also focus on land preservation and outreach/decision support. The federal objectives are almost exclusively concerned with forest management, while regional objectives reflect the orientation toward the Chesapeake Bay.

The above observations have been drawn from the aggregation of all policy items. Additional perspective can be gained by observing the emergence of policy objectives over time. Figure 2.3 illustrates the number of new objectives identified in each time period. There has been an increase over time in the number of objectives addressed at all administrative scales. The frequency values for the most current time period show the high degree of diversification of policy objectives that currently exist. The states consistently have the highest degree of diversification, followed by the counties, which rank closely to the federal level. While the county and state objectives have increased steadily over time, the objectives of the federal government did not begin to diversify notably until after 1969. At the regional scale, the strong focus on the Chesapeake Bay has limited the formation of multiple objectives.

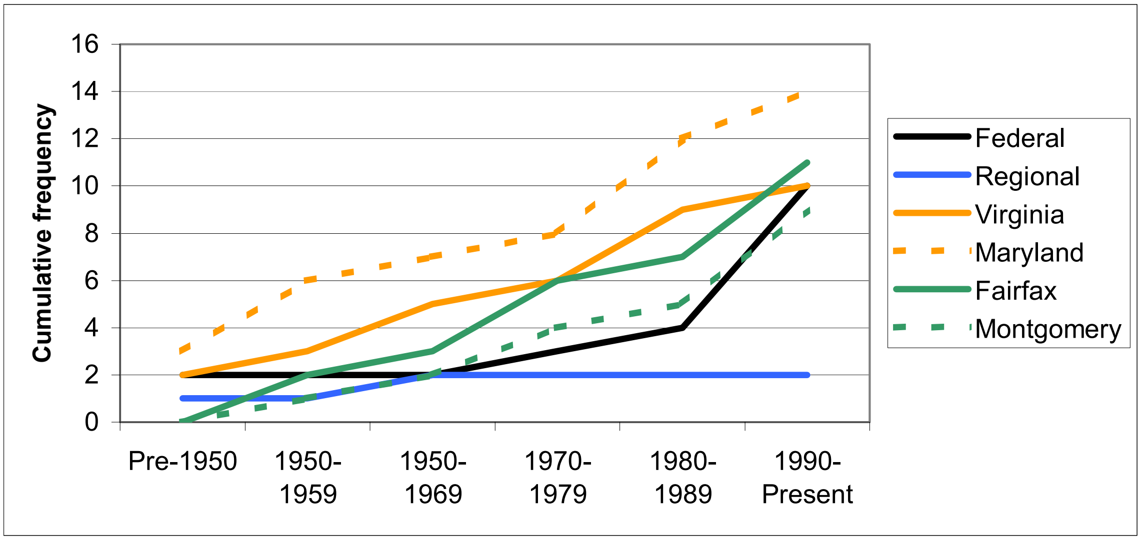


Figure 2.3 The emergence of policy objectives through time for all administrative scales.

Table 2.2, which notes the time period that a given objective emerged, allows for consideration of the content of policy objectives over time and across scales. Several themes cut across administrative scales, including land preservation, urban forestry, and growth management. Forest management objectives are restricted to the state and federal levels, while objectives such as open space preservation and planning are negotiated between the state and county levels. Unique to the county administrative scale are park funds. For both Montgomery and Fairfax County, these funds allow private citizens to donate money to support local land acquisition and park maintenance[1].

[1] In Montgomery County, the park fund is administered by the Montgomery County Park Foundation, and in Fairfax County the Fairfax County Park Authority administers the Land Preservation Fund.

Table 2.2 Policy objectives through time

	Pre-1950	1950-1959	1960-1969	1970-1979	1980-1989	1990-Present
Federal	➢ Forest management ➢ Water quality				➢ Environmental preservation	➢ Growth management ➢ Urban forestry ➢ Land acquisition[2] ➢ Land preservation ➢ BMPs
Regional	➢ Planning		➢ Chesapeake Bay			
Virginia	➢ Forest management ➢ Tree planting/ preservation	➢ Farmland preservation	➢ Open space preservation ➢ Land acquisition	➢ Planning	➢ Urban forestry ➢ Land preservation ➢ BMPs ➢ Outreach/decision support	➢ Growth management
Maryland	➢ Land acquisition ➢ Forest management ➢ Tree planting/ preservation	➢ Open space preservation ➢ Land preservation ➢ Erosion control	➢ Planning	➢ Farmland preservation	➢ Urban forestry ➢ BMPs ➢ Wetlands ➢ Chesapeake Bay	➢ Growth management ➢ Outreach/ decision support
Fairfax		➢ Outreach/ decision support ➢ Land acquisition	➢ Open space preservation	➢ Planning ➢ Farmland preservation ➢ Tree planting/ preservation	➢ Erosion control	➢ Park fund ➢ Urban forestry ➢ Land preservation ➢ BMPs
Montgomery		➢ Land acquisition	➢ Planning	➢ Erosion control ➢ Environmental preservation	➢ Farmland preservation	➢ Growth management ➢ Park fund ➢ Land preservation ➢ Tree planting/ conservation

[2] This refers to the Conservation and Reinvestment Act (CARA), a federal bill that would create a dedicated funding source for land acquisition for wildlife habitat, open space, and historic preservation. This bill (H.R. 701) was passed by the House of Representatives in 2000 but was never brought to a vote in the Senate.

The earliest attempts at regional management occurred in the 1920s and 1930s, when Maryland and Virginia attempted to formulate management goals that would address the degradation of aquatic resources (Ernst 2003). In 1967, the Chesapeake Bay Foundation was established. The activity of this activist group, coupled with the release of a report on the Chesapeake Bay published by the Environmental Protection Agency in 1983, resulted in the formal participation of Maryland, Pennsylvania, Virginia, the District of Columbia, the federal government and the Chesapeake Bay Commission in the first Chesapeake Bay Agreement in 1986 (Horton 2003). This document and subsequent Bay Agreements reflect the commitment of the signers to the restoration of the Chesapeake Bay.

2.3.2 Policy Approaches

In addition to the identification of policy objectives, policy items were also considered in terms of their approach (Figure 2.4). Policy approach is clearly dependent on administrative scale. At higher administrative levels, non-regulatory policies are more common; regulatory policies are most common at the county scale. Counties also have more policies devoted to land acquisition than the states or federal governments. Maryland has a higher proportion of both regulatory (32%) and non-regulatory (49%) policies than Virginia (24% and 44% respectively), but Virginia has a higher proportion of outreach and decision support policy items (24% versus 11% for Maryland). These differences between states are mirrored at the county level. One hundred percent of regional policy items are categorized as outreach and decision support.

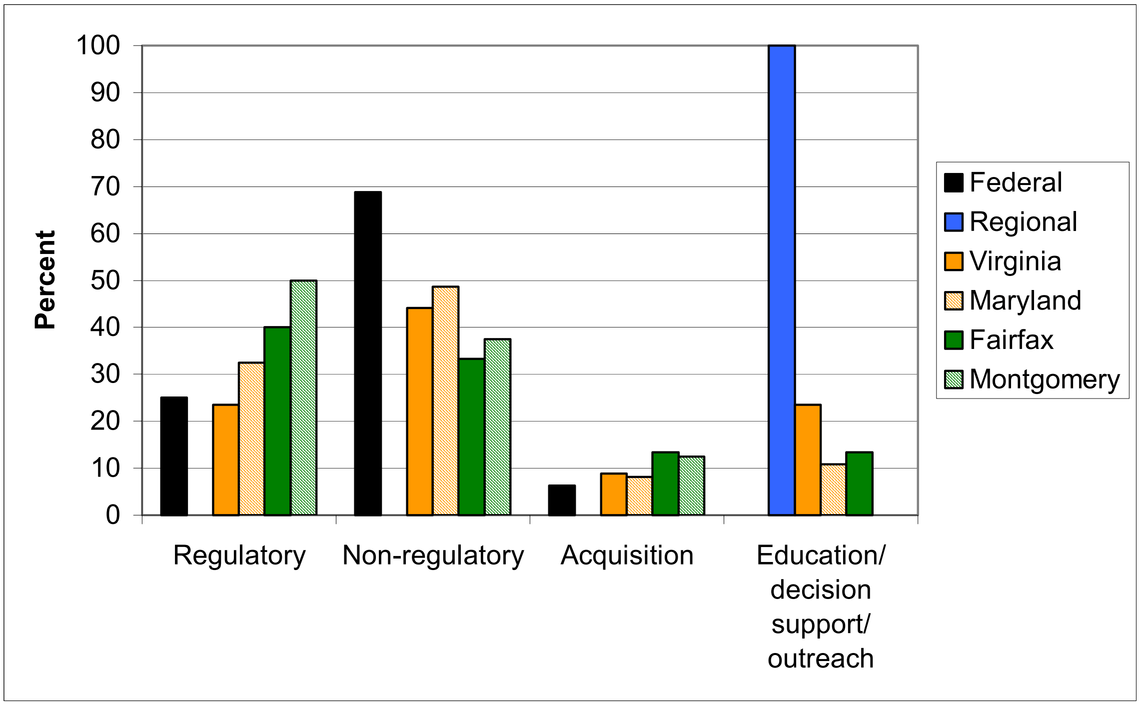


Figure 2.4 Policy approaches for all administrative scales.

2.4 Discussion

2.4.1 Policy Objectives: Defining the Forest

The Influence of Progressivism

The themes, or policy objectives, that emerge through time reflect changing societal values and resource definitions (Paehlke 1997). The emphasis on forestry that occurs early in the time period (pre-1950) is rooted in contemporary Progressivism, or the idea that natural resources should be managed scientifically for maximum efficiency and production without sacrificing future use of the resource (Scheffer 1991; Hirt 1994). In forestry, Gifford Pinchot, the first Chief Forester of the United States Forest Service, embodies this management orientation. During his twelve-year tenure with the Forest Service, Pinchot developed an institutional structure and the guiding principles for national forest management that was firmly based in Progressive ideals (Hirt 1994). The Progressive orientation is clearly evident in early forest management documents from Virginia and Maryland:

> "An axe in the woods, like a fire in the home, may be either an agency of immeasurable benefits or of tremendous evil. Properly used, the axe stimulates new forest growth as it harvests the old. Without forethought or reason to guide its use, irreparable damage may be done. … It is safe to say that practically all woodland growth [in Maryland] could, at one time or another, be profitably improved today" (Trenk 1929).

> "The forest products industry is one of the largest industries in the State [of Virginia]. It should be, and could be, doubled. … Only to the degree that Virginia is willing to grow a full crop of timber on the forest acres within her borders, can she profit by this expanding market" (Sanders, et al. 1955).

Indeed, Maryland's first state forester, Fred W. Besley, was a protégé of Gifford Pinchot (Maryland Department of Natural Resources 2000), and the philosophy of forest management espoused by Pinchot was a reflection of the broad societal attitudes towards the natural environment at the time. This emphasis on the economic value of forest resources persisted through the 1950's, and is still present in the current environmental discourse (Scheffer 1991; Hirt 1994; Paehlke 1997).

While the Progressivist management approach emphasized the economic aspect of the timber resource, other values were acknowledged. Integral to national forest policy management from the beginning were goals of watershed protection and timber management; uses such as livestock grazing and recreation were also considered to be legitimate uses of the national forests, and the phrase "multiple use" began to appear in National Forest Service publications as early as the 1930s (Hirt 1994). Multiple values are also ascribed to forests in Maryland's and Virginia's state documents. Objectives for public forest management in Virginia include providing "the general public with recreational and related facilities, and protection for game" (Virginia State Forester

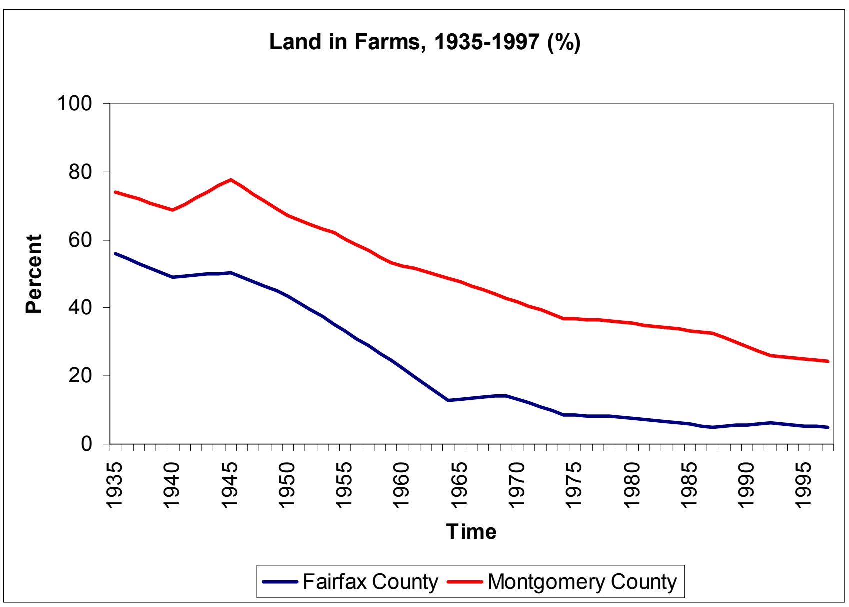
1942). Besley (1916) also emphasized the use of Maryland's public forests lands for recreation, watershed protection, including prevention of water pollution and sedimentation, and non-timber forest products, such as basket willows. These uses were generally encouraged in areas where timber extraction was untenable.

The Environmental Movement and Interactions with Land Use Change

Alternative values articulated by writers such as George Perkins Marsh, John Muir, and Aldo Leopold, while mostly latent during the Progressive era and through to the 1950s, gained prominence in the American environmental discourse in the 1960s (Cortner and Moote 1999). During this time, several factors converged to produce fundamental changes in environmental values. The emergence of post-materialist or post-industrialist values following World War II resulted in a growing focus on quality-of-life issues, including the environment (Kraft and Vig 1997). Several environmental disasters that occurred at the end of the 1960s, including a large oil spill in Santa Barbara, excessive DDT contamination in Minnesota and Wisconsin salmon, and the burning of the Cuyahoga River in Ohio, were widely publicized and resonated in the public conscience (Scheffer 1991). The federal response to the new environmental movement resulted in several new environmental policies, including the Clean Air Act of 1963, the Wilderness Act of 1964, the National Environmental Policy Act of 1969, and the Federal Water Pollution Control Act (the Clean Water Act) Amendments in 1972 (Kraft and Vig 1997; Clarke and Cortner 2002).

The late 1960s diversification of federal policy objectives observed in this study coincides with the federal response to the environmental movement. The diversification of state and county scale policy objectives preceded the federal response, reflecting the greater adaptability of local and state governments in responding to changing societal values. Locally, both the county and state governments in this study were also responding to land use change and its environmental and social implications. In the 1950s, population increases and other factors spurred the suburbanizataion of Montgomery and Fairfax counties. By the 1960s and 1970s, the character of these counties had been fundamentally altered as an increasing proportion of the population resided in suburban landscapes and held professional jobs in Washington, DC, Arlington, VA, Alexandria, VA, or one of the growing commercial centers within the counties. The decline of land area in farms in these counties (Figure 2.5A) is an indication of the shifting economy; by 1970, Montgomery County had lost 67% of the farmland that had existed in 1935, and Fairfax County had lost 86% (Figure 2.5B).

A



B

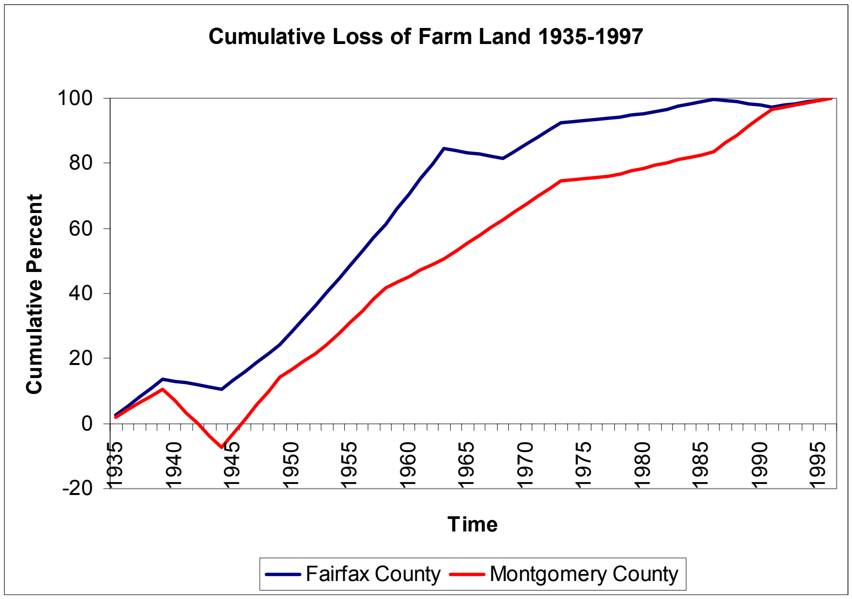


Figure 2.5. The percentage of county land in farms between 1935 and 1997 (A) and the cumulative loss of farmland between 1935 and 1997 (B). Sources: Bureau of the Census (1927), Bureau of the Census (1946), Bureau of the Census (1956), Bureau of the Census (1967), Bureau of the Census (1981), Bureau of the Census (1989), Manheimer (1999), Bureau of the Census (2001).

The land use changes that were occurring around Washington, DC were part of a nationwide trend of suburbanization (Knox 1993), and these changes were influencing the definition of forest resources in suburbanizing areas. Resource managers and scientists in the northeast wrestled with the problem of the suburban forest (Waggoner and Ovington 1962), attempting to define the forest, identify its purpose, and establish directions for scientific research and management. The roles of the forest as a moderator of the environment for human comfort, a filter for air and water and as a barrier for noise, and as an aesthetic element or amenity were emphasized. The policy objectives that emerged during the 1950s and 1960s (Table 2.2) focused on farmland preservation, open space preservation, erosion control, land acquisition and land use planning. These themes reflect the response of state and county governments to the changing landscape and changing societal values.

Ecology and Ecosystem Restoration

The ecological view is systems based, and considers the complex relationships between organisms and the environment, including the abiotic and biotic components. Publications such as Rachel Carson's *Silent Spring* (Carson 1962) and the Club of Rome's *Limits to Growth* (Meadows and et. al 1972) documented the ecological repercussions of intensive and industrialized human activity. The ecosystem worldview questioned the ability of Progressivist ideals of scientific management and technology to achieve resource sustainability, primarily due to the ability of current science to fully understand the complexity of natural systems (Scheffer 1991). This view was reinforced in the public conscience by environmental disasters such as the nuclear meltdowns at the Three Mile Island nuclear power plant in 1979 and the Chernobyl power plant in 1985, the discovery of the thinning ozone layer in Antarctica, and the growing number of scientists who were beginning to document the human-induced changing of the global climate (Clarke and Cortner 2002). Taken in the light of the globalization trend, these events caused the interconnectedness of the earth's systems to become a tangible concept in the western environmental conscience, to the extent that ecology and sustainability are considered to be core environmental values in contemporary western society (Paehlke 1997; Kempton, et al. 1995).

Ecosystem-based management, or integrated environment and development planning defined in terms of biophysical and socioeconomic goals (Slocombe 1993), is the result of the institutionalization of the ecosystem worldview. Spatially, ecosystem-based management tends to focus at broader scales that can extend beyond the boundaries of the specific resource in question, and can also cut across political boundaries. The socio-political aspect of the ecosystem approach is well-recognized (e.g. Bonnicksen 1991; Risser 1999; Gobster 2000), and the involvement of social scientists in ecosystem science is growing (Gobster and Hull 1999). While ecosystem-based management brings new themes to the resource management discourse, such as sustainability, human-environmental interactions, complexity and uncertainty, the role of science and technology for informing and implementing management decisions is still significant (Reichman and Pulliam 1995). A component of ecosystem-based management, ecosystem restoration, defined as “intentional human practices to actively manage areas for their desired natural qualities” (Gobster 2000), reflects both the holism of the ecosystem worldview and the strong faith in science and human engineering that is the heritage of Progressivism.

In the mid-Atlantic region, ecosystem restoration has become a dominant theme in the environmental discourse. The regional focus on the Chesapeake Bay, the participation of states in the Chesapeake Bay Program, and the high profile of restoration activities have resulted on an environmental policy focus that is oriented toward issues of water quality and watershed management. The prevalence of policy items at the state administrative scale that are concerned with the implementation of best management practices (BMPs) (Figure 2.2) is consistent with the strength of this theme in the discourse. There are many state policies that are specifically targeted toward Chesapeake Bay restoration, such as Maryland’s Buffer Incentive Program (McElfish and Wilkonson 2000) and the Stream Releaf Plan (Stream Releaf Coordinating Committee 1998), and Virginia’s Riparian Buffer Implementation Plan (Virginia Riparian Forest Buffer Panel 1998). Virginia formed the Chesapeake Bay Local Assistance Department to assist local governments in amending local policies so that they are consistent with state restoration goals (Department of Conservation and Recreation 2002). The prevalence of this discourse theme extends beyond the creation of policies specifically targeting Chesapeake Bay restoration. References to Chesapeake Bay restoration can be found throughout the text of many policy items at both the state and local administrative scale. Indeed, the governor of the state of Maryland recently announced that state land acquisitions would be prioritized in terms of their importance for Bay restoration goals (Maryland Department of Natural Resources 2003b). The prevalence of alternative management programs that do not have a strong link to water quality, such as those focused on urban forestry, is diminished.

2.4.2 Administrative Scale Interactions

Values across Administrative Scales

Some clear patterns in policy objectives emerge across administrative scales (Figure 2.2). The federal government, for example, is almost exclusively associated with forest management goals, with a smaller emphasis on land preservation, growth management, land acquisition, BMP implementation, environmental preservation, tree planting, and water quality. Most of these latter objectives have only emerged since 1990 (Table 2.2), in contrast to the federal government's long history focusing on forest management. This reflects the relative inertia of the federal government's policy orientation (Hirt 1994), although recent policies concerned with issues such as growth management and urban forestry are an indication of the continued growth of diversity in policy objectives.

State policy objectives are much more diverse, although there is still a strong emphasis on forest management, illustrating the connection between the state and federal levels on these objectives as well as the broad management scale for this resource. Many of the BMP implementation items are related to Chesapeake Bay restoration, tying these trends to the regional environmental discourse. Convergence between state and county objectives is apparent. For example, planning, open space preservation, farmland preservation, land acquisition, and tree planting programs are balanced by state and county involvement. This is in part due to feedbacks between the state and county governments, but also reflects the level of broad significance that these issues have attained at the state level. While the local component of many of these issues is strong, they reach across administrative scales.

While the county objectives are diverse, open space preservation, farmland preservation, land acquisition and tree planting programs are prevalent. This is the institutional response to local land use changes, which in Montgomery and Fairfax counties has been rapid and dramatic. The county-level objectives also reflect some values that are typically underrepresented at broader administrative scales. For example, park funds, policy items unique to the county scale, allow individuals to make monetary or time donations to the county parks system, directly supporting land acquisition or maintenance costs. This level of community involvement signifies place-specific connections that are institutionalized through the creation of organizations like the park funds, and are more closely affiliated with aesthetic, quality of life, or spiritual forest values.

Interactions with Land Use Change

Land use and demographic change has had a distinct influence on institutional structures and policy formation and has prompted institutional interactions across scales. Perhaps the most striking example of this is the development of planning institutions within the counties, which was instigated by the environmental, quality of life, and fiscal impacts of rapid suburban development, yet, which ultimately required state intervention for implementation. At the county level, the institutional structures of the governments were influenced by changes in land use and demographics, since the demands on government by the suburban population were significantly different from those of a rural or agrarian population. As the population increased and the agricultural economy faded, the need for public infrastructure, such as schools and roads, prompted centralization of the county governments (Hiebert and MacMaster 1976; Netherton and Sweig 1978). As suburban development proceeded in an essentially unregulated environment, the environmental and quality of life consequences became concerns for local residents and decision makers. Consequently, comprehensive land use planning, environmental protection, and landscape preservation became important goals.

By the 1950s, both counties had completed their first countywide land use inventories (McHugh 1954; Maryland National Capital Parks and Planning Commission 1957). In reaction to rapid land use change, multiple reports were published between 1950 and 1970 about the problems associated with rapid suburbanization (Montgomery County Commission on Zoning and Planning Law Procedure 1965; Montgomery County Planning Board 1973; Finz 1974; Office of the County Attorney Fairfax County Government 1974), many with an emphasis on the loss of open space and farmland

(Fairfax County Planning Division 1962; Smedley, et al. 1962; U.S. Department of Agriculture 1963). These circumstances resulted in the creation of a framework for extensive land use planning infrastructures in the counties. By 1964, the Maryland-National Capital Park and Planning Commission had drafted a land use plan for Montgomery and Prince George's counties (Maryland-National Capital Parks and Planning Commission 1964), which was adopted in 1969 by the Montgomery County council. In the early 1970s, Fairfax County developed the Planning and Land Use System (PLUS) (Peters 1974; Dawson 1977), and adopted the first comprehensive plan in 1975.

While pressure from county residents was forcing institutional change within the county governments, the state also put pressure on the county governments to better regulate growth. Issues related to land use planning were extremely contentious within the county governments. Residents who were impacted by increased traffic congestion and crowded schools were strongly in favor of land use planning, environmental concerns were focused on the declining quality of municipal water supplies (Peters 1974) and flooding caused by urban development (Anderson 1970), while real estate interests were opposed to increased regulation of the development process. Although Montgomery County's land use plan had been drafted in 1964, the county council did not adopt it until the state of Maryland required all counties to create and adopt comprehensive land use plans (Baker 1966). Virginia passed a similar law in 1974, which added impetus to the previous efforts of planners in Fairfax County and eventually resulted in the acceptance of the PLUS plan (Peters 1974; Dawson 1977).

These types of interactions between the state and county governments are not unique to this example and represent a feedback between local issues and state involvement. Local concerns associated with land preservation, farmland preservation, and urban forestry are often supported by state programs, either through direct regulation or through grants and incentive programs. State programs are then often supplemented by county initiatives. In the case of Virginia, many county-level regulatory actions require direct state involvement.

2.4.3 Approaches to Resource Management

As noted above, Maryland and Virginia have different administrative structures that can influence approaches to and options for forest management at the county scale. Maryland is a home rule state, where local governments can perform any function that is not prohibited by the state or that is not in conflict with the state constitution or statutes. Virginia, in contrast, is a Dillon rule state, where local governments possess only the powers explicitly granted to them by the state legislature. Dillon's rule can place significant limitations on local government, while home rule allows a greater degree of municipal autonomy (Weiland 1999). A home rule municipality may be expected to have a more rigorous regulatory structure, while incentive-based programs would be expected to be more prevalent in a Dillon rule environment.

When policy items were categorized according to approach (i.e. regulatory, non-regulatory, acquisition, education/decision support/outreach), it was found that both counties have a higher proportion of regulatory policy items than non-regulatory. However, compared to Montgomery County, the proportion of regulatory items in Fairfax County is significantly lower. This is consistent with the stronger regulatory environment that could exist in a home rule county. It is also interesting to note the higher proportion of education/decision support/outreach policy items found in Fairfax County. While Fairfax County is taking advantage of regulatory and incentive-based approaches to land use management, the emphasis on education/decision support/outreach strategies indicates possible limitations on local government. This conclusion is corroborated by the involvement of non-governmental organizations, such as Fairfax Releaf (Fairfax Releaf 2004), as well as clear statements to this effect made by county planners (Fairfax County Department of Planning and Zoning 2002).

These patterns of administrative structure observed at the county scale are more pronounced at the state level, indicating that administrative structures in Fairfax County are constitutive of the broader institutional framework. Virginia has as many policy items categorized as education/decision support/outreach as regulatory. This is a key contrast between the states and may point to deeper differences in institutional cultures. Maryland has historically had a stronger regulatory approach to land use management while Virginia tends to be less restrictive. For example, in 1943 the Maryland General Assembly passed the Forest Conservancy District Law (McElfish and Wilkonson 2000; Maryland Department of Natural Resources 2004a; Maryland Department of Natural Resources 2004b). At the time, this was one of the most progressive forestry laws in the nation and permitted state regulation of privately owned forests. During the same time period in Virginia, the State Forester strongly recommended the passage of a similar law, stating that effective forest management could not occur without direct state regulation of privately owned land (Virginia State Forester 1942). A comparable law in Virginia has not been passed, and the Forest Service continues to rely heavily on extension work to encourage good forestry practices.

In the 1930s and 1940s, forest policy documents in both Maryland and Virginia outlined similar management goals and strategies, and similar responses to common problems of the time, such as forest fire, tree planting, and forest management practices that did not maximize the production of timber products. Since this time, the agencies have evolved differently. The Maryland Forest Service has embraced ecosystem-based management (Maryland Department of Natural Resources 2003a), while the Virginia Forest Service remains committed to traditional forest management. There is evidence that, while the agency recognizes the changes in the public's attitude toward forest management, it is actively resisting institutional change. For example, recent public addresses by the Virginia State Forester reflect anti-urban, anti-environmental and anti-regulatory attitudes:

> "[State forestry professionals] have escaped serious burdens from [the Virginia state] government. A look at our surrounding states will tell you it's true. We are the only segment exempt from many regulations – Chesapeake Bay, erosion and sedimentation, air pollution restrictions" (Garner 1996).

> "The wildland-urban interface has become very real, very expensive and very dangerous. We are seeing a growing number of smaller, local environmental groups. They are changing their tactics as they move to the southern landscape. These grassroots groups are effectively changing land use decisions at the county level. More county ordinances, more zoning restrictions, and more taxes. They are attacking private property rights from left field at the local level and to some degree in Richmond" (Garner 2002).

> "The urban population view these forests as 'theirs.' They fail to understand the biology, the dynamics and the benefits. They don't own these forests, but they sure do try to control them. These people are picking up on buzzwords force fed by the media and special interest groups. And sadly, we, too, are trying to capture the public's attention with the same words just to stay in the conversation. That's a shame that we – state forestry professionals – are getting trapped in upholding terms like 'ecosystems' and 'sustainability' when we don't even know that they mean…" (Garner 2002).

It should be noted, however, that both states have more incentive-based or voluntary policies than regulatory policies, while the opposite case is true at the county scale. This is a reflection of the state government-local government relationship. Several of the non-regulatory policy items at the state level consist of enabling legislations, which allow counties to create local regulations but does not require them to do so. In this way, counties can have access to a suite of tools that can be applied as needed according to local circumstances. However, Fairfax County and other counties in rapidly urbanizing northern Virginia have repeatedly pushed the limits of local land use authority in their attempts to manage growth (Prichard and Riegle 1999). In the 1970s, attempts of the Fairfax County Board of Supervisors to downzone, or reduce the development density, were repeatedly and effectively challenged in the state supreme court. The outcome of similar cases in the 1980s was more supportive of local governmental power, but in 1998 the state passed a new resolution (Senate Bill 570) that clearly protects private property rights at the expense of local governmental power to regulate land use. While the use of downzoning to effectively manage growth is debatable (Burchell, et al. 1998), this state resolution exemplifies the implications of the Dillon rule administrative structure for local land use control (Weiland 1999) and the commitment of the Virginia General Assembly to protect the private property rights.

The relationship between the state and federal government is analogous to the relationship between the state and municipal governments. In the 1970s, northern Virginia was experiencing problems with drinking water quality and flooding as a result of rapid, unmitigated development (Anderson 1970; Peters 1974). The local and state governments were not able to reach a consensus on mitigation strategies until the federal government passed the 1972 Clean Water Act, which required all states to meet federal water quality standards. The total maximum daily load (TMDL) requirements, which indicate the maximum pollutant load that a water body can receive and still meet federal water quality standards (U.S. Environmental Protection Agency 1991), is another example of a federal program that has prompted the formation of regulations at the state level. Like the state governments, the federal government has a much stronger emphasis on non-regulatory approaches (Figure 2.4), relying on easement programs and tax incentives to provide options for resource preservation and management at lower administrative scales.

Approaches to resource management at the regional scale consist completely of education, decision support, and outreach activities. These efforts have not been ineffective, however. The Chesapeake Bay Foundation, now one of the largest environmental advocacy groups in the United States, has been and continues to be instrumental in raising public awareness about the declining health of the Chesapeake Bay estuary (Ernst 2003). The strength of this theme in the regional environmental discourse is a result of the activity of this group and similar advocacy groups, and the broad public support for Chesapeake Bay restoration eventually resulted in the formation of the Chesapeake Bay Program (Horton 2003). The Bay Program has had a significant influence on institutional interactions and environmental policy within the region through the establishment and coordination of a regional decision-making framework.

2.5 Conclusions

This analysis of policies related to forest management has revealed the complexity of the institutionalization of resource definition, which is influenced by multiple factors: environmental discourses at the macro- and micro-scales, patterns of institutional interactions across multiple administrative scales, institutional history and regional and local land use change.

The definition of forest resources is reflected in the emergent policy objectives. Policy objectives at all administrative scales reflected the broader environmental discourse as well as the changes in this discourse through time. Local and regional characteristics are also apparent. The dramatic land use change that occurred after 1950 coincided with a shift in the environmental discourse, resulting in an institutional response at the local and state level that incorporated new values, such as ecosystem services and quality of life. At the local level, values related to aesthetics and spiritualism are represented. While policy objectives continue to diversify at all levels of government, there is nevertheless a strong crosscutting institutional orientation on the role of forests for water quality enhancement. This orientation is reinforced by the dominance of Chesapeake Bay restoration in the regional environmental discourse.

Relationships between administrative scales are also important. It was found that different sets of values are represented at different administrative scales. In addition, regulatory responses to physical changes in the resource create feedbacks between administrative levels. Differences in approaches to resource management across administrative scales were also observed, with non-regulatory policies being more prevalent at higher administrative scales, and regulatory policies being more common at the local scale.

A comparison of Maryland's and Virginia's resource management approaches revealed the importance of both administrative structure and institutional culture. The autonomy of a local municipality in a Dillon rule state depends entirely on the state's application of the rule, so the fact that Virginia is a Dillon rule state does not necessarily mean that local governmental power in Fairfax County will be significantly restricted. In Virginia, however, there is evidence that indicates a strong state commitment to protect private property rights. Successful challenges of local land use regulations made on this basis indicate that the discourse of private property rights is quite strong in Virginia. Given this institutional culture, local governmental autonomy is frequently preempted through the application of the Dillon rule, potentially inhibiting the responsiveness of local government and stifling innovative solutions to community issues (Weiland 1999).

The fact that institutional culture can play an important role in resource definition, coupled with the institutional inertia that is apparent at higher administrative scales, indicates significant challenges to resource management problems ranging from local concerns about how suburban forests contribute to quality of life to regional ecosystem restoration efforts. Likewise, the dominance of the ecosystem theme in the environmental discourse hinders the development, success and funding support for alternative policy objectives, such as those focused on urban forestry.

CHAPTER 3: LANDSCAPE CHANGES

3.1 Describing and modeling landscape changes

The previous chapters have referred to the rapid landscape changes that occurred in the Washington, DC metropolitan region, including Fairfax and Montgomery counties. In Chapter 2, the transition from rural to urban landscapes (e.g. Figure 2.5) was argued to be one of the drivers for the formation of policies related to forest conservation, best management practices and smart growth. This chapter will focus explicitly on changes in the landscape that occurred at local scales between the 1930s and the late 1990s, and at the county scale between 1990 and 2000. The local case studies allow for a detailed temporal and spatial analysis of landscape changes and will inform the county scale analysis, which provides a synoptic view of recent changes. In addition to quantitative descriptions of land cover change at multiple scales, a second component of this research will be to quantify the spatial association between specific types of change and biophysical and policy elements. Using a Bayesian method, weights of evidence (Bonham-Carter 1997), the influence of spatial policy measures and biophysical factors can be considered, providing a link between the physical landscapes and the institutional framework with which they interact. Interpreting these results in the light of the policy trends presented in Chapter 2 will provide the basis for the synthesis presented in Chapter 4.

3.2 Data and Methods

3.2.1 Describing patterns of landscape change

<u>Landscape changes at the local scale, 1930s - 1998</u>

Local case studies were chosen to track land cover and land use change between the 1930s and 1998 using a roughly decadal time series of fine scale aerial photographs. Two study sites in each county were chosen within which detailed data collection occurred: Olney and Rockville in Montgomery County, MD and Herndon and Burke in Fairfax County, VA (Figure 3.1). These study sites are located in what are now the outer suburbs of Washington, DC. Rockville, MD and Burke, VA are historic centers of settlement, while Olney, MD and Herndon, VA are newer suburban centers.

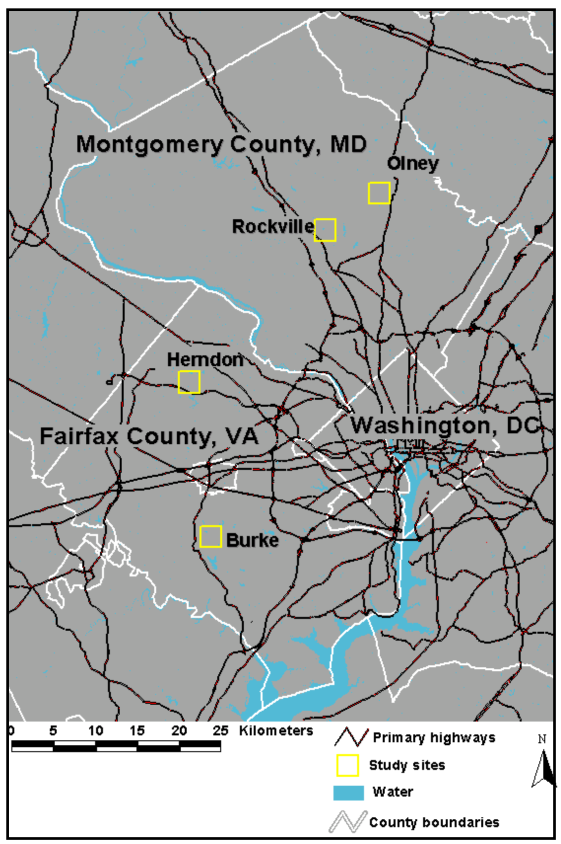


Figure 3.1 Location of case study sites

Land use/land cover (LULC) data were derived from a time series of aerial photographs for each study area. Six air photos at a scale of 1:20,000 and a resolution of roughly one meter were acquired that centered on the study area to capture the following time periods: mid- to late 1930s, 1950s, 1960s, 1970s, 1980s, and 1990s (Figure 3.2 and Table 3.1). The earlier photos (pre-1960s) were originally acquired through the United States Department of Agriculture (USDA) Soil Conservation Service and were obtained from the National Archives at College Park. The later photos were acquired by the United States Geological Survey (USGS) National High Altitude Photography (NHAP) program and were obtained directly from the USGS. Each photo was digitally scanned and geo-referenced to a USGS digital orthographic quarter quadrangle (DOQQ). The classification was performed manually with on-screen digitizing, and then rasterized to a ten-meter pixel size. An Anderson level I classification scheme was applied to forest and agriculture, but level II was applied to developed classes (Anderson, et al. 1976). Class definitions (Table 3.2) were adapted from the Maryland Department of Planning (Maryland Department of Planning 1999), which was found to be an appropriate existing classification scheme.

Figure 3.2 Example aerial photograph time series for Herndon, VA. Photos for 1954 and 1972 are not shown.

Table 3.1 Dates of air photos available for each study site.

Burke, VA	Herndon, VA	Olney, MD	Rockville, MD
1937	1934	1937	1934
1953	1954	1951	1951
1962	1961	1963	No data
1978	1972	1976	1975
1988	1988	1988	1988
1998	1998	1990	1998

Table 3.2 Land cover and land use definitions used in the air photo classification scheme.

Class	Definition
Agriculture	All agricultural activities, including row crops, pasture, orchards, etc.
Forest	Contiguous forest with an estimated canopy cover of 40% or greater. Forested areas of at least 10 meters in width and one hectare in area were included.
Water	Bodies of water, including lakes and retention reservoirs.
Low density residential	Residential density of 0.2-2 dwelling units/acre
Medium density residential	Residential density of 2-8 dwelling units/acre
High density residential	Residential density >8 dwelling units/acre
Commercial	Retail and wholesale services
Industrial	Manufacturing and industrial parks
Municipal	Schools, colleges, universities, military institutions. Also churches, medical facilities, and other government or institutional facilities that are separable from the surrounding land cover.
Open Space	Open spaces in developed areas. Includes golf courses, non-forested parks, the area under power lines, and other non-forested pervious areas.
Transitional	Areas in transition. Most, but not all, transitional areas were changing from a pervious or natural land cover to a developed land cover.

Rates of LULC change were tracked through time, although the developed classes were collapsed into one category to simplify the analysis and to mitigate classification errors. To specifically address patterns of forest cover, the data were reclassified into two categories: forest and non-forest. These forest maps were analyzed using RULE (Gardner 1999), a spatial analysis program that calculates several landscape metrics. All sites were clipped to the same area (250 x 250 cells or 625 hectares) to facilitate comparison between sites. RULE requires the assignment of a neighbor rule to determine cluster size and connectivity. In this analysis, the eight-neighbor or next-nearest-neighbor rule was applied. Four simple landscape metrics were used to observe changes over time: the percentage of the landscape occupied by forest, the largest forest patch size, the total number of forest patches, and the area-weighted mean patch size (SAV, Equation 3.1), which is calculated as:

$$SAV = \Sigma S_i^2 / \Sigma S_i \qquad \text{Equation 3.1}$$

where S_i is the size of patch i, and the sums are taken over all patches of the same class.

Each of these metrics describes either abundance (percentage of the landscape occupied by forests) or patchiness (largest forest patch size, number of forest patches and SAV), and many have links to the ecosystem functions performed by forests. However, this study will emphasize the use of the metrics to illustrate and compare changes in landscape patterns through time.

Landscape changes at the county scale, 1990 - 2000

While the use of fine resolution aerial photographs allow for a detailed analysis of land use and land cover change over several decades, broader scale data sets showing changes in impervious surface area between 1990 and 2000 have recently become available (Goetz, et al. 2004) (Figure 3.3). These data sets were derived from 30 m Landsat TM and ETM+ satellite imagery and were created to map changes in impervious surface cover over a much larger area, the 167,000 km^2 Chesapeake Bay watershed, but are appropriate for county-scale analyses. Using regression tree algorithms trained with high resolution planimetric and Ikonos satellite imagery, these maps estimate the percentage of impervious surface area (ISA) within each 30 m x 30 m pixel. A recent accuracy assessment of these maps report that spatial accuracy (i.e. the extent and location of ISA) is 79% for the 1990 map and 83% for the 2000 map. Comparisons between the mapped and an independent validation data set of subpixel impervious surface values (i.e. percent ISA ranging from 0 to 100%) produced a correlation of 0.61 for 1990 and 0.68 for 2000 (Jantz, et al. In press).

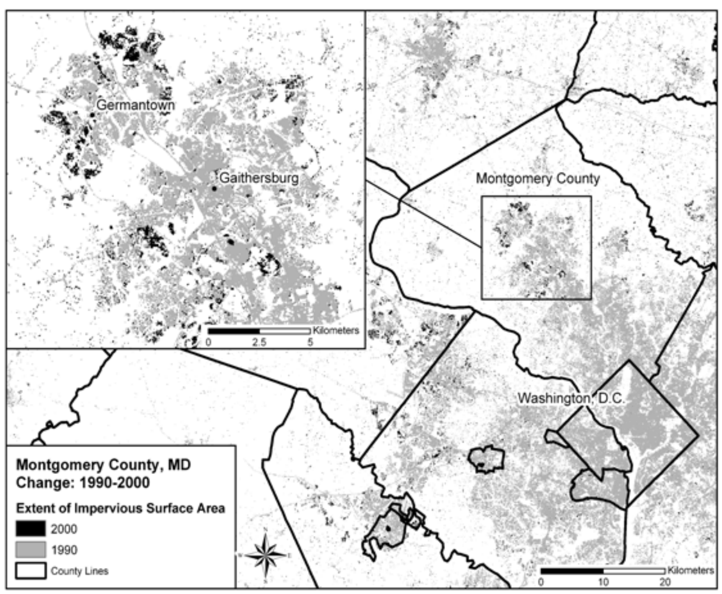


Figure 3.3 Changes in impervious surface area between 1990 and 2000

Subsets of these data will be used to show changes in ISA at the county scale in Montgomery and Fairfax. Using land cover maps for circa 1990 in conjunction with the above ISA change maps, areas of deforestation and agriculture loss due to development were identified (Jantz, et al. In press). In this study, pixels were considered developed if they contained at least 10% impervious surface cover. This resource lands loss data set (Figure 3.4) will allow for the investigation of development-related deforestation within the counties, and a Landsat satellite-derived forest cover map for 2000 (Huang, et al. 2001) will provide relatively current information about the present distribution of forests in the counties (Figure 3.5). Like the ISA maps, forest cover is mapped as a continuous variable, where the percent forest cover within each 900 m^2 pixel is estimated. To create county-wide forest/non-forest maps, a series of forest cover thresholds were compared to the 1998 forest classification based on the aerial photographs for the case study areas. A threshold of 40% was found to be a good representation of a discrete forest land cover class. Changes in mean ISA and ISA extent, forest loss, and current forest extent within HUC 11 watersheds will be calculated to illustrate general patterns of land cover change or forest cover within the counties.

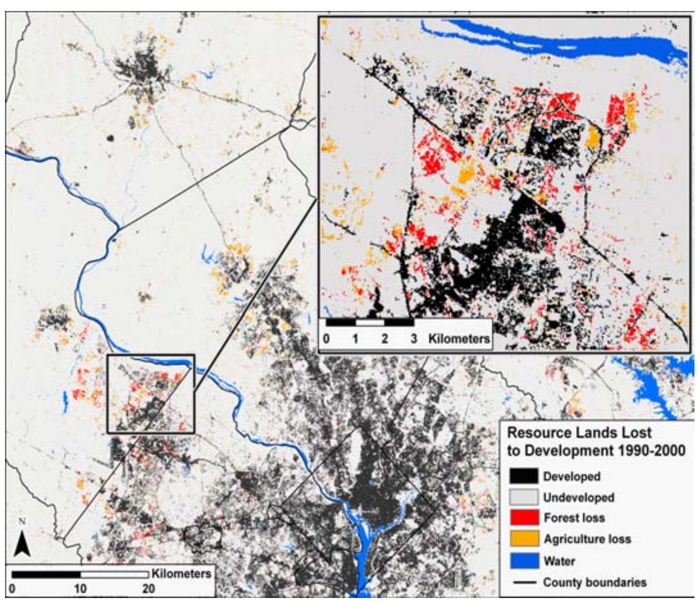


Figure 3.4 Forests and agriculture lands that were converted to impervious surfaces between 1990 and 2000

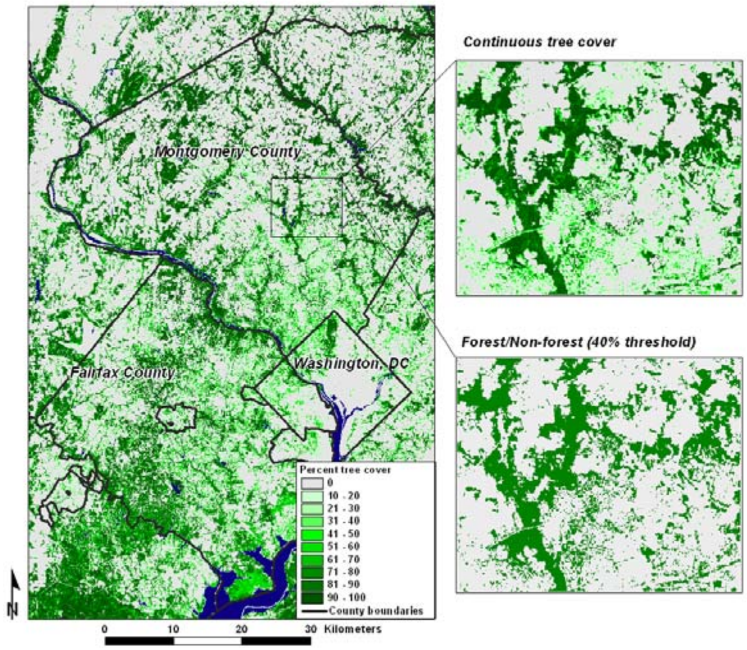


Figure 3.5 Tree cover data set showing the continuous (sub-pixel) classification in the main image and the upper right inset, and the forest/non-forest classification derived using a 40% threshold.

3.2.2 Quantifying "drivers" and "constraints" of change: weights of evidence analysis

<u>The weights of evidence statistical model</u>

Linking the relationship between land cover change and biophysical or policy factors presents a methodological challenge. For example, to what extent is the persistence of forests in certain areas due to a soil type that makes urban development difficult, or the fact that it has been protected through a parkland acquisition, or some combination of the two? A land use modeling approach utilizing the weights of evidence method (Agterberg, et al. 1993; Bonham-Carter 1997) allows the spatial association between an "event," such as deforestation or forest persistence, and "predictor" maps, such as soils, slope, and protected lands, to be quantified.

Weights of evidence is a data-driven Bayesian model and therefore relies on the concepts of prior and posterior probabilities. The prior probability of an event occurring is derived in the absence of additional information, and is essentially based on the frequency of the event occurrences (i.e. the countywide rate of deforestation). The prior probability can be updated to produce an estimate of the posterior probability if additional information is known about other factors that occur in conjunction with the event in question. These conditional probabilities are expressed as odds ratios (i.e. likelihood ratios), and the weights of evidence method uses the natural logarithm of likelihood ratios to determine positive (W+) and negative (W-) weighted coefficients for a set predictor variables (Leonard and Hsu 1990; Bonham-Carter 1997). The evaluation of the weights themselves often provides insight into the interactions between the dependent variable and the individual predictor variables, and the weighted predictor maps can be combined to produce a probability surface that expresses the likelihood of the event occurring across the landscape. In a predictive analysis, these output maps are used to identify areas where, for example, deforestation is likely to occur.

The weights of evidence model is applied in several steps. First, the prior probability of an event occurring within the study area is calculated. The prior probability is essentially the frequency of the event occurring and, given no additional spatial information, would be uniformly distributed across the landscape. The prior probability of the event occurring, in odds formulation, is given in Equation 3.2:

$$O(Y) = p(Y) / 1 - p(Y) \qquad \text{Equation 3.2}$$

where O(Y) represents the prior probability for event Y in odds formulation and p(Y) represents the probability, or frequency, of the event occurring within the study area.

Second, positive (W+) and negative (W-) weights for a set of predictor maps are calculated. Predictor maps are in binary format (i.e. the factor is either present or not present), and W+ is calculated for areas where the binary pattern is present, while W- is calculated for areas where the pattern is absent. Weights are calculated using measurements of the area of the binary predictor variable, the total study area, the area of overlap between the event occurrences and the presence of the binary predictor variable, and the overall area of the event occurrences. The positive weight for the presence of a binary predictor pattern ($W+_i$) is the ratio of the natural logarithm ($\log_e$) of the conditional probability that the event Y occurs in the presence of the predictor pattern (X_i) to the conditional probability that the event does not occur (Y_0) in the presence of the binary predictor pattern (X_i) (Equation 3.3). The negative weight for the absence of a binary predictor pattern ($W-_i$) is equal to the ratio of the natural logarithm of the conditional probability that the event Y occurs in the absence of the predictor variable (X_{i0}) to the conditional probability of the absence of the event (Y_0) corresponding to the absence of the predictor variable (X_{i0}) (Equation 3.4).

$$W+_i = \log_e [P(X_i \mid Y) / P(X_i \mid Y_0)]$$ Equation 3.3

$$W-_i = \log_e [P(X_{i0} \mid Y) / P(X_{i0} \mid Y_0)]$$ Equation 3.4

The conditional probability terms in the above equations are calculated from Equations 3.5 through 3.8:

$$P(X_i \mid Y) = A_{XY} / A_Y$$ Equation 3.5

$$P(X_i \mid Y_0) = (A_x - A_{XY}) / (A_T - A_Y)$$ Equation 3.6

$$P(X_{i0} \mid Y) = (A_Y - A_{XY}) / A_Y$$ Equation 3.7

$$P(X_{i0} \mid Y_0) = (A_T - A_X - A_Y + A_{XY}) / (A_T - A_Y)$$ Equation 3.8

where

A_Y = the total area of the event occurrences within the study area

A_X = the total area of the binary predictor pattern within the study area

A_T = the total area of the study area, and

A_{XY} = the area where the event occurs within the binary predictor pattern.

Values for W+ and W- can be both positive and negative. High positive values for W+ indicate a strong positive association between the event and the predictor variable, while strong negative weights for W- would indicate a negative association. A large negative value for W+ would indicate that the event is not likely to occur when the predictor variable is present, while a large positive value for W- indicates that the event is likely to occur where the predictor patterns in absent. Absolute weight values between 0.1 and 0.5 can be considered to be mildly predictive, between 0.5 and 1 are moderately predictive, between 1 and 2 are strongly predictive, and values greater than 2 are extremely predictive (Bonham-Carter 1997).

Uncertainty in the estimation of the weights can be estimated by calculating the variance (s^2) for W+ (Equation 3.9) and W- (Equation 3.10):

$$s^2(W+) = 1/A_{XY} - 1/A_{XY_o} \qquad \text{Equation 3.9}$$

$$s^2(W-) = 1/A_{X_oY} - 1/A_{X_oY_o} \qquad \text{Equation 3.10}$$

where

A_{XY} = the area where the event Y occurs within the binary predictor pattern X

A_{XY_o} = the area where the event Y does not occur within the predictor pattern X

A_{X_oY} = the area where the event Y occurs in the absence of the predictor pattern X, and

$A_{X_oY_o}$ = the area where both the event Y and the predictor pattern X are absent.

Weights and uncertainties are calculated for each predictor map and the contrast (C) (Equation 3.11) gives a measure of the strength of the relationship between the event and each predictor variable:

$$C = W+ - W- \qquad \text{Equation 3.11}$$

In the case of continuous predictor variables, such as slope, the contrast can also be used to identify appropriate cut off points that can be used to categorize the continuous map into a binary predictor variable (e.g. high and low slopes). In this case, the contrast would be calculated across a range of cut off values and the cut off point where C reaches a maximum value would be used to create a binary predictor map. A studentized version of C (C_s), which takes into account the uncertainty of the weights, can be also calculated (Equation 3.12):

$$C_s = C / \sqrt{s^2(W+) + s^2(W-)} \qquad \text{Equation 3.12}$$

A central assumption in the weights of evidence approach is that each pair of evidence maps is conditionally independent with respect to the event occurrences. Thus, the third step in the application of the weights of evidence model involves a test of this assumption. Conditional independence implies that the occurrence of one predictor variable is independent of the presence or absence of a second predictor variable within the areas where the event under consideration occurs. Violations of this assumption could inflate the apparent overall evidence, resulting in an overestimation of the event occurrences (Leonard and Hsu 1990; Bonham-Carter 1997). Contingency tables and chi-square (χ^2) tests are used to reject or accept the null hypothesis of conditional independence. The contingency table for a pair wise comparison of two predictor variables, X_1 and X_2, is given below (Table 3.3).

Table 3.3 Contingency table for testing conditional independence, based on areas where the event under consideration has occurred. "N" is the number of pixels where the given conditions within parentheses are true.

	X_1 present (X_1)	**X_1 absent ($X_{1\,0}$)**
X_2 present (X_2)	$N(X_1, X_2)$	$N(X_{1\,0}, X_2)$
X_2 absent ($X_{2\,0}$)	$N(X_1, X_{2\,0})$	$N(X_{1\,0}, X_{2\,0})$

The chi-square test is calculated from the contingency table values using the expression in Equation 3.13:

$$\chi^2 = \sum_{i=1}^{4} \frac{\text{Expected}_i}{(\text{Observed}_i - \text{Expected}_i)^2} \qquad \text{Equation 3.13}$$

and expected frequencies for each cell in the contingency table are calculated from Equation 3.14:

$$\text{Expected}_i = (\text{row total / column total}) / N \qquad \text{Equation 3.14}$$

where the row and column totals are pixel totals calculated from the 2 x 2 contingency table, and N is the total number of pixels under consideration. The null hypothesis of conditional independence is rejected if the calculated chi-square statistic exceeds the tabulated chi-square at the significance level α. For a 2 x 2 contingency table, there is one degree of freedom (df), if df = (r-1)(c-1) where *r* is the number of rows and *c* is the number of columns.

In practice, the assumption of conditional independence is frequently violated (Bonham-Carter 1997). It is therefore useful to know the degree to which two pairs of predictor maps are associated, which can be indicated with Cramer's coefficient, or Cramer's V (Bonham-Carter 1997; Almeida, et al. 2003). Cramer's V is based on the calculated chi-square statistic and lies between 0 (indicating no correlation between the maps) and 1 (indicating strong correlation between the maps) and is calculated as shown in Equation 3.15:

Equation 3.15

$$V = \sqrt{\chi^2 / NT}$$

where N is the total sample size and T is the smaller of the two numbers r-1 and c-1 (in a 2 x 2 matrix T = 1). If a set of predictor maps does not meet the criteria for conditional independence and the degree of correlation is found to be high, the two maps can be combined into a single predictor variable or one of the maps can be eliminated from the analysis.

Note that the ratios in Equations 3.2, 3.3 and 3.4 are odds formulations, and that because a natural log transformation is used in Equations 3.3 and 3.4, W+ and W- are logit weights. Logit weights are utilized so that multiple evidence maps can be combined independently to update the prior probability of the event occurring in the study area. In Equation 3.16, which represents the fourth step of the model application, the logit weights are combined with the prior logit to calculate the posterior logit:

Equation 3.16

$$\log_e O(Y|X^k_1, X^k_2 \ldots X^k_n) = \sum_{i=1}^{n} W^k_i + \log_e O(Y)$$

where the superscript *k* refers to the presence or absence of the binary pattern (X) and where

$W^k_i = W+_i$ for the *i*th pattern present, or

$W^k_i = W^-_i$ for the *i*th pattern absent, or

$W^k_i = 0$ if the *i*th pattern is unknown.

To calculate the posterior probability (P) for event Y from the posterior logit (Equation 3.16), simply calculate the base *e* exponential of the posterior logit (i.e. $\log_e O(Y)^e$)and reverse the odds formulation equation (Equation 3.17):

$$P(Y) = O(Y)/\ (1+O(Y)) \qquad \text{Equation 3.17}$$

After the final posterior probability has been calculated, the final step of the weights of evidence model application entails an overall test of conditional independence. The overall area of the event predicted by the model is compared with the observed occurrences of the event, and is tested using a χ^2 test. If the number of predicted occurrences greatly exceeds the observed, then the hypothesis of conditional independence is rejected.

Discussion of the weights of evidence approach

The weights of evidence model has been widely used in geosciences, particularly for mineral potential mapping (Bonham-Carter, et al. 1988; Agterberg, et al. 1993; Bonham-Carter 1997) and other geologic phenomena (e.g. landslides, Lee and Choi 2004). In land use or land cover change modeling it is less widely used, although there are some recent examples of its application (Felicisimo, et al. 2002; Almeida, et al. 2003). The traditional statistical approach in land use and land cover modeling has been the use of linear or logistic regression models to quantify the relationship between a change event and a set of explanatory variables (e.g. Kok, et al. 2001; Verburg, et al. 2004). While weights of evidence is also a type of log linear model, it requires an explicit test of the assumption of conditional independence. The weights are also easy to calculate, interpret and compare between sites, estimates of uncertainty can be made, and missing data are easily accommodated. However, limitations of the approach include the necessity to categorize all input maps into binary predictor maps and the fact that the distribution of the dependent event must be relatively well known, which is not always the case. Furthermore, neither weights of evidence nor traditional regression techniques take into account spatial autocorrelation. It is only recently that statistical regression techniques, such as geographically weighted regression (Fotheringham, et al. 2002), have been developed to address this issue.

Weights of evidence was selected for this study because it facilitates comparisons between the local case study sites and between the counties. The weights for each explanatory variable can be easily compared to assess the relative contribution of biophysical and policy variables that enable or constrain particular change events, and both positive and negative weights can be evaluated to determine positive and negative spatial associations between variables, a functionality that logistic regression does not provide (Felicisimo, et al. 2002). Tests for conditional independence reveal whether or not the contribution of a particular variable is statistically valid, and how the predictor maps themselves are spatially correlated. This latter point is particularly salient when considering the effectiveness of spatial policy measures in conjunction with a suite of biophysical variables.

Weights of evidence analysis for the local case studies

For the local scale analysis, a weights of evidence analysis was performed for each study area to examine the changes that occurred at each time step. Three change events were considered. Forest loss and forest persistence were considered in terms of their association with protected land, steep slopes, the presence of poorly drained soils, and distance from streams. New development was also considered in terms of its association with these variables and whether the previous land cover had been forest or agriculture. This latter set of predictor variables allows the relative vulnerability of forests and agriculture to development to be quantified and compared. In all cases, slope and soil type were considered to be biophysical variables that would constrain development and thus prevent deforestation. Permanently protected lands, primarily parks and easements, became prominent features of these landscape in the 1960s and 1970s, and represent a strong policy element that would preserve forests. Because of the policy focus on water quality protection, distance from streams was used to test the influence of this emerging policy orientation on the developing landscapes. Table 3.3 enumerates the geographic data sets used to derive each predictor variable.

Table 3.3 Geographic data sets used for local case study sites. An asterisk (*) indicates additional data sets that were used in the countywide analyses.

Geographic data	**Scale/ resolution**	**Date**	**Origin**
Protected lands	Maryland: Variable Virginia: Variable	Maryland: 1999 – 2004 Virginia: 2001	Maryland Department of Natural Resources GIS Services (http://dnrweb.dnr.state.md.us/gis/data/data.asp) Virginia's Conservations Lands Database, Virginia Department of Conservation and Recreation (www.dcr.state.va.us/dnh/conslandindex.htm)
Soil	Maryland: 1:12,000 Virginia: 1:6,000	Maryland: 2005 Virginia: 1990	NRCS Soil Survey Geographic (SSURGO) database for Montgomery County, MD (http://SoilDataMart.nrcs.usda.gov/) Fairfax County GIS and Mapping Department (http://www.co.fairfax.va.us/maps/map.htm)
Slope	1:24,000 (30m x 30m)	1997	USGS 7.5 Minute Digital Elevation Model (DEM) (http://edc.usgs.gov/products/elevation/dem.html)
Streams and water bodies	Maryland: 1:24,000 Virginia: 1:8,000	Maryland: 1998 Virginia: 1997	Montgomery County Geographic Information System Services (http://gis.montgomerycountymd.gov/) Fairfax County GIS and Mapping Department (http://www.co.fairfax.va.us/maps/map.htm)
*Roads	1:24,000	2003	GDT *U.S. Streets* vector digital data, available through ESRI (Environmental System Research Inst.) ArcGIS 9.0 licensing agreement
*County boundaries	1:500,000	2000	U.S. Census TIGER/Line files (http://www.census.gov/geo/www/cob/index.html)

While most of the original time series consisted of five time steps, simplified time series of three steps were derived to minimize computational time. As will be shown below, landscape changes between the 1930s and the 1950s/60s were minimal. The simplified time series consisted of a 1930s to 1970s time step, a 1970s to 1988 time step and a 1988 to 1998 time step.

The weights of evidence analysis was performed within a geographic information system using overlay modeling to identify the area of overlap between the event occurrences and the presence or absence of each binary predictor variable. The results of the overlay analyses were used to calculate W+ and W- for each predictor variable for each event and across all time steps and across all case study areas. Continuous variables, such as slope and distance from streams, were reclassified into several categories to test different cut off points. The contrast (C) was used to determine the cut off point with the highest explanatory power. To test for conditional independence given each event, pair wise comparisons of the predictor maps were performed. Chi-square and Cramer's V statistics were calculated for each set of predictor variables and evaluated.

Because the main focus of this study is to discover the spatial relationships between specific land cover change events and potential physical and policy-related explanatory variables, and to observe how these relationships change over time and across scales, comparisons of the weights between case study areas will be emphasized. The weights will be interpreted in the light of the tests for conditional independence among the explanatory variables. The weights of evidence analysis presented here is not intended for predictive purposes, so the final probability maps that would result from the combination of all predictor maps are less relevant.

Weights of evidence analysis for Fairfax and Montgomery counties

At the county scale, two land cover change events were modeled: new development and forest loss as derived from the 1990 to 2000 ISA change map and resource lands loss map, respectively (Jantz, et al. In press). In addition, the distribution of forest in 2000 as represented by pixels containing at least 40% forest cover in the NLCD forest cover map (Huang, et al. 2001) was considered. Forest loss between 1990 and 2000 and 2000 forest distribution were considered in terms of their association with protected lands, steep slopes, poorly drained soils, distance from streams, distance from main roads, and distance from the urban core areas of Washington, DC, and Arlington and Alexandria, VA. New development between 1990 and 2000 was also considered in terms of its association with these variables and whether the previous land cover had been forest or agriculture, as in the local scale case study areas. For new development, distance from protected lands and distance from water bodies were also included as explanatory variables, since areas close to these features are often viewed as desirable residential locations. Calculation of the weight coefficients and tests for conditional independence were performed as described above for the local case studies and were performed separately for each county.

3.3 Results

3.3.1 Describing patterns of landscape change

Landscape changes at the local scale, 1930s – 1998

The results of the land use/land cover classifications for each of the local case study areas are shown in Figure 3.6. These maps provided the basis for subsequent analyses of land use and land cover change. Note that small contiguous patches of forest within developed areas are captured, although forest or tree *cover* within, for example, suburban neighborhoods, is not captured. The Virginia sites, Herndon and Burke, are predominantly forested in the late 1930s, while the Maryland sites, Olney and Rockville, are predominantly agricultural. All sites experience significant development in the 1960s or 1970s, and by the end of the time period are predominantly in urban land uses.

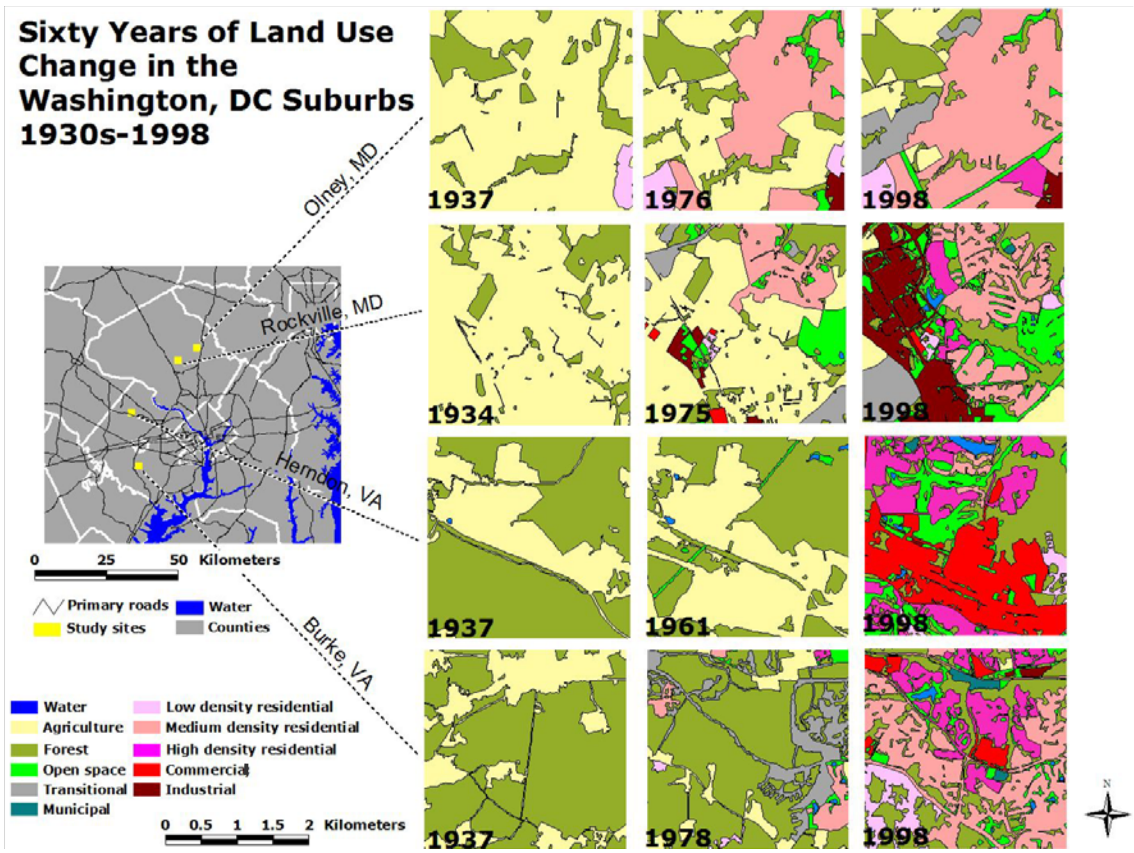
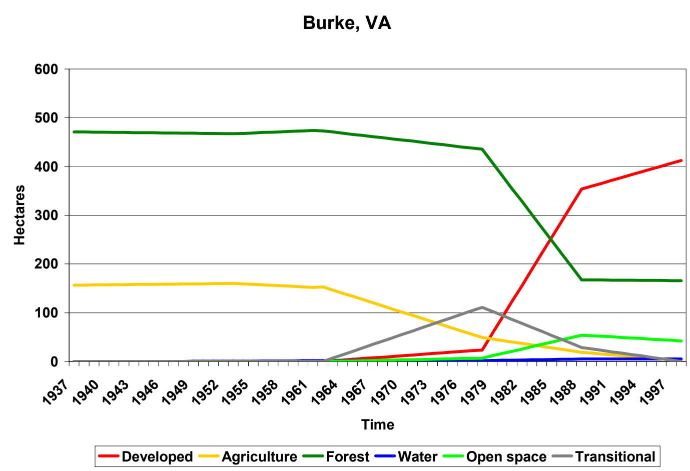


Figure 3.6 Classified aerial photograph time series for each of the study sites, although the full time series is not shown.

Rates and types of change varied through time for each of the case study areas (Figure 3.7) and also indicate the differences in the land use histories of the two counties as noted above. In the Virginia sites, forests and agricultural land uses decline rapidly as development occurs during the latter part of the time series, with forests experiencing the most significant losses to development. In Herndon, a large area was cleared for pasture during the 1950s and thus displays an increase in agricultural land for that time step. In Olney and Rockville, the amount of forests in the landscapes does not change significantly over the time series, although agriculture declines significantly as development increases. A slight increase in forest cover is observed in both of the Maryland sites in the middle part of the time series, indicating the farm abandonment that occurred in the 1940s and 1950s just prior to the development boom in these areas. At all four sites, development and forest loss slow between 1988 and 1998 and in some sites (e.g. Rockville) forests show some recovery, although agriculture continues to decline. Agriculture is completely eliminated from the two Virginia sites. Olney, MD retains the most agricultural land at the end of the time series.



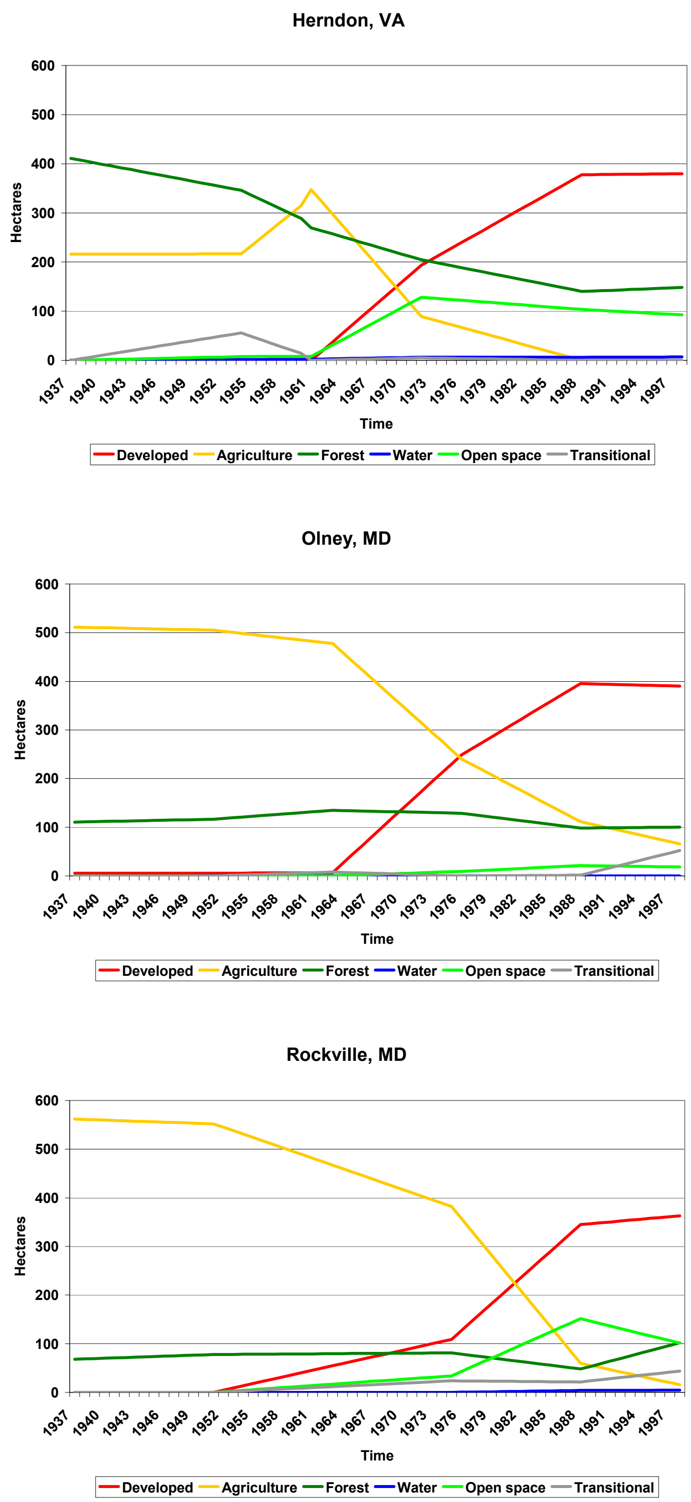


Figure 3.7 Charts showing rates of land use change for each study site.

Specifically considering how forest patterns change through time substantiates many of the results presented above. The proportion of forest within each landscape declines through time for the two sites in Virginia, but remains relatively constant for the two Maryland sites (Figure 3.8). Again indicating the differences in the land use histories between the counties, the two sites in Virginia retain higher proportions of forested area compared with the two sites in Maryland, and Burke, VA consistently maintains the highest forest area compared with the other three sites. Rockville, MD is the only site that demonstrates significant forest regeneration, which can be noted between the 1980s and 1990s.

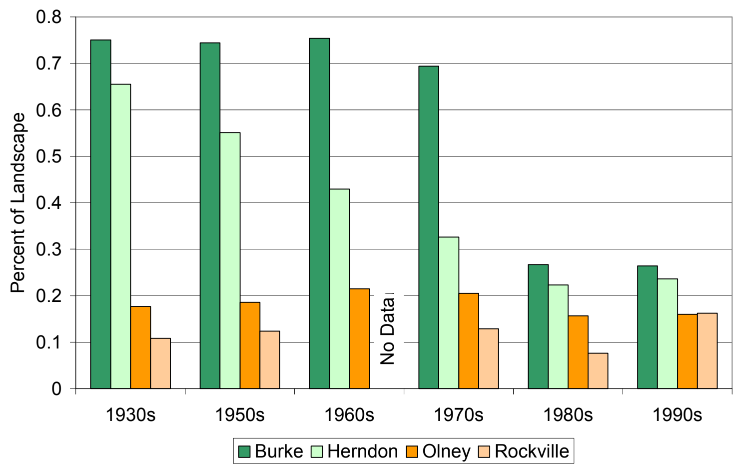


Figure 3.8 Proportion of landscape occupied by forests for each case study site through time.

Additional pattern metrics indicate increasing forest fragmentation as development occurs, particularly for the Virginia case studies. The total number of forest patches tends to increase (Figure 3.9) as the proportion of forest decreases. This trend is most dramatic in Burke, VA, while Olney, MD shows the least variation through time. Although the number of patches increases through time, both Maryland sites display little variation through time in terms of the largest forest patch size (Figure 3.10). In contrast, the large contiguous forest patches that existed at the beginning of the time series for the two Virginia sites become increasingly fragmented as development occurs, especially in

Burke, VA. Area weighted mean patch size (Figure 3.11) follows similar trends across sites, with dramatic decreases in the two Virginia sites and little variation through time for the Maryland sites. At the end of the time series, all sites have a largest patch size that is less than 100 hectares and an area weighted mean patch size that is smaller than 50 hectares.

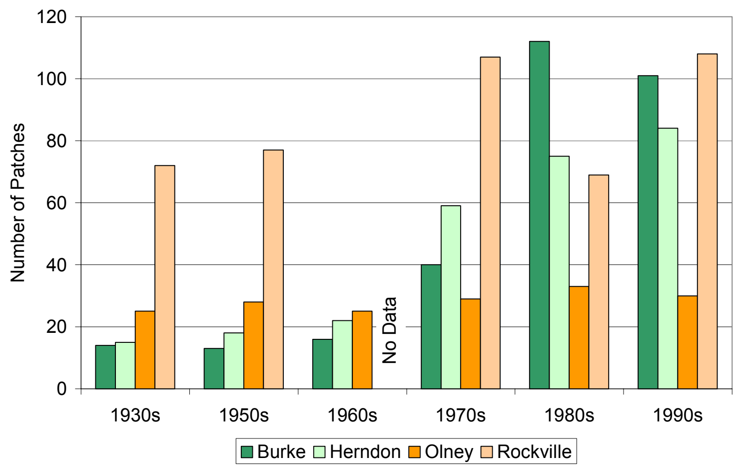


Figure 3.9 The number of forest patches occurring in each study site through time.

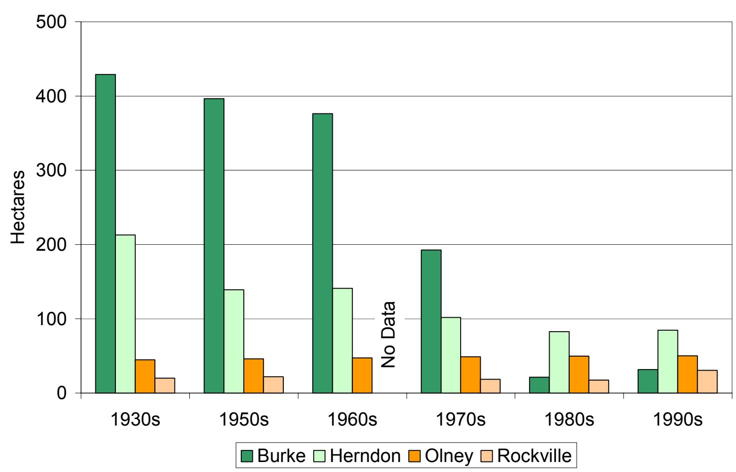


Figure 3.10 The area of the largest forest patch found in each study site for each time period.

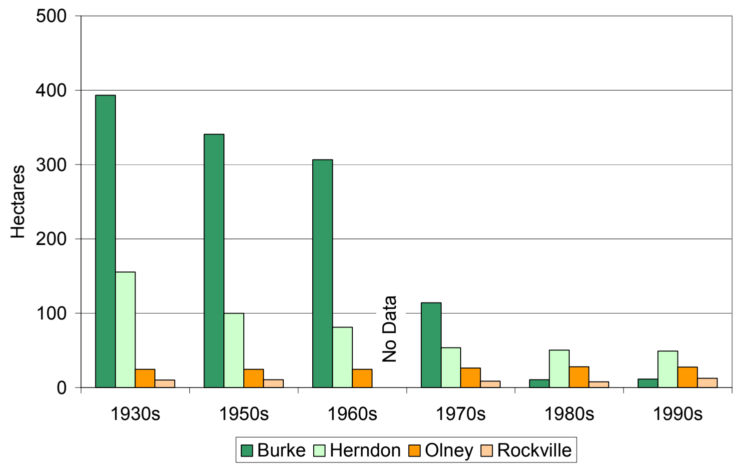


Figure 3.11 Area weighted mean patch size at each time period for each study site.

Landscape changes at the county scale, 1990 – 2000

Within Montgomery and Fairfax counties, the intensity of development in 2000 within watersheds close to the urban core indicates the historic connection to the Washington, DC – Arlington – Alexandria metropolitan center (Figure 3.12). In addition, Montgomery County has a development corridor that follows the I-270 corridor though the central part of the county, while Fairfax County has developed several exurban cores in the western and southern portions of the county (Figure 3.3), and these patterns are also evident at the watershed scale. Within these developed areas, forest cover is sparse, as indicated by lower percent forest cover values (Figure 3.5, Figure 3.13). In northern Montgomery County, which is currently designated as a rural planning area, there are several large forest patches, while forest remains a dominant landscape feature in much of the central part of Fairfax County, an area that is also zoned for lower density development. Watersheds with the highest forest cover are in these outlying areas (Figure 3.13).

Changes in impervious surface areas between 1990 and 2000 have been dramatic and indicate that recent growth is occurring in previously undeveloped, outlying areas. In watersheds close to the Washington, DC – Arlington – Alexandria urban core, increases in mean impervious surface area range between 8 and 18% (Figure 3.14). Increases between 38 and 60% have occurred in the watersheds along Montgomery County's development corridor. Watersheds in western Fairfax County show similar levels of change, although impervious surface increases in watersheds in central Fairfax County are less intense (18 – 38%). Some of these outlying watersheds also experienced significant loss of the 1990 extent of forest (Figure 3.15), but the watersheds with the highest fractional forest loss were those closest to the urban core, indicating that considerable development pressure on urban forests also exists.

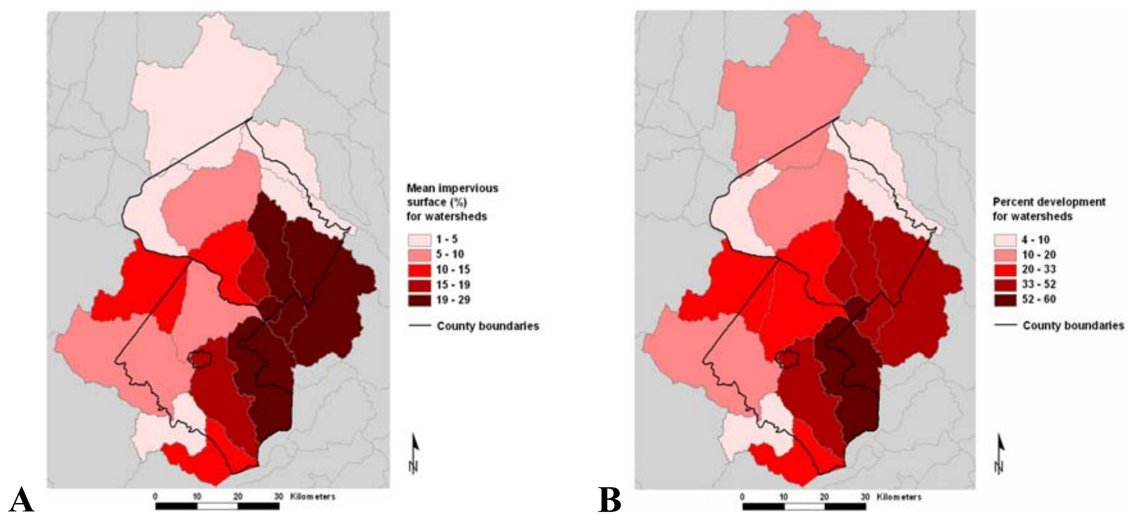


Figure 3.12 Mean impervious surface (A) for watersheds intersecting Montgomery and Fairfax counties and the percent of the watershed areas developed (B). The former is an average derived from the subpixel impervious surface values found within each watershed, and the latter is derived from the area developed, where pixels are considered to be "developed" if they are at least 10% impervious.

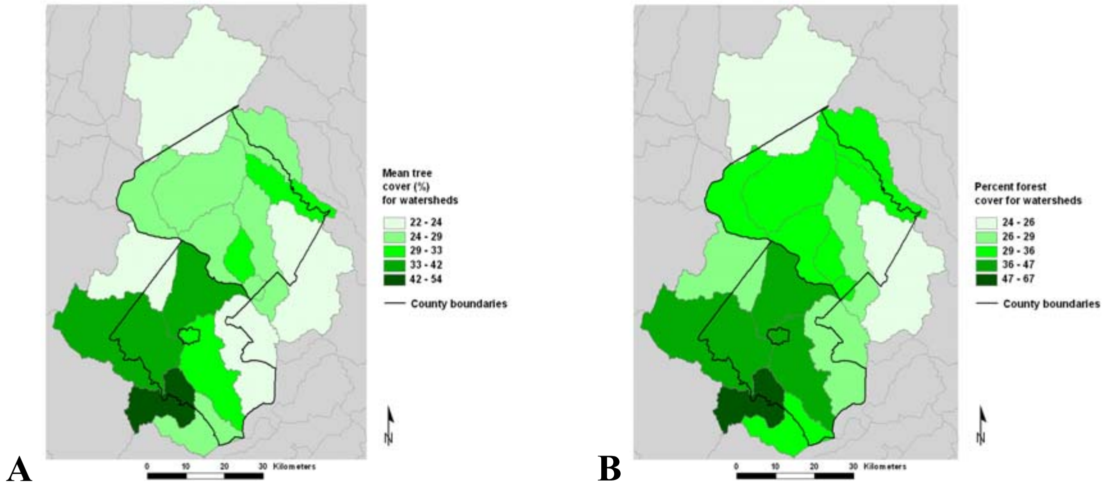


Figure 3.13 Mean tree cover (A) for watersheds intersecting Montgomery and Fairfax counties and the percent of the watershed areas that are forested (B). The former is an average derived from the subpixel tree cover values found within each watershed, and the latter is derived from the area covered by forest, where pixels are considered to be "forest" if they have a tree cover of at least 40%.

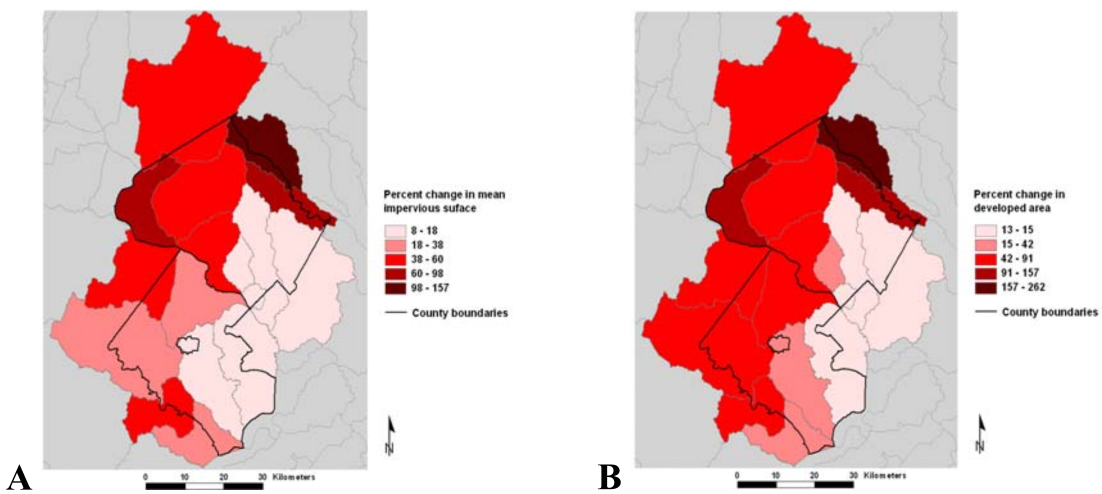


Figure 3.14 Percent change between 1990 and 2000 in mean impervious surfaces (A) for watersheds intersecting Montgomery and Fairfax counties and the percent change in the area of the watershed developed (B). The former was calculated by comparing the mean ISA for each watershed in 1990 with the 2000 mean, and the latter was calculated by comparing the areas developed in 1990 and 2000.

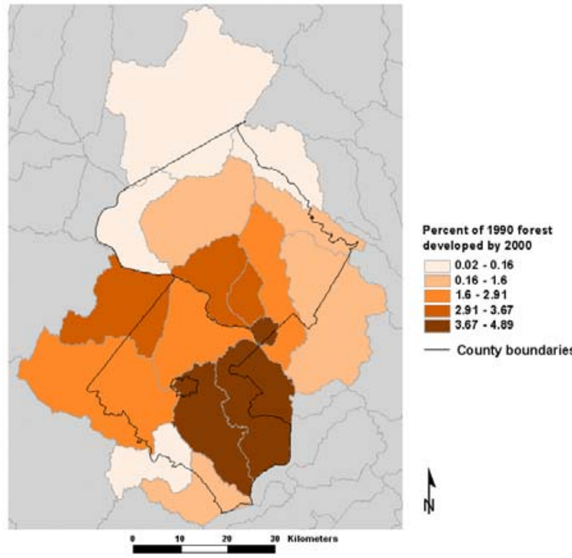


Figure 3.15 The percent of forests that existed in 1990 that were converted to development by 2000.

3.3.2 Weights of evidence

Weights of evidence analysis for the local case studies

The events considered at the local scale include forest loss and forest persistence, which were considered in terms of their association with protected land, steep slopes, the presence of poorly drained soils, and distance from streams. A third event, new development, was considered in terms of its association with these four variables and whether the previous land cover had been forest or agriculture. Positive and negative weights illustrate trends in the spatial association between each event and the predictor variables for each study site (Tables 3.4 – 3.15). In almost all cases, the studentized contrast (C_S) exceeds 1, indicating a high certainty for the calculated weights (Bonham-Carter 1997).

Table 3.4 Positive (W+) and negative (W-) weights, contrast (C) and the studentized contrast (CS) for each predictive variable for **development** occurring in **Burke, VA**. The category range with the highest C is given for continuous variables.

	Time period	Category range	W+	W-	C	C_S
SLOPE	37-78	0 – 7.36°	0.03	-0.78	0.81	13.13
	78-88	0 – 9.81°	-0.00	2.29	-2.30	-8.93
	88-98	0 – 4.91°	0.16	-0.71	0.87	18.85
STREAM DISTANCE	37-78	0 – 379 m	-0.01	1.14	-1.15	-8.41
	78-88	0 – 379 m	0.01	-2.25	2.25	8.92
	88-98	0 – 379 m	-0.01	1.74	-1.75	-11.71
PROTECTED AREAS	37-78	--	-0.85	0.04	-0.89	-15.15
	78-88	--	-1.79	0.07	-1.87	-33.75
	88-98	--	0.01	-0.00	0.01	0.09
SOIL	37-78	--	-0.18	0.03	-0.21	-7.06
	78-88	--	-1.60	0.20	-1.80	-55.86
	88-98	--	-0.62	0.07	-0.68	-11.89
FOREST	37-78	--	0.08	-0.28	0.37	15.33
	78-88	--	0.60	-1.90	2.50	99.03
	88-98	--	1.10	-0.95	2.05	59.56
AGRICULTURE	37-78	--	-0.28	0.08	-0.37	-15.33
	78-88	--	-0.34	0.03	-0.37	-11.79
	88-98	--	2.81	-0.25	3.06	-61.06

Table 3.5 Positive (W+) and negative (W-) weights, contrast (C) and the studentized contrast (C_S) for each predictive variable for **development** occurring in **Herndon, VA**. The category range with the highest C is given for continuous variables.

	Time period	Category range	W+	W-	C	C_S
SLOPE	37-72	0 – 5.06°	0.10	-0.52	0.62	24.69
	72-88	0 – 5.06°	0.13	-0.76	0.90	33.14
	88-98	0 – 5.06°	0.08	-0.46	0.54	8.31
STREAM DISTANCE	37-72	0 – 567 m	-0.04	1.08	-1.13	-25.66
	72-88	0 – 189 m	-0.16	0.25	-0.42	-23.50
	88-98	0 – 378 m	-0.04	0.27	-0.31	-5.32
PROTECTED AREAS	37-72	--	-1.82	0.26	-2.08	-56.12
	72-88	--	-2.15	0.27	-2.42	-55.49
	88-98	--	-1.21	0.16	-1.37	-15.73
SOIL	37-72	--	-2.09	0.11	-2.21	-36.32
	72-88	--	-1.19	0.08	-1.28	-29.54
	88-98	--	-0.71	0.05	-0.76	-7.57
FOREST	37-72	--	-0.16	0.28	-0.43	-24.40
	72-88	--	-0.00	-0.01	0.01	0.66
	88-98	--	1.08	-0.72	1.81	42.16
AGRICULTURE	37-72	--	0.28	-0.16	0.44	24.61
	72-88	--	3.07	-0.53	3.60	95.96
	88-98	--	--	--	--	--

Table 3.6 Positive (W+) and negative (W-) weights, contrast (C) and the studentized contrast (C_S) for each predictive variable for **development** occurring in **Olney, MD**. The category range with the highest C is given for continuous variables.

	Time period	Category range	W+	W-	C	C_S
SLOPE	37-76	0 – 1.53°	0.25	-0.14	0.39	23.38
	76-88	0 – 1.53°	-0.18	0.09	-0.27	-13.61
	88-98	0 – 3.06°	-0.18	0.65	-0.83	-25.78
STREAM DISTANCE	34-76	0 – 291 m	-0.32	0.58	-0.90	-51.71
	76-88	0 – 436 m	0.12	-0.94	1.06	29.98
	88-98	0 – 291 m	0.18	-0.46	0.64	18.88
PROTECTED AREAS	37-76	--	-1.66	0.18	-1.85	-51.47
	76-88	--	-2.35	0.17	-2.53	-38.78
	88-98	--	0.44	-0.09	0.53	14.78
SOIL	37-76	--	-2.77	0.16	-2.93	-43.59
	76-88	--	-0.84	0.07	-0.91	-22.41
	88-98	--	0.10	-0.01	0.11	2.49
FOREST	37-76	--	-0.53	0.10	-0.63	-27.18
	76-88	--	0.13	-0.03	0.16	7.21
	88-98	--	-0.36	0.06	-0.42	-9.38
AGRICULTURE	37-76	--	0.12	-0.59	0.71	30.96
	76-88	--	1.02	-1.06	2.08	97.00
	88-98	--	2.02	-1.77	3.79	94.79

Table 3.7 Positive (W+) and negative (W-) weights, contrast (C) and the studentized contrast (C_S) for each predictive variable for **development** occurring in **Rockville, MD**. The category range with the highest C is given for continuous variables.

	Time period	Category range	W+	W-	C	C_S
SLOPE	34-75	0 – 1.93°	-0.24	0.17	-0.42	-20.89
	75-88	0 – 1.93°	0.22	-0.18	0.40	24.55
	88-98	0 – 3.86°	0.06	-0.52	0.57	11.45
STREAM DISTANCE	34-75	0 – 331 m	-0.29	1.37	-1.66	-65.82
	75-88	0 – 110 m	-0.29	0.17	-0.46	-26.70
	88-98	0 – 110 m	0.47	-0.41	0.88	32.96
PROTECTED AREAS	34-75	--	-2.46	0.24	-2.69	-41.92
	75-88	--	-1.18	0.21	-1.38	-51.99
	88-98	--	-3.27	0.22	-3.49	-24.02
SOIL	34-75	--	-1.03	0.04	-1.07	-17.59
	75-88	--	-1.94	0.07	-2.01	-32.90
	88-98	--	0.08	-0.00	0.09	1.57
FOREST	34-75	--	-0.19	0.02	0.03	-6.53
	75-88	--	0.09	-0.01	0.02	4.13
	88-98	--	0.19	-0.02	0.05	4.52
AGRICULTURE	34-75	--	0.02	-0.19	0.22	6.53
	75-88	--	0.60	-1.19	1.80	90.28
	88-98	--	3.18	-1.13	4.31	116.51

Table 3.8 Positive (W+) and negative (W-) weights, contrast (C) and the studentized contrast (C_S) for each predictive variable for **forest loss** occurring in **Burke, VA**. The category range with the highest C is given for continuous variables.

	Time period	Category range	W+	W-	C	C_S
SLOPE	37-78	0 – 7.36°	0.02	-0.69	0.72	11.78
	78-88	0 – 9.81°	-0.00	2.35	-2.35	-8.65
	88-98	0 – 7.36°	0.03	-0.81	0.84	6.53
STREAM DISTANCE	37-78	0 – 379 m	-0.01	1.13	-1.13	-8.24
	78-88	0 – 95 m	-0.30	0.26	-0.55	-34.01
	88-98	0 – 379 m	-0.02	2.04	-2.06	-13.72
PROTECTED AREAS	37-78	--	-0.76	0.03	-0.80	-13.75
	78-88	--	-1.85	0.07	-1.93	-35.25
	88-98	--	0.25	-0.02	0.26	3.54
SOIL	37-78	--	-0.25	0.04	-0.29	-9.49
	78-88	--	-1.14	0.16	-1.30	-47.52
	88-98	--	-1.23	0.11	-1.35	-15.17

Table 3.9 Positive (W+) and negative (W-) weights, contrast (C) and the studentized contrast (C_S) for each predictive variable for **forest loss** occurring in **Herndon, VA**. The category range with the highest C is given for continuous variables.

	Time period	Category range	W+	W-	C	C_S
SLOPE	37-72	0 – 10.11°	0.01	-1.82	1.83	12.71
	72-88	0 – 7.58°	0.02	-0.41	0.42	6.38
	88-98	0 – 10.11°	0.00	-0.38	0.38	1.24
STREAM DISTANCE	37-72	0 – 189 m	-0.28	0.44	-0.72	-42.22
	72-88	0 – 189 m	0.09	-0.17	0.27	10.60
	88-98	0 – 567 m	0.03	-1.67	1.70	5.62
PROTECTED AREAS	37-72	--	-1.43	0.24	-1.67	-56.86
	72-88	--	-2.06	0.21	-2.28	-33.21
	88-98	--	-1.36	0.16	-1.52	-13.32
SOIL	37-72	--	-0.73	0.06	-0.79	-23.31
	72-88	--	-0.03	0.01	-0.03	-0.87
	88-98	--	-0.48	0.03	-0.51	-4.62

Table 3.10 Positive (W+) and negative (W-) weights, contrast (C) and the studentized contrast (C_S) for each predictive variable for **forest loss** occurring in **Olney, MD**. The category range with the highest C is given for continuous variables.

	Time period	Category range	W+	W-	C	C_S
SLOPE	37-76	0 – 4.59°	0.01	-0.43	0.44	3.39
	76-88	0 – 4.59°	-0.03	0.62	-0.65	-8.36
	88-98	0 – 3.06	0.18	-0.46	0.64	18.88
STREAM DISTANCE	37-76	0 – 291 m	-0.20	0.32	-0.52	-14.06
	76-88	0 – 291 m	0.18	-0.48	0.67	15.96
	88-98	0 – 145 m	0.46	-0.37	0.83	9.96
PROTECTED AREAS	37-76	--	-1.02	0.10	-1.12	-13.59
	76-88	--	-1.05	0.10	-1.16	-14.80
	88-98	--	0.66	-0.16	0.82	8.57
SOIL	37-76	--	-0.65	0.05	-0.70	-8.58
	76-88	--	0.39	-0.05	0.44	8.84
	88-98	--	0.53	-0.07	0.60	5.36

Table 3.11 Positive (W+) and negative (W-) weights, contrast (C) and the studentized contrast (C_S) for each predictive variable for **forest loss** occurring in **Rockville, MD**. The category range with the highest C is given for continuous variables.

	Time period	Category range	W+	W-	C	C_S
SLOPE	34-75	0 – 7.72°	-0.02	1.76	-1.78	-10.63
	75-88	0 – 1.93°	0.22	-0.21	0.43	13.49
	88-98	0 – 7.72°	-0.05	2.50	-2.55	-13.68
STREAM DISTANCE	34-75	0 – 441 m	-0.05	1.17	-1.22	-11.69
	75-88	0 – 441 m	-0.05	1.30	-1.26	-19.71
	88-98	0 – 331 m	0.13	-3.68	3.8	5.38
PROTECTED AREAS	34-75	--	0.23	-0.06	0.29	4.81
	75-88	--	-0.39	0.07	-0.46	-9.63
	88-98	--	-0.92	0.13	-1.04	-6.73
SOIL	34-75	--	-0.19	0.01	-0.20	-1.62
	75-88	--	-1.12	0.04	-1.16	-10.08
	88-98	--	-2.84	0.05	-2.90	-4.09

Table 3.12 Positive (W+) and negative (W-) weights, contrast (C) and the studentized contrast (C_S) for each predictive variable for **forest persistence** occurring in **Burke, VA**. The category range with the highest C is given for continuous variables.

	Time period	Category range	W+	W-	C	C_S
SLOPE	37-78	0 – 9.81°	-0.00	2.60	-2.60	-4.57
	78-88	0 – 9.81°	0.00	-0.97	0.97	3.56
	88-98	0 – 9.81°	0.00	-1.02	1.02	3.52
STREAM DISTANCE	37-78	0 – 284 m	0.03	-0.96	0.99	6.87
	78-88	0 – 379 m	-0.00	1.04	-1.05	-7.63
	88-98	0 – 95 m	0.57	-0.72	1.29	60.07
PROTECTED AREAS	37-78	--	1.12	-0.05	1.17	43.89
	78-88	--	2.22	-0.16	2.38	58.22
	88-98	--	2.38	-0.19	2.56	61.69
SOIL	37-78	--	0.06	-0.38	0.45	10.13
	78-88	--	1.12	-0.24	1.34	55.36
	88-98	--	1.51	-0.36	1.87	75.70

Table 3.13 Positive (W+) and negative (W-) weights, contrast (C) and the studentized contrast (C_S) for each predictive variable for **forest persistence** occurring in **Herndon, VA**. The category range with the highest C is given for continuous variables.

	Time period	Category range	W+	W-	C	C_S
SLOPE	37-72	0 – 10.11°	-0.03	3.25	-3.28	-22.98
	72-88	0 – 10.11°	-0.04	2.90	-2.94	-28.60
	88-98	0 – 10.11°	-0.03	2.69	-2.73	-28.24
STREAM DISTANCE	37-72	0 – 378 m	0.12	-1.49	1.60	36.34
	72-88	0 – 378 m	0.11	-1.56	1.68	28.86
	88-98	0 – 189 m	0.42	-1.18	1.60	55.18
PROTECTED AREAS	37-72	--	0.60	-0.16	0.76	36.00
	72-88	--	1.14	-0.41	1.55	68.02
	88-98	--	1.20	-0.44	1.64	71.90
SOIL	37-72	--	1.01	-0.11	1.13	38.96
	72-88	--	1.22	-0.16	1.38	46.42
	88-98	--	1.26	-0.17	1.43	48.29

Table 3.14 Positive (W+) and negative (W-) weights, contrast (C) and the studentized contrast (C_S) for each predictive variable for **forest persistence** occurring in **Olney, MD**. The category range with the highest C is given for continuous variables.

	Time period	Category range	W+	W-	C	C_S
SLOPE	37-76	0 – 6.12°	0.00	-2.42	2.43	3.41
	76-88	0 – 6.12°	-0.00	0.75	-0.76	-4.21
	88-98	0 – 6.12°	-0.00	0.91	-0.91	-5.26
STREAM DISTANCE	37-76	0 – 436 m	0.11	-0.98	1.09	21.79
	76-88	0 – 436 m	0.11	-1.11	1.23	24.97
	88-98	0 – 436 m	0.12	-1.19	1.32	25.79
PROTECTED AREAS	37-76	--	1.99	-0.75	2.73	97.84
	76-88	--	2.35	-0.89	3.24	113.67
	88-98	--	2.34	-0.88	3.23	113.29
SOIL	37-76	--	2.27	-0.52	2.79	86.48
	76-88	--	2.27	-0.48	2.74	86.18
	88-98	--	2.41	-0.52	2.93	90.47

Table 3.15 Positive (W+) and negative (W-) weights, contrast (C) and the studentized contrast (C_S) for each predictive variable for **forest persistence** occurring in **Rockville, MD**. The category range with the highest C is given for continuous variables.

	Time period	Category range	W+	W-	C	C_S
SLOPE	34-75	0 – 7.72°	-0.03	2.62	-2.65	-23.28
	75-88	0 – 7.72°	-0.05	2.91	-2.96	-25.91
	88-98	0 – 7.72°	-0.04	2.67	-2.71	-23.75
STREAM DISTANCE	34-75	0 – 221 m	0.29	-1.06	1.35	29.12
	75-88	0 – 221 m	0.21	-0.64	0.85	17.81
	88-98	0 – 110 m	0.45	-0.40	0.86	25.46
PROTECTED AREAS	34-75	--	0.58	-0.18	0.76	22.69
	75-88	--	0.73	-0.25	0.98	25.322
	88-98	--	1.03	-0.43	1.46	42.84
SOIL	34-75	--	0.55	-0.04	0.59	11.00
	75-88	--	0.97	-0.09	1.06	19.33
	88-98	--	1.17	-0.12	1.29	26.69

The emergence of strong weights, either positive or negative, that would indicate a strong explanatory relationship is variable across sites and for each event, and in many cases changes through time. Some general trends can be identified, however. For the occurrence of new development (Tables 3.4 – 3.7), slope is a weak to moderate predictor, and in general there is an association between development and moderate slopes. In Herndon, for example (Table 3.5), the negative weights (W-) are consistently negative, indicating that development is less likely to occur when the slope exceeds 5.06°. The 1978-1988 period in Burke shows an exception to this generalization, where development is associated with slopes greater than 9.81° (W- = 2.29, Table 3.4). Distance from streams is a weak to moderate predictor of development, with some time periods exhibiting strong negative weights (e.g. in Burke, Table 3.4). It should be noted that the cut-off point for the stream distance factor, which was identified using the distance category with the highest contrast value (C), is greater than 100 meters in all cases for the development event. The presence of protected areas exhibited a strong negative relationship with development, as expected. With the exception of Rockville, all study sites have a maximum contrast value during the period of rapid development that occurred between the late 1970s and 1988. The presence of poorly drained soils exhibits a similar relationship, showing a moderate to strong negative association with development. Weights for the forest and agriculture land cover types show that both land cover types are likely to be developed, although agriculture tends to show a higher positive association with development, particularly later in the time series. Forests in the Virginia sites also tend to be more at risk to development than the Maryland sites.

Forest loss is an event that is primarily, although not entirely, associated with the occurrence of development, and therefore exhibits many of the same relationships with the predictor variables (Tables 3.8 – 3.11). Forest loss is less likely to occur on steep slopes, although this relationship is not consistent across all sites for all time periods. In Rockville, for example, between 1934 and 1976 and between 1988 and 1998, forest loss is strongly associated with slopes steeper than 7.72° (Table 3.11). The cut-off points identified for stream distance are again large, in almost all cases exceeding 100 meters, although in some cases a strong relationship emerges. Both Burke and Rockville, for example (Tables 3.8 and 3.11 respectively), exhibit strong positive W- values for stream distance, indicating that forest loss is more likely to occur farther away from streams. This relationship is not consistent through time, as can be noted in Rockville where the relationship reverses at the end of the time series. Moderate to strong negative values for W+ are again observed for protected areas, indicating that these areas are much less likely to experience deforestation. A similar pattern is observed at most sites with the presence of poorly drained soils.

Compared to the occurrences of development and forest loss, forest persistence reveals much clearer relationships with many of the explanatory variables (Tables 3.12 – 3.15). Forests are more likely to persist on steep slopes, as indicated by the strong positive values for W-, and this trend is identified with relatively good consistency across all sites and throughout the time series. Likewise, forests are less likely to persist as the distance from streams increases, as indicated by the negative values for W- that are observed. Protected areas are strongly associated with forest persistence, a relationship that grows stronger through time at most of the sites. A similar trend is observed for the presence of poorly drained soils.

Conditional independence tests for the local case studies

Using the χ^2 tests, the lack of conditional independence was frequently observed between map pairs across all sites for all events (Tables 3.16 – 3.27). The hypothesis of conditional independence was tested for p = 0.001 with one degree of freedom. The sample size (N) is measured in numbers of pixels and varied depending on the frequency of the event in question, as shown in each table. For the occurrence of development, N ranged from 2,442 to 28,021. For forest loss, N ranged from 586 to 29,353 and for forest persistence N ranged from 3,257 to 33,987. Considering these large sample sizes, it is not surprising that relatively small differences between the expected and observed frequencies in map pair cross tabulations are identified as statistically significant. The Cramer's V coefficient, indicated in parentheses in Tables 3.16 – 3.27, measures the degree of similarity between the expected and observed frequencies and is therefore a useful measure in evaluating whether or not there are serious violations of conditional independence between map pairs. Cramer's V does not, however, provide a statistical measure of the spatial association between map pairs. In previous work, a threshold of V < 0.5 has been applied to identify maps that demonstrate less association rather than more (Bonham-Carter 1997; Almeida, et al. 2003). A more conservative threshold, V ≤ 0.10, is used here to identify potential problems with conditional independence (indicated in bold typeface in Tables 3.16 – 3.27).

Table 3.16 Burke development χ^2 scores for each time step. If the calculated $\chi^2 > 10.83$, then the hypothesis of conditional independence is rejected ($p = 0.001$, $df = 1$). Map pairs that violate the conditional independence assumption are highlighted in grey. Cramer's V scores are indicated in parentheses. Scores that exceed 0.10 are in bold.

1937 – 1978 N = 13615	Stream distance	Slope	Protected land	Forest	Agriculture
Soil	12.54 (0.03)	39.59 (0.05)	2131.02 **(0.40)**	210.06 **(0.12)**	210.06 **(0.12)**
Stream distance		1.34 (0.01)	1.64 (0.01)	14.67 (0.03)	14.67 (0.03)
Slope			6.66 (0.02)	60.25 (0.07)	60.25 (0.07)
Protected land				4.59 (0.02)	4.59 (0.02)
Forest					13447.67 **(0.99)**
1978 – 1988 N = 28021	**Stream distance**	**Slope**	**Protected land**	**Forest**	**Agriculture**
Soil	0.08 (0.00)	5.22 (0.01)	1193.79 **(0.21)**	493.20 **(0.13)**	493.20 **(0.13)**
Stream distance		0.08 (0.00)	0.24 (0.00)	14.16 (0.02)	14.16 (0.02)
Slope			1.01 (0.01)	20.23 (0.03)	20.23 (0.03)
Protected land				0.11 (0.00)	0.11 (0.00)
Forest					27990.39 **(1.00)**
1988 – 1998 N = 4410	**Stream distance**	**Slope**	**Protected land**	**Forest**	**Agriculture**
Soil	4.49 (0.04)	45.88 (0.10)	318.30 **(0.27)**	132.73 **(0.17)**	132.73 **(0.17)**
Stream distance		8.55 (0.04)	2.59 (0.02)	14.79 (0.06)	14.79 (0.06)
Slope			19.32 (0.07)	153.85 **(0.19)**	153.85 **(0.19)**
Protected land				73.73 **(0.13)**	73.73 **(0.13)**
Forest					4403.91 **(1.00)**

Table 3.17 Herndon development χ^2 scores for each time step. If the calculated $\chi^2 > 10.83$, then the hypothesis of conditional independence is rejected ($p = 0.001$, $df = 1$). Map pairs that violate the conditional independence assumption are highlighted in grey. Cramer's V scores are indicated in parentheses. Scores that exceed 0.10 are in bold.

1937 – 1972 N = 19558	STREAM DISTANCE	SLOPE	PROTECTED LAND	FOREST	AGRICULTURE
SOIL	4.04 (0.01)	30.79 (0.02)	0.42 (0.00)	58.91 (0.05)	58.91 (0.05)
STREAM DISTANCE		6.69 (0.01)	122.65 (0.08)	59.73 (0.05)	59.73 (0.05)
SLOPE			29.27 (0.04)	62.30 (0.06)	62.30 (0.06)
PROTECTED LAND				251.67 **(0.11)**	251.67 **(0.11)**
FOREST					19858.88 **(1.00)**
1972 – 1988 N = 19099	**STREAM DISTANCE**	**SLOPE**	**PROTECTED LAND**	**FOREST**	**AGRICULTURE**
SOIL	112.58 **(0.12)**	849.67 (0.08)	8.54 (0.02)	115.70 (0.08)	168.22 (0.09)
STREAM DISTANCE		288.04 **(0.21)**	0.26 (0.00)	236.43 **(0.11)**	23.03 (0.03)
SLOPE			15.94 (0.03)	52.67 (0.05)	313.05 **(0.13)**
PROTECTED LAND				341.45 **(0.13)**	1.61 (0.01)
FOREST					1368.25 **(0.27)**
1988 – 1998 N = 2442	**STREAM DISTANCE**	**SLOPE**	**PROTECTED LAND**	**FOREST**	
SOIL	15.16 (0.08)	1.36 89 (0.02)	19.55 (0.09)	1.05 (0.02)	
STREAM DISTANCE		5.01 (0.05)	100.62 **(0.20)**	250.29 **(0.32)**	
SLOPE			0.18 (0.01)	2.17 (0.03)	
PROTECTED LAND				108.85 **(0.21)**	

Table 3.18 Olney development χ^2 scores for each time step. If the calculated $\chi^2 > 10.83$, then the hypothesis of conditional independence is rejected ($p = 0.001$, $df = 1$). Map pairs that violate the conditional independence assumption are highlighted in grey. Cramer's V scores are indicated in parentheses. Scores that exceed 0.10 are in bold.

1937 – 1976 N = 24396	STREAM DISTANCE	SLOPE	PROTECTED LAND	FOREST	AGRICULTURE
SOIL	60.32 (0.05)	0.08 (0.00)	75.86 (0.06)	137.45 (0.08)	137.21 (0.07)
STREAM DISTANCE		701.78 **(0.17)**	817.66 **(0.18)**	5.88 (0.02)	6.18 (0.02)
SLOPE			12.37 (0.02)	20.03 (0.03)	19.39 (0.03)
PROTECTED LAND				1.99 (0.01)	2.02 (0.01)
FOREST					24359.18 **(1.00)**

1976 – 1988 N = 14942	STREAM DISTANCE	SLOPE	PROTECTED LAND	FOREST	AGRICULTURE
SOIL	41.31 (0.05)	1.17 (0.02)	3.59 (0.00)	662.04 **(0.21)**	556.72 **(0.19)**
STREAM DISTANCE		178.95 **(0.11)**	16.48 (0.03)	17.03 (0.03)	5.55 (0.02)
SLOPE			30.99 (0.05)	4.61 (0.02)	3.69 (0.02)
PROTECTED LAND				0.01 (0.00)	0.17 (0.00)
FOREST					12882.17 **(0.93)**

1988 – 1998 N = 5484	STREAM DISTANCE	SLOPE	PROTECTED LAND	FOREST	AGRICULTURE
SOIL	24.24 (0.07)	5.75 (0.03)	959.48 **(0.42)**	16.86 (0.06)	1.05 (0.01)
STREAM DISTANCE		0.16 (0.01)	13.49 (0.05)	40.68 (0.09)	35.66 (0.08)
SLOPE			115.17 **(0.14)**	2.15 (0.02)	3.48 (0.03)
PROTECTED LAND				18.53 (0.06)	26.52 (0.07)
FOREST					3905.86 **(0.84)**

Table 3.19 Rockville development χ^2 scores for each time step. If the calculated $\chi^2 > 10.83$, then the hypothesis of conditional independence is rejected ($p = 0.001$, df = 1). Map pairs that violate the conditional independence assumption are highlighted in grey. Cramer's V scores are indicated in parentheses. Scores that exceed 0.10 are in bold.

1934 – 1975 N = 13382	Stream distance	Slope	Protected land	Forest	Agriculture
Soil	1.71 (0.01)	42.82 (0.06)	8.41 (0.03)	15.39 (0.03)	15.39 (0.03)
Stream distance		18.03 (0.04)	16.41 (0.04)	112.16 (0.09)	112.16 (0.09)
Slope			31.87 (0.05)	69.65 (0.07)	69.65 (0.07)
Protected land				0.05 (0.00)	0.05 (0.00)
Forest					13369.10 **(1.00)**
1975 – 1988 N = 25007	**Stream distance**	**Slope**	**Protected land**	**Forest**	**Agriculture**
Soil	427.73 **(0.13)**	43.28 (0.04)	7.31 (0.02)	62.38 (0.03)	16.09 (0.04)
Stream distance		188.55 (0.09)	0.15 (0.00)	1.57 (0.01)	3.48 (0.01)
Slope			355.57 **(0.12)**	22.73 (0.03)	0.12 (0.00)
Protected land				62.38 (0.05)	16.09 (0.03)
Forest					19871.53 **(0.89)**
1988 – 1998 N = 6349	**Stream distance**	**Slope**	**Protected land**	**Forest**	**Agriculture**
Soil	290.65 **(0.21)**	30.78 (0.07)	2.05 (0.02)	38.34 (0.08)	177.21 **(0.17)**
Stream distance		159.60 **(0.16)**	10.69 (0.04)	328.75 **(0.23)**	685.88 **(0.33)**
Slope			274.44 **(0.21)**	2226.37 **(0.59)**	413.84 **(0.26)**
Protected land				217.36 **(0.19)**	102.73 **(0.13)**
Forest					1375.76 **(0.47)**

Table 3.20 Burke forest loss χ^2 scores for each time step. If the calculated $\chi^2 > 10.83$, then the hypothesis of conditional independence is rejected ($p = 0.001$, $df = 1$). Map pairs that violate the conditional independence assumption are highlighted in grey. Cramer's V scores are indicated in parentheses. Scores that exceed 0.10 are in bold.

1937 – 1978 N = 13046	STREAM DISTANCE	SLOPE	PROTECTED LAND
SOIL	11.12 (0.03)	38.21 (0.05)	1431.19 **(0.33)**
STREAM DISTANCE		1.42 (0.01)	1.73 (0.01)
SLOPE			7.56 (0.02)

1978 – 1988 N = 29353	STREAM DISTANCE	SLOPE	PROTECTED LAND
SOIL	2567.23 **(0.30)**	8.56 (0.02)	942.97 **(0.18)**
STREAM DISTANCE		3.78 (0.01)	356.00 **(0.11)**
SLOPE			0.99 (0.01)

1988 – 1998 N = 3237	STREAM DISTANCE	SLOPE	PROTECTED LAND
SOIL	1.88 (0.02)	1.88 (0.02)	773.80 **(0.49)**
STREAM DISTANCE		0.48 (0.01)	3.48 (0.03)
SLOPE			3.48 (0.02)

Table 3.21 Herndon forest loss χ^2 scores for each time step. If the calculated $\chi^2 > 10.83$, then the hypothesis of conditional independence is rejected ($p = 0.001$, $df = 1$). Map pairs that violate the conditional independence assumption are highlighted in grey. Cramer's V scores are indicated in parentheses. Scores that exceed 0.10 are in bold.

1937 – 1972 N = 23162	STREAM DISTANCE	SLOPE	PROTECTED LAND
SOIL	1012.61 **(0.21)**	0.03 (0.00)	176.57 (0.09)
STREAM DISTANCE		46.96 (0.05)	470.03 **(0.14)**
SLOPE			2.62 (0.01)

1972 – 1988 N = 8249	STREAM DISTANCE	SLOPE	PROTECTED LAND
SOIL	235.09 **(0.17)**	7.73 (0.03)	125.11 **(0.12)**
STREAM DISTANCE		123.59 **(0.12)**	15.28 (0.04)
SLOPE			6.50 (0.03)

1988 – 1998 N = 1630	STREAM DISTANCE	SLOPE	PROTECTED LAND
SOIL	0.02 (0.01)	0.29 (0.00)	0.04 (0.00)
STREAM DISTANCE		0.08 (0.01)	0.00 (0.00)
SLOPE			0.00 (0.00)

Table 3.22 Olney forest loss χ^2 scores for each time step. If the calculated $\chi^2 > 10.83$, then the hypothesis of conditional independence is rejected ($p = 0.001$, $df = 1$). Map pairs that violate the conditional independence assumption are highlighted in grey. Cramer's V scores are indicated in parentheses. Scores that exceed 0.10 are in bold.

1937 – 1976 N = 3095	STREAM DISTANCE	SLOPE	PROTECTED LAND
SOIL	45.72 **(0.12)**	2.81 (0.03)	58.77 **(0.14)**
STREAM DISTANCE		52.16 **(0.13)**	135.93 **(0.21)**
SLOPE			4.36 (0.04)

1976 – 1988 N = 3559	STREAM DISTANCE	SLOPE	PROTECTED LAND
SOIL	40.74 **(0.11)**	15.28 (0.07)	65.01 **(0.14)**
STREAM DISTANCE		36.52 **(0.10)**	38.56 (0.01)
SLOPE			91.67 **(0.16)**

1988 – 1998 N = 586	STREAM DISTANCE	SLOPE	PROTECTED LAND
SOIL	204.59 **(0.59)**	22.55 **(0.20)**	58.77 **(0.32)**
STREAM DISTANCE		90.49 **(0.39)**	257.29 **(0.66)**
SLOPE			7.54 **(0.11)**

Table 3.23 Rockville forest loss χ^2 scores for each time step. If the calculated $\chi^2 > 10.83$, then the hypothesis of conditional independence is rejected ($p = 0.001$, $df = 1$). Map pairs that violate the conditional independence assumption are highlighted in grey. Cramer's V scores are indicated in parentheses. Scores that exceed 0.10 are in bold.

1934 – 1975 N = 1623	STREAM DISTANCE	SLOPE	PROTECTED LAND
SOIL	1.32 (0.03)	1.41 (0.03)	71.86 **(0.21)**
STREAM DISTANCE		2.06 (0.04)	32.06 **(0.14)**
SLOPE			27.45 **(0.13)**

1975 – 1988 N = 4223	STREAM DISTANCE	SLOPE	PROTECTED LAND
SOIL	4.54 (0.03)	20.84 (0.07)	3.34 (0.03)
STREAM DISTANCE		117.19 **(0.17)**	41.90 (0.10)
SLOPE			132.86 **(0.18)**

1988 – 1998 N = 622	STREAM DISTANCE	SLOPE	PROTECTED LAND
SOIL	0.01 (0.00)	0.12 (0.01)	13.73 **(0.15)**
STREAM DISTANCE		0.12 (0.01)	0.16 (0.02)
SLOPE			22.98 **(0.19)**

Table 3.24 Burke forest persistence χ^2 scores for each time step. If the calculated $\chi^2 > 10.83$, then the hypothesis of conditional independence is rejected ($p = 0.001$, df = 1). Map pairs that violate the conditional independence assumption are highlighted in grey. Cramer's V scores are indicated in parentheses. Scores that exceed 0.10 are in bold.

1937 – 1978 N = 33987	STREAM DISTANCE	SLOPE	PROTECTED LAND
SOIL	37.97 (0.04)	4.73 (0.02)	843.38 **(0.28)**
STREAM DISTANCE		0.11 (0.01)	18.32 (0.03)
SLOPE			1.92 (0.01)

1978 – 1988 N = 13953	STREAM DISTANCE	SLOPE	PROTECTED LAND
SOIL	37.97 (0.05)	4.73 (0.02)	843.38 **(0.25)**
STREAM DISTANCE		0.11 (0.00)	18.32 (0.04)
SLOPE			1.92 (0.01)

1988 – 1998 N = 12855	STREAM DISTANCE	SLOPE	PROTECTED LAND
SOIL	2640.51 **(0.45)**	5.88 (0.02)	562.63 **(0.21)**
STREAM DISTANCE		3.98 (0.02)	826.72 **(0.25)**
SLOPE			1.82 (0.01)

Table 3.25 Herndon forest persistence χ^2 scores for each time step. If the calculated $\chi^2 > 10.83$, then the hypothesis of conditional independence is rejected ($p = 0.001$, df = 1). Map pairs that violate the conditional independence assumption are highlighted in grey. Cramer's V scores are indicated in parentheses. Scores that exceed 0.10 are in bold.

1937 – 1972 N = 18013	STREAM DISTANCE	SLOPE	PROTECTED LAND
SOIL	102.71 (0.08)	56.37 (0.06)	407.19 **(0.15)**
STREAM DISTANCE		203.10 **(0.11)**	23.46 (0.04)
SLOPE			1097.16 **(0.25)**

1972 – 1988 N = 11729	STREAM DISTANCE	SLOPE	PROTECTED LAND
SOIL	50.14 (0.07)	34.02 (0.05)	69.54 (0.08)
STREAM DISTANCE		13.48 (0.03)	3.43 (0.02)
SLOPE			4.82 (0.02)

1988 – 1998 N = 11649	STREAM DISTANCE	SLOPE	PROTECTED LAND
SOIL	412.97 **(0.19)**	36.51 (0.06)	48.76 (0.06)
STREAM DISTANCE		72.74 (0.08)	92.67 (0.09)
SLOPE			5.84 (0.02)

Table 3.26 Olney forest persistence χ^2 scores for each time step. If the calculated $\chi^2 > 10.83$, then the hypothesis of conditional independence is rejected ($p = 0.001$, $df = 1$). Map pairs that violate the conditional independence assumption are highlighted in grey. Cramer's V scores are indicated in parentheses. Scores that exceed 0.10 are in bold.

1937 – 1976 N = 7739	STREAM DISTANCE	SLOPE	PROTECTED LAND
SOIL	0.91 (0.01)	0.28 (0.01)	188.01 **(0.16)**
STREAM DISTANCE		0.12 (0.00)	507.59 **(0.26)**
SLOPE			0.29 (0.01)

1976 – 1988 N = 8875	STREAM DISTANCE	SLOPE	PROTECTED LAND
SOIL	4.30 (0.02)	27.15 (0.06)	180.74 **(0.14)**
STREAM DISTANCE		764.92 **(0.29)**	76.42 (0.09)
SLOPE			25.05 (0.05)

1988 – 1998 N = 8853	STREAM DISTANCE	SLOPE	PROTECTED LAND
SOIL	1.75 (0.01)	33.58 (0.06)	65.45 (0.09)
STREAM DISTANCE		956.76 **(0.33)**	35.37 (0.06)
SLOPE			28.50 (0.06)

Table 3.27 Rockville forest persistence χ^2 scores for each time step. If the calculated $\chi^2 > 10.83$, then the hypothesis of conditional independence is rejected ($p = 0.001$, $df = 1$). Map pairs that violate the conditional independence assumption are highlighted in grey. Cramer's V scores are indicated in parentheses. Scores that exceed 0.10 are in bold.

1934 – 1975 N = 4770	STREAM DISTANCE	SLOPE	PROTECTED LAND
SOIL	9.55 (0.04)	0.16 (0.01)	742.35 **(0.39)**
STREAM DISTANCE		8.28 (0.04)	110.55 **(0.15)**
SLOPE			2.47 (0.02)

1975 – 1988 N = 3257	STREAM DISTANCE	SLOPE	PROTECTED LAND
SOIL	82.29 **(0.16)**	5.10 (0.04)	538.61 **(0.41)**
STREAM DISTANCE		20.04 (0.08)	357.25 **(0.33)**
SLOPE			5.81 (0.04)

1988 – 1998 N = 3948	STREAM DISTANCE	SLOPE	PROTECTED LAND
SOIL	404.24 **(0.32)**	5.41 (0.04)	267.72 **(0.26)**
STREAM DISTANCE		76.26 **(0.14)**	141.01 **(0.19)**
SLOPE			32.66 (0.09)

The correlations that emerge between map pairs are often not unexpected, but are variable between sites, time periods, and the event being considered. Considering the predictive factors for new development (Tables 3.16 – 3.19), for example, Burke exhibits correlations between poorly drained soils and the presence of protected land, forests and agriculture (Table 3.16). Forest and agriculture tend to be strongly correlated because they are mutually exclusive. Protected land is frequently correlated with slope, soil, and forests. For forest loss (Tables 3.20 – 3.23), protected land is again frequently correlated with poorly drained soils and, for some sites, with slope and stream distance. For many sites, stream distance is correlated with poorly drained soils and less frequently with slope. Slope and poorly drained soils are rarely correlated. When considering forest persistence (Tables 3.24 – 3.27), protected lands again demonstrate a consistent association with poorly drained soils, and less frequently with stream distance. Associations occasionally emerge between slope and stream distance and poorly drained soils and stream distance.

Weights of evidence analysis for Fairfax and Montgomery counties

The weights of evidence results for the counties show several similar trends, although the strength of the observed relationships is variable in some cases (Tables 3.28 – 3.33). In all cases, the studentized contrast (C_S) exceeds 1, indicating a high certainty for the calculated weights.

Table 3.28 Positive (W+) and negative (W-) weights, contrast (C) and the studentized contrast (C_S) for each predictive variable for **development** occurring in **Fairfax County**. The category range with the highest C is given for continuous variables.

Factor	Category range	W+	W-	C	C_S
SLOPE	0 – 10.53°	0.01	-1.52	1.53	16.33
STREAM DISTANCE	0 – 120 m	-0.25	0.16	-0.41	-43.20
WATER BODY DISTANCE	0 – 1260 m	-0.19	1.01	-1.21	-99.87
URBAN CENTER DISTANCE	0 – 24 km	0.02	-0.42	0.44	13.34
PROTECTED LANDS DISTANCE	0 – 180 m	-0.39	0.19	-0.58	-59.13
ROADS DISTANCE	0 – 3480 m	0.03	-1.54	1.57	22.51
PROTECTED LANDS	--	-1.36	0.16	-1.51	-82.74
SOIL	--	-0.01	0.00	-0.01	-0.71
FOREST	--	-0.30	0.12	-0.43	-42.61
AGRICULTURE	--	0.48	-0.05	0.53	43.06

Table 3.29 Positive (W+) and negative (W-) weights, contrast (C) and the studentized contrast (CS) for each predictive variable for development occurring in Montgomery County. The category range with the highest C is given for continuous variables.

Factor	Category range	W+	W-	C	C_S
SLOPE	0 – 9.62°	0.03	-1.77	1.79	19.80
STREAM DISTANCE	0 – 90 m	-0.35	0.20	-0.55	-52.91
WATER BODY DISTANCE	0 – 90 m	-0.52	0.05	-0.57	-32.76
URBAN CENTER DISTANCE	0 – 35 km	0.16	-1.26	1.42	55.86
PROTECTED LANDS DISTANCE	0 – 2220 m	0.25	-1.68	1.93	71.41
ROADS DISTANCE	0 – 4800 m	0.02	-2.14	2.16	18.53
PROTECTED LANDS	--	-1.13	0.10	-1.24	-59.90
SOIL	--	-0.99	-0.19	-1.19	-79.22
FOREST	--	-0.64	0.12	-0.76	-54.00
AGRICULTURE	--	0.07	-0.04	0.11	11.19

Table 3.30 Positive (W+) and negative (W-) weights, contrast (C) and the studentized contrast (C_S) for each predictive variable for **forest loss** occurring in **Fairfax County**. The category range with the highest C is given for continuous variables.

Factor	Category range	W+	W-	C	C_S
SLOPE	0 – 10.53°	0.01	-1.13	1.14	7.21
STREAM DISTANCE	0 – 120 m	-0.14	0.09	-0.23	-12.60
WATER BODY DISTANCE	0 – 90 m	-0.90	0.05	-0.96	-21.97
URBAN CENTER DISTANCE	0 – 24 km	0.02	-0.72	0.74	9.69
ROADS DISTANCE	0 – 3480 m	0.02	-1.58	1.61	11.04
PROTECTED LANDS	--	-1.82	0.17	-1.99	-42.95
SOIL	--	-0.43	0.06	-0.49	-18.00

Table 3.31 Positive (W+) and negative (W-) weights, contrast (C) and the studentized contrast (C_S) for each predictive variable for **forest loss** occurring in **Montgomery County**. The category range with the highest C is given for continuous variables.

Factor	Category range	W+	W-	C	C_S
SLOPE	0 – 9.62°	0.02	-1.01	1.03	5.44
STREAM DISTANCE	0 – 90 m	-0.22	0.13	-0.36	-11.70
WATER BODY DISTANCE	0 – 90 m	-0.68	0.06	-0.74	-13.12
URBAN CENTER DISTANCE	0 – 35 km	0.19	-2.32	2.51	19.34
ROADS DISTANCE	0 – 4800 m	0.03	-3.51	3.53	5.00
PROTECTED LANDS	--	-0.96	0.09	-1.05	-23.49
SOIL	--	-0.83	0.17	-1.00	-23.49

Table 3.32 Positive (W+) and negative (W-) weights, contrast (C) and the studentized contrast (C_S) for each predictive variable for **forest distribution** in **Fairfax County**. The category range with the highest C is given for continuous variables.

Factor	Category range	W+	W-	C	C_S
SLOPE	0 – 10.53°	-0.02	1.76	-1.78	-84.18
STREAM DISTANCE	0 – 390 m	0.08	-0.81	0.88	94.86
WATER BODY DISTANCE	0 – 2070 m	0.01	-0.47	0.48	21.56
URBAN CENTER DISTANCE	0 – 6 km	-0.48	0.11	-0.60	-130.83
ROADS DISTANCE	0 – 3480 m	-0.03	1.03	-1.06	-76.71
PROTECTED LANDS	--	1.22	-0.27	1.49	394.80
SOIL	--	0.72	-0.13	0.85	208.77

Table 3.33 Positive (W+) and negative (W-) weights, contrast (C) and the studentized contrast (C_S) for each predictive variable for **forest distribution** in **Montgomery County**. The category range with the highest C is given for continuous variables.

Factor	Category range	W+	W-	C	C_S
SLOPE	0 – 9.62°	-0.05	1.81	-1.86	-135.09
STREAM DISTANCE	0 – 90 m	0.60	-0.53	1.13	282.96
WATER BODY DISTANCE	0 – 90 m	0.50	-0.07	0.56	124.17
URBAN CENTER DISTANCE	0 – 9 km	0.05	-0.01	0.06	12.85
ROADS DISTANCE	0 – 4800 m	-0.01	0.46	-0.47	-32.52
PROTECTED LANDS	--	1.29	-0.23	1.52	393.04
SOIL	--	0.85	-0.33	1.17	315.14

For the occurrence of development between 1990 and 2000 (Tables 3.28 and 3.29), both counties demonstrate a strong negative association for steep slopes. A weak negative relationship is also found between the occurrence of development and proximity to streams for a 120 meter stream buffer in Fairfax and a 90 meter buffer in Montgomery. In Montgomery county, a weak negative association is found between the occurrence of development within a 90 meter buffer around water bodies (W+ = -0.52), while in Fairfax development is more likely to occur at distances greater than 1,260 meters (W- = 1.01). In both counties, development is less likely to occur far from the Washington, DC – Alexandria – Arlington urban core (>24 km in Fairfax and >35 km in Montgomery), although this relationship is stronger in Montgomery (W- = -1.26 vs. W- = -0.42 in Fairfax County). Distance from protected lands was not a strong predictor of development in Fairfax County, although in Montgomery County development is less likely to take place at distances greater than 2,220 meters (W- = -1.68). In both counties, development is not likely to occur in areas that are far from roads (>3,480 meters in Fairfax and >4,800 meters in Montgomery). As expected, new development is not associated with the presence of protected areas. In Montgomery County, poorly drained soils are a moderately strong explanatory variable, although this negative association is not observed in Fairfax County. As observed at the local scale, agriculture is more likely to experience development than forest, although these relationships are weak to moderate. It is interesting to note that forests in Montgomery County have a stronger negative association with development (W+ = -0.64, C = -0.76) than forests in Fairfax County (W+ = -0.30, C = -0.43).

Forest loss between 1990 and 2000, considered as a subset of the occurrence of new development, shows similar trends as those presented above (Tables 3.30 and 3.31), and is less likely to occur on steep slopes, in areas close to streams or water bodies, in areas far from the urban center or from roads, in protected areas, or where poorly drained soils exist. For Fairfax County, the strongest explanatory variables are slope, distance from roads, and the presence of protected land, while in Montgomery County, the strongest explanatory variables are slope, urban center distance and distance from roads.

Slope and protected lands emerge as strong predictors in both counties when considering the current extent of forests (Tables 3.32 and 3.33). Stream distance is a moderately strong predictor. In Fairfax County, forests are less likely to be found at distances greater than 390 meters (W- = -0.81). In Montgomery County, the presence of forests is moderately associated with a 90 meter stream buffer (W+ = 0.60) and forests are also less likely to be found beyond this buffer (W- = -0.53). Similar relationships are observed with the distance to water bodies, although in both counties the weight values for this variable are not as strong. In Fairfax County, a weak to moderate negative relationship is found between the presence of forests and the distance from the urban core (W+ = -0.48). Urban core distance is not a good predictor of forest distribution in Montgomery County. In both counties, forests are more likely to be found far from roads, and this relationship is stronger in Fairfax County. The presence of forests shows a moderate positive association with poorly drained soils in both counties.

Conditional independence tests for Montgomery and Fairfax counties

As in the local case studies, Chi-squared tests of conditional independence often indicated spatial correlation between map pairs across all sites for all events (Tables 3.34

– 3.39). The hypothesis of conditional independence was tested for p = 0.001 with one degree of freedom. For the occurrence of development, N = 67,805 in Fairfax and N = 57,830 in Montgomery. For forest loss, N = 16,685 in Fairfax and N = 6,375 in Montgomery; and for the current forest distribution N = 484,904 in Fairfax and N = 463,369 in Montgomery. Because of these large sample sizes, Cramer's coefficient was again a useful indicator of the level of similarity between map pairs.

For new development (Tables 3.34 and 3.35), agriculture and forest in both counties indicate spatial dependence, but this is expected given that they are mutually exclusive land cover categories. In Fairfax County, there were few other map pairs where Cramer's coefficient exceeded 0.10, but protected land and distance from protected lands are correlated, as are roads distance and distance from the urban center. In Montgomery County, distance from protected lands and distance from the urban core show a strong similarity (V = 0.47), and protected lands distance also shows some similarity with roads distance, slope and agriculture. Not unexpectedly, poorly drained soils are associated with distance from streams and water bodies.

For forest loss in Fairfax County (Table 3.36) only the map pairs roads distance and urban center distance and roads distance and the presence of protected land have Cramer coefficient values that exceed 0.10. In Montgomery County (Table 3.37), the Cramer coefficient indicates correlation when stream distance is paired with water body distance and poorly drained soil, when water body distance is paired with protected land and poorly drained soil, and when protected land is paired with poorly drained soil.

Table 3.34 Fairfax County development χ^2 scores. If the calculated $\chi^2 > 10.83$, then the hypothesis of conditional independence is rejected ($p = 0.001$, $df = 1$, $N = 67805$). Map pairs that violate the conditional independence assumption are highlighted in grey. Cramer's V scores for each map pair are indicated in parentheses. Scores that exceed 0.10 are in bold. Cells with "--" indicate that the factor did not occur within areas of new development.

	Roads Distance	Stream Distance	Water Body Distance	Protected Lands Distance	Slope	Protected Land	Soil	Forest	Agriculture
Urban Center Distance	1303.42 **(0.14)**	--	217.45 (0.06)	297.31 (0.07)	6.63 (0.01)	360.28 (0.07)	66.33 (0.03)	45.58 (0.03)	502.44 (0.09)
Roads Distance		--	1.58 (0.00)	24.04 (0.02)	25.99 (0.02)	397.23 (0.08)	18.54 (0.02)	0.00 (0.00)	178.42 (0.05)
Stream Distance			--	--	--	--	--	--	--
Water Body Distance				21.23 (0.02)	0.04 (0.00)	152.35 (0.05)	1.90 (0.01)	7.74 (0.01)	86.76 (0.04)
Protected Lands Distance					22.95 (0.02)	9306.25 **(0.37)**	2.15 (0.01)	72.94 (0.03)	15.76 (0.02)
Slope						30.61 (0.02)	93.59 (0.04)	13.21 (0.01)	12.57 (0.01)
Protected Land							9.91 (0.01)	166.72 (0.05)	43.18 (0.03)
Soil								4.39 (0.01)	25.74 (0.02)
Forest									3176.21 **(0.22)**

Table 3.35 Montgomery County development χ^2 scores. If the calculated $\chi^2 > 10.83$, then the hypothesis of conditional independence is rejected ($p = 0.001$, df = 1, N = 57830). Map pairs that violate the conditional independence assumption are highlighted in grey. Cramer's V scores for each map pair are indicated in parentheses. Scores that exceed 0.10 are in bold.

	Roads Distance	Stream Distance	Water Body Distance	Protected Lands Distance	Slope	Protected Land	Soil	Forest	Agriculture
Urban Center Distance	10.42 (0.01)	6.43 (0.01)	6.67 (0.01)	13167.22 **(0.47)**	26.33 (0.02)	24.31 (0.02)	62.25 (0.03)	183.19 (0.06)	1473.22 **(0.16)**
Roads Distance		25.11 (0.02)	321.85 (0.07)	2896.24 **(0.22)**	0.63 (0.00)	0.05 (0.00)	497.21 (0.09)	10.24 (0.01)	108.68 (0.04)
Stream Distance			9311.44 (0.04)	2.95 (0.01)	115.70 (0.04)	353.46 (0.08)	2963.11 **(0.23)**	49.18 (0.03)	42.65 (0.03)
Water Body Distance				31.60 (0.02)	19.22 (0.02)	382.86 (0.08)	2188.96 **(0.19)**	12.99 (0.01)	37.95 (0.03)
Protected Lands Distance					1049.12 **(0.11)**	64.67 (0.03)	97.36 (0.04)	158.15 (0.05)	1355.14 **(0.15)**
Slope						31.57 (0.02)	235.94 (0.06)	32.36 (0.02)	13.66 (0.02)
Protected Land							348.22 (0.08)	8.41 (0.01)	45.42 (0.03)
Soil								16.79 (0.02)	112.50 (0.04)
Forest									4439.44 **(0.28)**

Table 3.36 Fairfax County forest loss χ^2 scores. If the calculated $\chi^2 > 10.83$, then the hypothesis of conditional independence is rejected ($p = 0.001$, df = 1, N = 16685). Map pairs that violate the conditional independence assumption are highlighted in grey. Cramer's V scores for each map pair are indicated in parentheses. Scores that exceed 0.10 are in bold. Cells with "--" indicate that the factor did not occur within areas of new development.

	Roads distance	Stream distance	Water body distance	Slope	Protected land	Soil
Urban center distance	1023.40 **(0.25)**	--	13.96 (0.03)	1.69 (0.01)	91.67 (0.07)	6.15 (0.02)
Roads distance		--	1.47 (0.01)	19.29 (0.03)	475.07 **(0.17)**	11.40 (0.03)
Stream distance			--	--	--	--
Water body distance					43.61 (0.05)	11.78 (0.03)
Slope					49.13 (0.05)	21.15 (0.04)
Protected land						31.48 (0.04)

Table 3.37 Montgomery County forest loss χ^2 scores. If the calculated $\chi^2 > 10.83$, then the hypothesis of conditional independence is rejected ($p = 0.001$, df = 1, N = 6375). Map pairs that violate the conditional independence assumption are highlighted in grey. Cramer's V scores for each map pair are indicated in parentheses. Scores that exceed 0.10 are in bold.

	Roads distance	Stream distance	Water body distance	Slope	Protected land	Soil
Urban center distance	11.58 (0.04)	1.29 (0.01)	0.34 (0.01)	0.00 (0.00)	5.96 (0.03)	7.30 (0.03)
Roads distance		0.49 (0.01)	2.95 (0.02)	0.03 (0.00)	3.25 (0.02)	0.85 (0.01)
Stream distance			733.24 **(0.24)**	25.45 (0.06)	65.91 (0.10)	378.75 **(0.24)**
Water body distance				3.17 (0.02)	144.11 **(0.15)**	135.20 **(0.15)**
Slope					6.58 (0.03)	49.39 (0.09)
Protected land						53.21 (0.09)

Table 3.38 Fairfax County forest distribution χ^2 scores. If the calculated $\chi^2 > 10.83$, then the hypothesis of conditional independence is rejected ($p = 0.001$, $df = 1$, $N = 484904$). Map pairs that violate the conditional independence assumption are highlighted in grey. Cramer's V scores for each map pair are indicated in parentheses. Scores that exceed 0.10 are in bold.

	ROADS DISTANCE	STREAM DISTANCE	WATER BODY DISTANCE	SLOPE	PROTECTED LAND	SOIL
URBAN CENTER DISTANCE	3541.01 (0.09)	18814.67 **(0.20)**	27222.02 **(0.24)**	754.22 (0.04)	5357.92 **(0.11)**	310.16 (0.03)
ROADS DISTANCE		23.21 (0.01)	231.74 (0.02)	48.58 (0.01)	9977.87 **(0.14)**	30.33 (0.01)
STREAM DISTANCE			10852.14 **(0.15)**	657.34 (0.04)	2523.77 (0.07)	1618.90 (0.06)
WATER BODY DISTANCE				115.09 (0.02)	1194.36 (0.05)	655.21 (0.04)
SLOPE					3036.18 (0.08)	212.73 (0.02)
PROTECTED LAND						15544.88 **(0.18)**

Table 3.39 Montgomery County forest distribution χ^2 scores. If the calculated $\chi^2 > 10.83$, then the hypothesis of conditional independence is rejected ($p = 0.001$, $df = 1$, $N = 463369$). Map pairs that violate the conditional independence assumption are highlighted in grey. Cramer's V scores for each map pair are indicated in parentheses. Scores that exceed 0.10 are in bold.

	ROADS DISTANCE	STREAM DISTANCE	WATER BODY DISTANCE	SLOPE	PROTECTED LAND	SOIL
URBAN CENTER DISTANCE	202.60 (0.02)	100.33 (0.01)	1568.43 (0.06)	971.22 (0.05)	8366.05 **(0.13)**	788.12 (0.04)
ROADS DISTANCE		485.52 (0.03)	1567.55 (0.06)	163.77 (0.02)	18.34 (0.01)	4686.49 (0.10)
STREAM DISTANCE			3106.24 (0.08)	3201.26 (0.08)	4069.05 (0.09)	369.65 (0.03)
WATER BODY DISTANCE				3106.24 (0.08)	24858.65 **(0.23)**	28389.68 **(0.25)**
SLOPE					4069.05 (0.09)	369.65 (0.03)
PROTECTED LAND						12375.97 **(0.16)**

When considering the current distribution of forest, several map pairs indicate spatial association in Fairfax County (Table 3.38), including when urban center distance is paired with stream and water body distances and protected land. Protected land shows an association with both roads distance and soil. The association between water body distance and stream distance is not unexpected. In Montgomery County (Table 3.39), protected lands show an association with urban center distance, water body distance and poorly drained soils. Soils are also associated with water body distance.

<u>3.4 Discussion and Conclusions</u>

3.4.1 Describing patterns of landscape change

Within the local case study sites, development is the major drive of forest change, although ties to the land use histories of the respective counties can be identified in the present day landscapes. The sites in Virginia, for example, have more forests in the current developed landscapes than those in Montgomery County, while the Montgomery County sites still retain small patches of agricultural land use. In fact, forests in the Montgomery County sites show little change over the time period, with minimal changes in the proportion of the landscapes occupied by forests (Figure 3.8), the largest patch size area (Figure 3.10), or the area weighted mean patch size (Figure 3.11). Because of the dominance of agriculture in the Montgomery County early in the time period, much of the forest cover had already been removed. While forests experienced some fragmentation, as shown by an increase in the number of forest patches (Figure 3.9), the impacts of development on forest patterns were much less dramatic in the Montgomery County sites than in the Fairfax County sites. The Fairfax County sites exhibited prominent losses in forest and increased fragmentation as a result of development, and by the end of the time series many forest pattern metrics in the Fairfax sites resemble those found in the Montgomery County sites. Another aspect that is evident for the local scale studies is the degree of forest fragmentation that occurs when a rural landscape becomes developed. This impact was most evident in the Fairfax sites, although is also apparent in the Montgomery county sites, where forests showed little change otherwise.

At the county scale, Fairfax County retains higher average forest cover within watersheds, as well as more forested land than watersheds in Montgomery County (Figure 3.13). This trend is especially evident in watersheds that have minimal development, and is another indicator of the different land use histories in these counties. As expected, both counties have low forest cover in highly developed watersheds that are close to the urban core. While many of the outlying watersheds have lower mean impervious surface values and less developed land (Figure 3.12), these are the watersheds that have experienced the highest rates of change between 1990 and 2000 (Figure 3.14). Patterns of development-related forest loss, however, show that the remaining forests in the urbanized watersheds close to the urban core are under considerable pressure, particularly in Fairfax County (Figure 3.15).

3.4.2 Weights of evidence analysis

While the weights of evidence analyses for local case study sites are variable across time and space, some general conclusions can be drawn. For example, steep slopes, protected lands, and poorly drained soils tend to constrain development, limit deforestation and enhance forest persistence. At the local sites, stream distance did not show a consistent trend for development or deforestation and the cut-off point was high (>100 meters in most cases) (Tables 3.4 – 3.11). However, most sites exhibited a low likelihood of forest persistence in areas far from streams (Tables 3.12 – 3.15). Forests persistence in general revealed much clearer relationships with the explanatory variables. Forest persistence typically occurred more frequently in the landscape and was less affected by overlay errors, providing a better estimation of prior probabilities and a better description of co-occurrence with the explanatory variables. Although a minor occurrence, overlay errors are a potential source of error when detecting areas of new development or deforestation. Since these events occur less frequently across the landscape, these errors may have confounded the spatial relationships between the events and the explanatory factors.

When evaluating the conditional independence between map pairs for the local study sites, using the Chi-squared statistic alone was not an effective measure of similarity. Because of the large sample sizes, even relatively small differences between the expected and observed frequencies within a contingency table were found to be statistically significant. While the Cramer's V coefficient cannot be used as a test for statistical significance, it provides a simple measure of similarity that is not sensitive to large sample sizes. Among all sites for all change events, Cramer's V seldom exceeded 0.10. However, consistent correlations did emerge between forests, protected lands, and soils. These trends in similarities between map pairs make it difficult to separate the roles of the biophysical variables (slope and soil type) and the presence of protected lands. In many cases, land protection policies, including land acquisition, target environmentally sensitive areas, such as hydric soils or areas of contiguous forest. These areas are also present engineering challenges for development, and may therefore be less likely to undergo development unless development pressures are very high.

At the county scale, the role of the biophysical variables (slope and soil type) and protected lands (a policy variable) generally emerged as expected: steep slopes, poorly drained soils, and the presence of protected lands tend to constrain development, limit deforestation and enhance forest persistence. The relationships between the land cover change events and distance to roads and distance to the urban core, which can be considered proxy economic variables, also show the expected trends: development and forest loss are less likely to happen far from roads or far from the urban core, while forests are more likely to be found in these areas. A strong association between development and amenity landscape features (protected lands and water bodies) was not found. In fact, in Montgomery County, development was more likely in areas far from protected lands and a moderate negative association between development and water body proximity was found in both counties. For stream proximity, which was considered a proxy policy variable, weak negative associations were found between development and forest loss. Stronger relationships were found when considering forest persistence and showed that forests are less likely to persist in areas far from streams. Thus there is supporting evidence for the success of policy measures aimed at protecting riparian forest areas.

When comparing the vulnerability of forests and agriculture to development, both counties show a small positive association between development and agriculture and this association is stronger in Fairfax County. Both counties also exhibit a low to moderate negative association between development and forests and this association is stronger in Montgomery County. The fact that Montgomery County exhibits a low positive association between development and agriculture lands and a moderate negative association between development and forests may indicate the effectiveness of policy measures, including the aggressive agricultural preservation programs and Maryland's Forest Conservation Act (Galvin, et al. 2000).

When comparing map pairs at the county scale, tests for conditional independence often indicated a violation of this assumption. Like the local scale sites, however, sample sizes for the counties were large. The Cramer's V coefficient showed few problems with map correlations for most events. Some correlations were high, but were not consistent between counties or events.

3.4.3 Summary

Quantitative descriptions of landscape change in this study point to several broad conclusions. First, at both the local and county scales, land use histories remain evident in the landscape, even within landscapes that have been intensely developed. At the county scale, ties to the urban core area of Washington, DC – Alexandria – Arlington urban core can be observed, although more recent patterns of development also point to the emergence of commercial and residential centers that are more loosely tied to the urban core. When considering forest patterns, the abundance of forests within landscapes can be linked to land use history, although the occurrence of development produces higher patterns of fragmentation.

The application of the weights of evidence statistical model confirmed many of the hypotheses regarding the role of biophysical variables, such as slope and poorly drained soils, in determining patterns of development, deforestation and forest persistence. At both the local and county scales, the role of the policy variables was also confirmed. Protected lands are a strong policy measure that is associated with forest persistence and current forest distribution, and deforestation rarely happens in these areas. These results also indicate the association between forests and stream proximity, a variable that has strong links to policy. When comparing the vulnerability of forests and agriculture to development, agriculture is more likely to become developed, particularly in Fairfax County, and forests are less likely to be developed in both counties. These results may be tied to policy measures, although within the local case study areas, which present rapidly developing landscapes, the results are less clear, since both forests and agriculture are likely to be developed. Finally, the rate of forest loss in watersheds that are already highly developed indicate that these remaining urban forest patches are under considerable pressure from development.

The weights of evidence model was successful in identifying these relationships in the landscapes. At the local scale, overlay errors that occurred when identifying areas of change may have decreased the effectiveness of the model. For events that were widely distributed across the landscapes, such as forest persistence for the local case study sites and forest distribution at the county scale, the observed relationships were often much clearer than for events that occurred less frequently. The weight values facilitated comparison between the local sites and the counties. Relationships between the events and the explanatory variables were also often revealed by the W- value, indicating that a traditional regression model may have failed to provide equally insightful results. The large sample sizes used in this study confounded the evaluation of conditional independence, since Chi-square tests often revealed similarities between map pairs even if differences between the observed and expected frequencies were relatively small. While the Cramer’s V coefficient provided guidance for identifying serious problems with correlations between map pairs, the use of this coefficient does not provide a valid statistical test.

CHAPTER 4: SYNTHESIS AND CONCLUSIONS

4.1 Linking policies to patterns

One of the principle objectives of this study is to link suburban forest landscape patterns to the socio-cultural framework within which they exist. Dominant social values ascribed to forest resources are institutionalized in land use policies, and the adoption and implementation of these policies can have a direct influence on the landscape. Because of the highly regulated environments found within suburban environments throughout much of the United States, land use policies provide a focal point that can be used to analyze the relationship between culture and the environment. Coupled with a quantitative analysis of landscape changes, the observed patterns of forests can be interpreted in light of land use policies, biophysical and socio-economic factors. While the primary premise for this research rests on social constructivist approaches to cultural landscape interpretation, the use of quantitative spatial analyses provides a basis for linking landscape patterns to the cultural processes that produced them.

The suburban counties of Montgomery County, MD and Fairfax County, VA provided an excellent opportunity to examine the relationship between land use policies and landscape patterns. In many respects, the counties are similar. Both experienced very rapid residential and commercial growth in the decades following World War II, and the populations within these counties are wealthy and well educated. In addition, both Maryland and Virginia are partners in the Chesapeake Bay Program, and have participated in the formation of land use policy goals that are intended to restore the Chesapeake Bay estuary. The counties exist within different institutional frameworks, however. Maryland is a home rule state, which gives local governments implied authority to regulate many aspects of land use that are not specifically addressed in state enabling legislations. Virginia is a Dillon rule state, where local governments must be given explicit authority by the state government to regulate specific aspects of land use. Given these circumstances, it is possible to examine how natural resource values are institutionalized within differing administrative frameworks.

Following a summary of the key findings from the policy and landscape change analyses, this chapter will conclude with a discussion of the future of forests in suburban landscapes.

4.2 Policy findings

The policy analysis presented in Chapter 2 captures the complex interaction of factors influencing policy development, including the broader environmental discourse, interactions between administrative scales, rapid land use change, and differing administrative structures. The policy objectives that emerged through time exhibit a strong link to the broader environmental discourse, reflecting Progressivist ideals early in the time period. In the 1960s and 1970s, the emerging Environmental movement resulted in a proliferation of environmental protection policies. The recent shift to a more holistic ecosystems-based policy orientation is evident, and is due in part to the dominance of the Chesapeake Bay restoration in the regional environmental discourse. That these national scale shifts in environmental attitudes is reflected in policies ranging from the federal to the local level is evidence of the link between socio-cultural values and land use policies.

Despite evidence of a recent shift to more holistic values, the policies indicated a broad institutional focus on the role of forests in protecting and enhancing water quality, particularly in recent decades. For example, one of the primary policy objectives at the state level is the development and implementation of best management practices (BMPs) that focus on the protection or creation of vegetated riparian buffers, for both agricultural and developed land use activities, in order to mitigate erosion and non-point source pollution. This institutional focus on water quality issues is likely not unique to this area due to the importance of water for sustaining human activities and federal mandates to protect water resources, including the Clean Water Act (U.S. Environmental Protection Agency 2002) and the establishment of total maximum daily loads (TMDLs) for pollution in streams and water bodies (U.S. Environmental Protection Agency 1991). The focus on Chesapeake Bay restoration is, however, unique and this theme was prominent in the environmental discourse in Maryland and Virginia. While others have discussed some of the political obstacles facing Chesapeake Bay restoration (Ernst 2003; Horton 2003), this research demonstrates that efforts by the Chesapeake Bay Foundation, Chesapeake Bay Program and other groups to raise public awareness and support for restoration activities have been successful. This provides ready public support for the formation and prioritization of environmental policies that target Chesapeake Bay restoration. In Maryland, for example, the governor recently committed to coordinate all state land acquisition programs to target Bay restoration goals (Maryland Department of Natural Resources 2003b).

Because of the national and regional focus on water quality issues and the dominance of Chesapeake Bay restoration in the regional environmental discourse, policies and programs that focus on alternative values for forests are less dominant. State and local programs focusing on urban forestry initiatives, for example, occur less frequently. Maryland's Forest Conservation Act (Galvin, et al. 2000) is one notable exception to this, providing a statewide requirement to mitigate development-related deforestation activities. Likewise, Fairfax County recently adopted minimum tree cover requirements into the subdivision regulations. There are other examples that demonstrate the institutionalization of alternative values, such as the county-level park fund programs. These funds allow private citizens to make financial contributions to the county park systems; some contributions can be made in memoriam. While these local policies reflect the presence of alternative values, the ecological role of forests for water quality protection is the overarching dominant institutional value.

The comparison of policy approaches revealed differences in administrative scale, and also differences between the states of Maryland and Virginia. At the state and federal level, non-regulatory approaches are more common than regulatory approaches, primarily as a result of the creation of enabling legislation, tax incentives, and funding mechanisms that are made available at lower levels of government. At the county scale, regulatory approaches become more common. This reflects the response of the counties to local land use issues, and the implementation of policies that are optional or mandated at the state level. Both Maryland and Montgomery County have more regulatory policies than Virginia and Fairfax County, and that Virginia and Fairfax County have a higher frequency of policies and organizations that focus on outreach, education and decision support. These differences can be related to the institutional histories in the two states, where Maryland has emphasized a regulatory approach while Virginia has favored non-regulatory or incentive-based programs to protect private property rights.

4.3 Landscape changes

The landscape change analysis illustrated the rapid shift in land use that occurred in Montgomery County, MD and Fairfax County, VA. Over a few decades, both counties shifted from predominantly rural land uses to the present-day intensely developed residential and commercial landscapes. The land use history of the two counties is apparent, however, as evidenced in differences in forest cover. Within the local case study areas, the two sites in Fairfax County retained more forest cover despite reaching similar levels of development intensity as the sites in Montgomery County. Likewise, the sites in Montgomery County have retained small areas of agricultural land uses. At the county scale, watersheds within Fairfax County are more forested than those in Montgomery County. The local case studies also demonstrate the high degree of forest fragmentation that occurs with development. In Rockville, MD, for example, the total area of forest does not vary significantly throughout the time series, but the forests become patchier as development occurs.

The statistical analysis of land cover change using the weights of evidence technique quantified many of the interactions between the physical environment, economic factors, and land use policy factors. In this case, the biophysical variables, including steep slopes and poorly drained soils, were consistently associated with low development probabilities and high likelihoods of forest persistence or forest presence. Proximity to the urban core and proximity to roads enabled development and facilitated deforestation in these areas. Protected lands were effective in preventing development and enhancing forest persistence. There is also evidence, particularly at the county scale, that development does not occur near streams and that forests are more likely to be found in riparian areas.

4.4 Synthesis: landscape-policy linkages and the future of suburban forests

The patterns observed in the landscape change analysis, particularly the results related to the role of parks and riparian areas in enhancing forest persistence, represent a link between policy factors and forest patterns in suburban environments. Within the counties, land protections through parks and easements programs were found to be strong predictors of forest persistence or occurrence. This represents a strong policy element related to forest preservation, although land acquisition is an expensive policy tool particularly given the competitive housing markets in the Washington, DC region.

In both counties, forests were found to be associated with riparian areas, indicating the success of policies aimed at protecting water quality through the establishment and maintenance of vegetated riparian buffers. Within the counties, policies protecting riparian areas are primarily regulatory in approach. In Fairfax County, erosion and sediment control regulations that have been in place since 1982 require protection of vegetated areas, and the Chesapeake Bay Preservation Ordinance, enacted in 1993, requires a 100 foot buffer around tidal wetlands, tidal shores, some non-tidal wetlands, and perennial streams. In Montgomery County, subdivision regulations in place since 1979 protect environmentally sensitive areas, including critical wildlife habitat, steep slopes or erodable soils, wetlands, perennial and intermittent streams, and stream buffers. Maryland’s Non-tidal Wetland Act, established in 1989, limits development within a 25 feet vegetated buffer around non-tidal wetlands greater than 5000 square feet.

Both counties also have regulatory and non-regulatory policies related to general forest preservation. In Fairfax County, cluster development is permitted to allow for the preservation of forest and open space, and the subdivision regulations allow the Director of Public Works and Environmental Services to require the dedication of up to ten percent of a proposed subdivision to the county for recreational purposes. Fairfax County has also incorporated tree cover requirements into the subdivision regulations, as allowed by 1989 state enabling legislation. In Montgomery County, the state's 1991 Forest Conservation Law led to the adoption of the Montgomery County Forest Conservation Law in 1992, which requires that existing trees are preserved wherever possible and that planting of trees occurs to compensate for unavoidable loss. This law also established a tree fund where reforestation funds are paid if a developer cannot remediate on-site. The effects of these policies are reflected in the mildly to moderately strong negative values for W+ when considering the occurrence of development on forested lands between 1990 and 2000 at the county scale (W+ = -0.30 in Fairfax County, see Table 3.28; W+ = -0.60 in Montgomery County, see Table 3.29).

Given trends in land cover change and land use policies, and the relationships between them, the future of suburban forests can be evaluated. First, recent changes show that the rate of development in outlying areas is outpacing development rates in watersheds close to the urban core. As developable land near the urban core decreases, it is not unexpected that outlying areas will begin to experience development pressure. Between 1990 and 2000, for example, some of the highest rates of development-related deforestation in the Chesapeake Bay region occurred in the counties just beyond Fairfax and Montgomery (Jantz, et al. In press). Although largely beyond the scope of this research, development driven deforestation may become more widespread as the regional population grows unless demands for suburban housing diminish significantly or low impact development techniques become more widely adopted.

Second, forests within highly developed areas may continue to decline, especially in non-riparian areas or in areas that are not defined as being environmentally sensitive. Although moderate effects of the general protection of forest cover within the counties are evident, as noted above, the association between existing forests and riparian areas is evident, as shown in the negative and positive weight values for forest presence and stream proximity (Tables 3.32 and 3.33). Development between 1990 and 2000 was more likely to occur close to the urban core, indicating that development pressures still exist in these intensely developed areas (Tables 3.28 and 3.29).

In Montgomery and Fairfax counties, development pressure on existing forested lands can be visualized using a probability map for development likelihood generated from the weights of evidence analysis presented in Chapter 4 (Figure 4.1). The extent of forests in 2000 was overlaid with this development probability map to highlight unprotected forests that exist in areas of high development pressure (Figure 4.2).

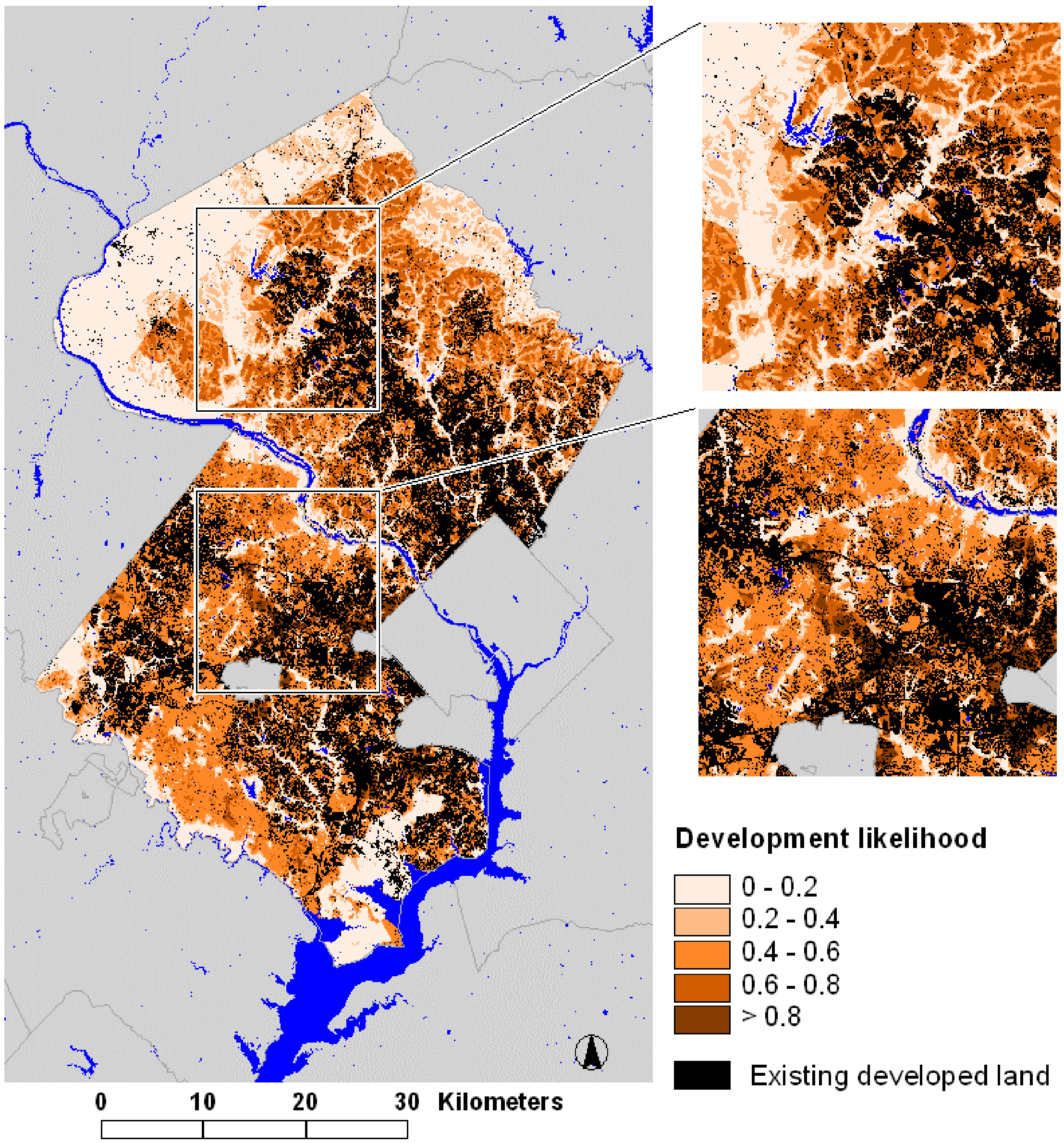


Figure 4.1 The likelihood of development occurring within Montgomery and Fairfax counties, as modeled with the weights of evidence method.

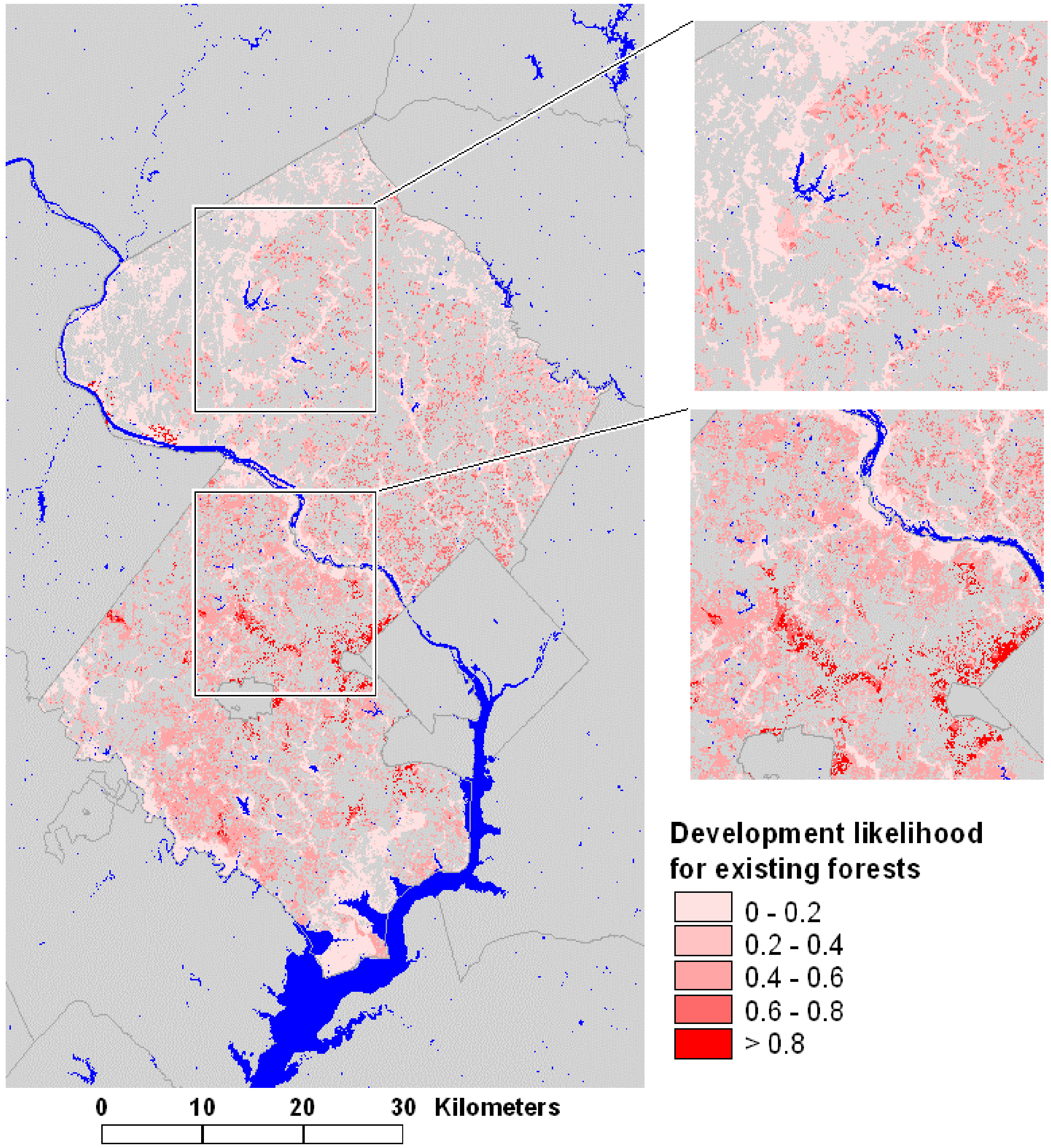


Figure 4.2 The likelihood of forest loss due to development within Montgomery and Fairfax counties, based on the development likelihoods shown in Figure 4.1.

The probability map represents the final step of the weights of evidence method as described in section 3.2.2 of the previous chapter, where the logit weight values for each predictive variables are combined with the prior logit to calculate the posterior logit (Equation 3.16). The posterior logit was converted to posterior probabilities by calculating the base *e* exponential of the posterior logit, and then reversing the odds formulation equation, as shown in Equation 3.17. To minimize violations of the conditional independence assumption (Tables 3.34 and 3.35), proximity to protected lands was eliminated from the model for both counties. Because of the lack of conditional independence between forest and agriculture, the variable with the strongest explanatory power in each county was used in the model. In Fairfax County, agriculture was included, and in Montgomery County, forest was included. Table 4.1 summarizes the variables and corresponding positive and negative weight values that were incorporated into the final weights of evidence models for each county.

The above maps of development likelihood can be considered to be a map of development *potential* based on observed patterns of development between 1990 and 2000. Given this assumption, caution must be used when considering these development probabilities in a predictive sense. However, many of the smaller patches of forests within highly developed areas have a higher likelihood of development. In Montgomery County, unprotected forests southwest and northeast of the central development corridor also exhibit moderate levels of development pressure, as does the contiguous forest land that currently exists in central Fairfax County. Riparian forests, however, are associated with lower development probabilities, again illustrating the success of riparian forest policies in these two counties.

Table 4.1 Variables and corresponding weight values used to model development likelihood in Montgomery and Fairfax counties.

	Fairfax County		Montgomery County	
Factor	W+	W-	W+	W-
SLOPE	0.01	-1.52	0.03	-1.77
STREAM DISTANCE	-0.25	0.16	-0.35	0.20
WATER BODY DISTANCE	-0.19	1.01	-0.52	0.05
DISTANCE FROM URBAN CENTER	0.02	-0.42	0.16	-1.26
ROADS DISTANCE	0.03	-1.54	0.02	-2.14
PROTECTED LANDS	-1.36	0.16	-1.13	0.10
SOIL	-0.01	0.00	-0.99	-0.19
FOREST	NA	NA	-0.64	0.12
AGRICULTURE	0.48	-0.05	NA	NA

These patterns have implications for urban and suburban quality of life. While these remnant forest patches within highly developed areas may have a limited ecological value (Forman 1999), they are important social resources, enhancing urban microclimate and decreasing infrastructure costs associated with storm water management (Cooksey and Todd 1996), providing residents with contact with nature (Kaplan 1983), and enhancement of urban and suburban viewscapes (Stamps 1997). Trees and forests can provide an important spiritual and symbolic aspect to the suburban landscape (Dwyer, et al. 1991), and can also provide permeability for pedestrians and wildlife to move through and between neighborhoods (Matlack 1993; Gobster 1995). While these values appear in recent policies, they tend to occur as voluntary guidelines, for example in cluster or low impact development guidelines, or as special voluntary programs, such as the county park funds. In areas where new development is occurring more frequently, the landscape patterns observed in the study counties will be reproduced unless cultural values and policy orientations shift.

Furthermore, it is also clear that, despite the multiple policies directed toward water quality protection, water quality within the Chesapeake Bay remains compromised (Ernst 2003; Horton 2003). While the success of riparian protections can be documented in Montgomery and Fairfax counties, rapid development occurring throughout the watershed and the failure to adequately manage non-point source pollution from agricultural lands is offsetting many of the gains made (Ernst 2003; Goetz, et al. 2004). Land use policy represents one approach for addressing these issues, but the link between policy development and socio-cultural values indicates that urban forestry and ecosystem restoration must be more broadly valued in environmental attitudes occur before these policies can be successfully implemented.

Given the differences between Maryland's and Virginia's regulatory frameworks, the capacity of local governments to address issues related to urban forestry and Chesapeake Bay restoration can be evaluated. Because most landscape differences documented in this research can be linked to land use history rather than policies, this study is not able to address the question of the relative success of regulatory or non-regulatory approaches. Hawks, et al. (1993) argue that voluntary approaches for forestry activities can be equally successful in terms of landowner participation, provided that they are vigorously promoted. These authors also suggest that voluntary approaches are more cost-effective and carry a lower bureaucratic burden for landowners. In rapidly suburbanizing landscapes, however, regulatory approaches are necessarily more prevalent. In Virginia, the Dillon rule administrative framework may prevent county or municipal governments from responding to local land use issues related to rapid development with appropriate regulatory action. In Fairfax County, repeated litigation over local land use control indicates an adversarial relationship between the local and state government and fosters the perception that state decision-makers value economic development over local environmental and quality of life issues.

4.6 Future research directions

This research has documented the relationships between land use policies and forest patterns within developed landscapes in Montgomery County, MD and Fairfax County, VA, illustrating how cultural values can become integrated into a landscape. It has also explored the administrative frameworks within which the suburban landscapes are situated. While many of the results are compelling, they raise additional questions that point to future research directions.

First, this study has focused primarily on Maryland and Virginia, where Chesapeake Bay restoration was found to be a dominant theme in the environmental discourse. Will this be the case in states that have a less direct connection to the estuary? Pennsylvania, for example, is also a Chesapeake Bay Program partner, and land use activities in this state have a strong influence on water quality within the estuary due to the large drainage area associated with the Susquehanna River. However, Pennsylvania does not have a direct geographic connection to the Chesapeake Bay. What is the status of Chesapeake Bay restoration in the environmental discourse of Pennsylvania, or in states such as New York and Delaware, which are not CBP partners? In terms of assessing the long-term success of Chesapeake Bay restoration activities, these are questions worth pursuing.

Second, this research points to the differences in approaches between levels of governments and between states with different regulatory structures. In the suburban counties in this study, many of the policies influencing forest patterns were regulatory, so these areas may not be appropriate for pursuing a comparison of regulatory and non-regulatory approaches. However, given that Pennsylvania's approach to land use management is more closely allied with Virginia, this would be another area of research relevant to Chesapeake Bay restoration, particularly for agricultural land use practices.

The fact that forests within highly developed environments continue to experience pressure from development, coupled with the relatively weak role of urban forestry policies, emphasizes the recommendations made by Lammers and Knapp (1999) and American Forests (1999), which include broader monitoring efforts of urban forests, a stronger commitment by county staff to place a greater emphasis on tree preservation, a planning vision that emphasizes urban forestry, and broad public participation. This latter point cannot be overemphasized given the findings presented in this research. Raising the intensity of urban forestry issues in the broader public discourse is a key component for the successful adoption of these values into policies. An investigation of successful urban forestry initiatives would provide useful insights for incorporating these elements into the broader discourse.

Finally, the weights of evidence technique was found to be an effective means to compare the explanatory power of multiple variables between many different sites. Similar comparisons could be made with traditional regression techniques, but in several instances the relationships between the predictive factor and the event under consideration became evident in the values for W-. These negative relationships are not as clearly identified using traditional regression techniques (Felicisimo, et al. 2002). Because of the large sample size, evaluating the assumption of conditional independence was difficult. Statistical tests using the Chi-square distribution frequently showed a significant difference between the observed and expected frequencies even if the actual differences were small. The Cramer's V statistic was a useful indicator, although not a definitive measure of conditional independence. To better understand the utility of this approach, however, it would be beneficial to conduct a comparative analysis that would evaluate multiple techniques, including weights of evidence, logistic regression and geographically weighted regression, applied to the same area and using the same set of variables.

APPENDIX A: POLICY DATABASE

Federal, state and county policies are presented separately, in chronological order. For each policy, the year, a description, the objective, the approach and the source, website and/or state or county code reference are given.

A.1 Federal Policies

Division of Forestry (US Department of Agriculture (USDA))

Year: 1881

Description: The Division was the precursor to the US Forest Service, and its mission was information and scientific experimentation. The first timber reserve was established in 1891 and in 1901 the Division became the US Forest Service with Gifford Pinchot as the first Chief Forester.

Objective: Forest management

Approach: Regulatory

Website: Forest History Society, U.S. Forest Service History. http://www.lib.duke.edu/forest/Research/usfscoll/index.html

Federal Estate Tax (Internal Revenue Service (IRS))

Year:1916

Description: Federal estate taxes can force the liquidation of forest lands to meet estate tax obligations. Conveyance of a conservation easement can reduce the tax burden. A 1997 provision to the law allows addition exclusion of land from taxation if the land is located with a metropolitan statistical area (MSA), within 25 miles of a MSA, or within 10 miles of a national urban park.

Objective: Land conservation

Approach: Non-regulatory tax incentive

Source: McElfish and Wilkonson (2000)

Website: U.S. Department of the Treasures, History of Taxes. http://www.ustreas.gov/education/faq/taxes/history.html

The Clean Water Act (Environmental Protection Agency and the Army Corps of Engineers (Section 404))

Year: 1972

Description: Addresses pollution caused by storm water runoff, discharge and wetland loss. Section 208 required all states to developed regulatory or non-regulatory programs to control non-point source pollution, which entailed developing BMPs for all major land uses and an implementation plan. Section 404 regulates the disposal of dredge or fill materials in waters and wetlands.

Objective: Water quality

Approach: Regulatory
Website: Environmental Protection Agency, Clean Water Act.
http://www.epa.gov/region5/water/cwa.htm

Forestry Incentives Program (Natural Resource Conservation Service (NRCS))
Year: 1978 (de-authorized in the 2002 Farm Bill)
Description: The FIP provided cost share assistance to land owners for site preparation, tree planting and improvement of tree stands by thinning and release. The cost share rate was 40% for pine and65% for hardwoods, and the minimum acreage was one acre. The cost share included wetlands and riparian areas on private, non-industrial forestland.
Objective: Forest management
Approach: Non-regulatory cost share
Website: NRCS, Forestry Incentives Program.
http://www.nrcs.usda.gov/programs/fip/
Virginia Department of Forestry, Riparian cost-Share Programs.
http://www.vdof.org/rfb/rwg/costshare.htm

Reforestation Tax Credit (IRS)
Year: 1980
Description: Provides an income tax credit of 10% of the expenses incurred from reforestation.
Objective: Forest management
Approach: Non-regulatory income tax credit
Source: McElfish and Wilkonson (2000)
Website: Internal Revenue Service, Farmer’s Tax Guide.
http://www.irs.gov/publications/p225/

Conservation Reserve Program (USDA)
Year: 1985
Description: Landowners agree to convert highly erodable and environmentally sensitive lands to vegetative cover. They receive rental payments and a cost share.
Objective: Environmental protection
Approach: Non-regulatory cost share
Source: McElfish and Wilkonson (2000)
Website: USDA Farm Service Agency, Conservation Reserve Program.
http://www.fsa.usda.gov/dafp/cepd/crp.htm

Urban and Community Forestry Program (USFS)
Year: 1990 (Farm Bill)
Description: Provides state matching funds for urban and community forest programs and authorized the formation of urban and community forest councils.
Objective: Urban forestry
Approach: Non-regulatory cost share

Website: USFS, Urban and Community Forestry. http://www.fs.fed.us/ucf/

Forest Stewardship Program (US Forest Service (USFS))
Year: 1990 (Farm Bill)
Description: Provides fund and technical assistance for the development of Forest Stewardship Plans to manage private forests for timber, wildlife, watershed management, and recreational uses.
Objective: Forest management
Approach: Non-regulatory cost share and technical assistance
Source: McElfish and Wilkonson (2000)
Website: Pinchot Institute for Conservation, History of Forestry in the Farm Bill. http://www.pinchot.org/pic/farmbill/History.html

Stewardship Incentives Program (USFS)
Year: 1990 (Farm Bill, de-authorized in 2002 Farm Bill)
Description: Cost share for non-industrial private land owners to develop and implement a Forest Stewardship Plan. Unfunded since 1999.
Objective: Forest management
Approach: Non-regulatory cost share
Source: McElfish and Wilkonson (2000)
Website: USFS, Forest Stewardship Program. http://www.fs.fed.us/spf/coop/programs/loa/fsp.shtml

Forest Legacy Program (USFS)
Year: 1990 (Farm Bill)
State forestry agencies can acquire easements or purchase private in tact forest lands. They can also restrict development and require sustainable forestry practices. States must establish Forest Stewardship Coordinating Committee to identify Forest Legacy areas, and private landowners must prepare a Stewardship Management Plan.
Objective: Forest conservation
Approach: Acquisition
Source: McElfish and Wilkonson (2000)
Website: USFS, Forest Legacy Program. http://www.fs.fed.us/spf/coop/programs/loa/flp.shtml

Livable Communities Initiative (Federal Transit Administration (FTA))
Year: 1994
Description: Transit operators, metropolitan planning organizations, city and county governments, state planning agencies and other public bodies can apply for funds, which can be used for property acquisition or improvements, including redevelopment.
Objective: Acquisition
Approach: Grants
Website: FTA, Livable Communities Initiative. http://www.fta.dot.gov/library/planning/livbro.html

Conservation Reserve Enhancement Program (USDA)

Year: 1996

Description: State cost share to target specific geographic areas or natural resources.

Objective: Land conservation

Approach: Cost share

Source: McElfish and Wilkonson (2000)

Website: USDA Farm Service Agency, Conservation Reserve Enhancement Program. http://www.fsa.usda.gov/dafp/cepd/crep.htm

Environmental Quality Incentives Program (NRCS)

Year: 2002

Description: Cost share to develop and implement conservation practices, including vegetative riparian buffer strips, with a focus on improving water quality on rangeland.

Objective: BMPs

Approach: Non-regulatory cost share

Website: NRCS, Environmental Quality Incentives Program. http://www.nrcs.usda.gov/programs/eqip/

Forestland Enhancement Program (USFS)

Year: 2002 (Farm Bill, all funds cancelled in 2005 budget)

Description: This program replaced the Forest Incentive Program and the Stewardship Incentive Program. State participation is optional. This is a voluntary program for non-industrial forest land owners and provides technical, educational and cost share assistance to promote forest sustainability.

Objective: Forest management

Approach: Non-regulatory cost share

Website: USFS. Forestland Enhancement Program. http://www.fs.fed.us/spf/coop/programs/loa/flep.shtml

Healthy Forests Initiative (USFS)

Year: 2003

Description: Controversial presidential initiative intended to promote forest management practices, including thinning of forests and forest understories, that would prevent catastrophic forest fires.

Objective: Forest management

Approach: Regulatory on federal lands

Website: USFS, The Healthy Forests Initiative and Health Forests Restoration Act Interim Field Guide. http://www.fs.fed.us/projects/hfi/field-guide/web/toc.php

Conservation and Reinvestment Act

Year: Passed House of Representatives in 2000, but was never brought before the Senate

Description: Provide a dedicated source of funding for the federal Land and Water Conservation Fund and assist states in land acquisition

Objective: Land acquisition

Approach: Land acquisition

Website: North Carolina Conservation News, What's Happening with the Conservation and Reinvestment Act (CARA)? http://www.ncwildlife.org/pg07_WildlifeSpeciesCon/pg7d1.htm

A.2 Regional Policies

1924 Governors' meeting

Year: 1924

Description: Governors of Maryland and Virginia met to discuss management needs of the blue crab fishery. No formal agreements were made.

Objective: Fisheries management

Approach: Decision support

Source: Ernst (2003)

Chesapeake Biological Lab

Year: 1925

Description: A research land established to investigate the conditions of the Bay resources.

Objective: Research

Approach: Decision support, education

Source: Horton (2003)

Website: University of Maryland Center for Environmental Science, Chesapeake Biological Laboratory. http://www.cbl.umces.edu/

Chesapeake Bay Foundation

Year: 1967

Description: Non-profit environmental advocacy group, focused on promoting Chesapeake Bay restoration.

Objective: Education, outreach and advocacy

Approach: Outreach, education, decision support

Source: Horton (2003)

Website: The Chesapeake Bay Foundation, Save the Bay. http://www.cbf.org

Chesapeake Bay Commission

Year: 1980

Description: A tri-state legislative commission that advises the members of the General Assemblies of Maryland, Virginia, and Pennsylvania on matters of Chesapeake Bay restoration.

Objective: Chesapeake Bay restoration

Approach: Decision support
Source: Horton (2003)
Website: Chesapeake Bay Commission, a Tri-state Advisory Commission Serving Maryland, Pennsylvania and Virginia. http://www.chesbay.state.va.us/home.htm

1979 Chesapeake Bay Agreement
Year: 1979
Description: An agreement between Maryland and Virginia to cooperatively manage the Chesapeake Bay resources.
Objective: Chesapeake Bay restoration and management
Approach: Decision support
Source: Horton (2003)

The Chesapeake Bay Program (CBP)
Year: 1983
Description: A regional watershed restoration partnership, consisting of the states of Maryland, Virginia, and Pennsylvania, the District of Columbia, the Chesapeake Bay Commission, the Environmental Protection Agency and citizen advisory groups. The CBP coordinates regional restoration efforts.
Objective: Chesapeake Bay restoration and management
Approach: Decision support
Source: Horton (2003)
Website: The Chesapeake Bay Program. http://www.chesapeakebay.net/

1983 Chesapeake Bay Agreement
Year: 1983
Description: The second Bay Agreement included Maryland, Virginia, Pennsylvania and the District of Columbia in regional Bay restoration and management. Restoration and management goals focused primarily on point-source pollution reduction.
Objective: Chesapeake Bay restoration and management
Approach: Decision support
Source: Horton (2003)
Website: The Chesapeake Bay Program, Chesapeake Bay History. http://www.chesapeakebay.net/history.htm

Chesapeake 2000
Year: 2000
Description: The third and most recent Chesapeake Bay agreement sets new restoration and management goals. Many of these new goals focus on non-point source pollution sources and land use issues.
Objective: Chesapeake Bay restoration and management
Approach: Decision support
Website: The Chesapeake Bay Program, Chesapeake 2000 Agreement. http://www.chesapeakebay.net/c2k.htm

A.3 State Policies in Maryland

General Forestry Acts of 1906

Year: 1906

Description: This legislation established the State board of Forestry, now the Dept. of Natural Resources (DNR) Forest Service. The initial objectives were concerned with information, such as the completion of the first comprehensive forest survey, and fire prevention.

Objective: Forest management

Approach: Regulatory

Source: Besley (1916)

Website: Maryland DNR, A Brief History of the Forest Service. http://www.dnr.state.md.us/forests/aghistory.html

Patapsco Reserve Acts of 1912

Year: 1912

Description: Empowered the State Board of Forestry to purchase land within the watershed of the Patapsco River to create a State Forest Reserve.

Objective: Land acquisition

Approach: Land acquisition

Source: Besley (1916)

State nurseries (DNR)

Year: 1914

Description: Established a state nursery to provide planting stock for Maryland forests.

Objective: Tree planting

Approach: Non-regulatory

Source: Besley (1916)

Roadside Tree Law (DNR)

Year: 1914

Description: Requires permits for work on roadside or street trees. Permits granted for tree removal usually require replanting.

Objective: Tree planting, tree conservation

Approach: Regulatory

Source: McElfish and Wilkonson (2000)

Website: Maryland DNR, Tree Laws. http://www.dnr.state.md.us/forests/treelaws.asp

Maryland State Code: Natural Resources, Title 5 (Forests and Parks), Subtitle 4 (Trees and Forest Nurseries)

Forest Conservancy District Law

Year: 1943

Description: This legislation authorized the Commission of State Forests and Parks to establish rules and regulations of forest practices in private land. It also created local forestry boards, charged with implementing these regulations in the field. The legislation emphasized that commercially cut timber lands must be left in a state where they can regenerate, and young growth and seed trees should be retained. It requires an inspection by the local forestry board 30 days prior to cutting, and also requires that any person engaged in the forest products industry, including loggers, sawmill operators and professional foresters, obtain a license.

Objective: Forest management

Approach: Regulatory

Source: McElfish and Wilkonson (2000)

Website: Maryland DNR, Tree Laws. http://www.dnr.state.md.us/forests/treelaws.asp

Maryland Code: Natural Resources, Title 5 (Forests and Parks), Subtitle 6 (Forest Conservancy Districts)

Open space tax credits

Year: 1957

Description: State enabling legislation that allowed counties to designate tax credits on "open space" land. Counties can define functional or geographical categories of open space, including woodland.

Objective: Open space preservation

Approach: Non-regulatory property tax credits

Source: McElfish and Wilkonson (2000)

Maryland Code: Tax Property, Title 9. (Property Tax Credits and Property Tax Relief), Subtitle 2 (Statewide optional)

Maryland Environmental Trust (MET)

Year: 1957

Description: Quasi-governmental land trust under the umbrella of the DNR, formed to protect farmland, forest, wildlife, waterfront areas, natural areas and historic sites. Funding for easement acquisition comes from Program Open Space, state highway funds and the general fund.

Objective: Land conservation

Approach: Non-regulatory land trust

Source: McElfish and Wilkonson (2000)

Website: Maryland DNR, Maryland Environmental Trust. http://www.dnr.state.md.us/met/

Easement tax credits

Year: 1957

Description: Provides a 100% property tax credit for donations of conservation easements, of at least 15 years, to MET.

Objective: Land conservation

Approach: Non-regulatory easement tax credit

Source: McElfish and Wilkonson (2000)

Website: Maryland Environmental Trust, State Income Tax Credit. http://www.dnr.state.md.us/met/sitc.html

Grading and Clearing Law (Maryland Department of Environment (MDE))

Year: 1957

Description: Requires that counties prepare a sediment control plan for soil conservation district review and approval and requires counties to issue permits for grading and clearing. This legislation established streamside management zones where forested buffers are retained. No landings or haul roads are permitted in the buffer. This law applies to logging operations greater than 5,000 square feet and requires a 50 foot forested buffer at 0% grade, with an additional 4 feet for every 1% increase in grade.

Objective: Water quality

Approach: Regulatory

Source: McElfish and Wilkonson (2000)

Maryland Code: Environment, Title 4 (Water Management), Subtitle 1 (Sediment Control)

Forest Conservation and Management Plan Program (DNR)

Year: 1957

Description: Landowners can obtain a tax assessment reduction of 50% based on active forest use. Owners of 5 or more contiguous acres can apply for reducing or freezing the property tax assessment under a Forest Conservation Management Agreement, which stipulates that the land will not be developed for non-forest uses. Owners must prepare a forest management plan, and the agreement duration is 15 years.

Objective: Forest management

Approach: Non-regulatory property tax incentive

Source: McElfish and Wilkonson (2000)

Website: Maryland DNR, Forest Conservation and Management Program. http://www.dnr.state.md.us/forests/programapps/fcmp.html

Maryland Code: Tax Property, Title 8 (Valuation and Assessment), Subtitle 2 (Assessment procedures)

Program Open Space (DNR)

Year: 1969

Description: Provides a state-level dedicated funding source for land acquisition. This program also provides grants to local governments, MET, and the Maryland Agricultural Land Preservation Foundation (MALPF) in support of land acquisition efforts.

Objective: Land acquisition

Approach: Land acquisition

Source: McElfish and Wilkonson (2000)

Website: Maryland DNR, Program Open Space. http://www.dnr.state.md.us/pos.asp

Maryland Comprehensive Land Use Planning Act

Year: 1969

Description: Required all counties to develop and adopt master plans.

Objective: Planning

Approach: Regulatory

Maryland Code: Article 66B Land Use, General Development Regulations and Zoning

Maryland Agricultural Land Preservation Foundation (MALPF)

Year: 1974

Description: Landowners agree to maintain agricultural land use for at least 5 years, and not to subdivide or otherwise develop the land. Participants can apply to sell an agricultural easement to MALPF.

Objective: Farmland preservation

Approach: Non-regulatory

Source: McElfish and Wilkonson (2000)

Website: Maryland Agricultural Land Preservation Foundation, http://www.malpf.info/

Maryland Code: Agriculture, Title 2 (Department of Agriculture), Subtitle 5, Maryland Agricultural Land Preservation Foundation

Agricultural use tax credits

Year: 1977

Description: State enabling legislation that allowed counties to give property tax credits for land enrolled in an agricultural land preservation district (MALPF).

Objective: Farmland preservation

Approach: Non-regulatory property tax credit

Source: McElfish and Wilkonson (2000)

Website: MALPF, Fact Sheets about Maryland's Agricultural Land Preservation Program. http://www.malpf.info/facts.html

Maryland Code: Agriculture, Title 2 (Department of Agriculture), Subtitle 5, Maryland Agricultural Land Preservation Foundation

Pine Tree Reforestation Act (Maryland Seed Tree Law (DNR)

Year: 1977

Description: Requires landowners to reforest loblolly, shortleaf and pond pines after harvest. These trees cannot be removed from areas of 5 or more acres unless seed trees have been reserved or a reforestation plan has been approved.

Objective: Forest management

Approach: Regulatory

Source: McElfish and Wilkonson (2000)

Website: Maryland DNR, Maryland Seed Tree Law. http://www.dnr.state.md.us/forests/programapps/treelaw.html

Maryland Code: Natural Resource, Title 5 (Forests and Parks), Subtitle 5 (Pine Tree Reforestation)

Agricultural Water Quality Cost Share (Maryland Dept. of Agriculture)

Year: 1982

Description: Provides up to 87.5% cost share for agricultural water quality programs, including the cost of installing BMPs, such as riparian buffers, stream fencing and alternative watering sources.

Objective: Water quality

Approach: Non-regulatory cost share

Source: McElfish and Wilkonson (2000)

Website: University of Maryland College of Agriculture and Natural Resources, A Citizen's Guide to the Water Quality Improvement Act of 1998. http://www.agnr.umd.edu/waterquality/CitizWQ.html

Maryland Code: Agriculture, Title 8 (Soil Conservation), Subtitle 7 (Cost Sharing, Water Pollution Control)

Urban and Community Forest Program (DNR)

Year: 1984

Description: Provides matching funds and technical support for county or municipal governments to implement an urban and community forest program. Local governments are authorized to implement a program by adopting a resolution or ordinance, or by entering into a cooperative agreement with the DNR. The tree cover goal for urban and community forest programs is 40%.

Objective: Urban forestry

Approach: Non-regulatory matching funds

Source: McElfish and Wilkonson (2000)

Website: Maryland DNR, Urban and Community Forestry. http://www.dnr.state.md.us/forests/programs/urban/

Maryland Code: Natural Resource, Title 5 (Forests and Parks), Subtitle 4 (Trees and Forest Nurseries)

Chesapeake Bay Critical Areas Act

Year: 1984

Description: Limits activity in proximity to the Chesapeake Bay and its tributaries. This act mandated that counties develop a critical areas program that requires timber harvests occurring within 1,000 feet of tidal waters to be conducted according to a timber harvest plan. Development activity within 1,000 feet of tidal waters is restricted. This act requires the establishment of a 100 foot vegetated buffer around tidal waters, within which impervious surface cover cannot exceed 15%.

Objective: Water quality

Approach: Regulatory

Source: McElfish and Wilkonson (2000)

Website: Maryland DNR, Critical Area Commission – Frequently Asked Questions. http://www.dnr.state.md.us/criticalarea/faq.html

Chesapeake Bay Trust

Year: 1985

Description: Provides financial support for Bay restoration and education projects, including buffer plantings, tree plantings and educational activities.

Objective: Chesapeake Bay restoration

Approach: Non-regulatory grants

Source: McElfish and Wilkonson (2000)

Website: Chesapeake Bay Trust. http://www.chesapeakebaytrust.org/

Maryland Code: Natural Resource, Title 8 (Waters), Subtitle 19 (Chesapeake Bay Trust)

Woodland Incentives Program (DNR)

Year: 1986

Description: A cost share program that funds tree planting, site preparation, and timber stand improvements for properties 10 – 500 acres in size that have the potential to be harvested.

Objective: Forest management

Approach: Non-regulatory cost share

Source: McElfish and Wilkonson (2000)

Website: Maryland DNR, Woodland Incentive Program. http://www.dnr.state.md.us/forests/programapps/wood.html

Maryland Code: Natural Resources, Title 5 (Forests and Parks), Subtitle 3 (Woodland Incentives Program)

Timber Stand Improvement Certification and Reforestation Tax Program (DNR)

Year: 1988

Description: Allows landowners to subtract from their adjusted gross income twice the cost of reforestation and timber stand improvements. Participation in the program requires a timber stand certification from DNR, with renewal every two years. The land must be 10 – 500 acres and

must produce more than 20 cubic feet per year. The tax credit can only be taken for up to 100 acres.
Objective: Forest management
Approach: Non-regulatory income tax credit
Source: McElfish and Wilkonson (2000)
Website: Maryland DNR, Income Tax Modification Program. http://www.dnr.state.md.us/forests/programapps/tax.html
Maryland Code: Natural Resources, Title 5 (Forests and Parks), Subtitle 2. (Organization and Authority of Department Pertaining to Forests and Parks)

Reforestation Law (DNR)
Year: 1988
Description: State highway construction projects must mitigate acre for acre forest impacts of at least 1 acre. Replanting is to be done on public lands, including parts and schools, preferably within the same county.
Objective: Forest conservation
Approach: Regulatory
Source: McElfish and Wilkonson (2000)
Website: Maryland DNR, Maryland Reforestation Law. http://www.dnr.state.md.us/forests/programapps/reforest.html
Maryland Code: Natural Resources, Title 5 (Forests and Parks), Subtitle 1 (In General)

Buffer Incentives Program (Green Shores Program) (DNR)
Year: 1989
Description: Provides a one-time payment of up to $300 per acre for planting and maintenance of stream and shoreline buffers. Eligible land is 1 – 50 acres of crop land, pasture, open land or successional vegetation within 300 feet of a stream, river, pond, nontidal wetland or open water.
Objective: Riparian buffer BMPs
Approach: Non-regulatory cost share
Source: McElfish and Wilkonson (2000)
Website: Maryland DNR, Conservation and Restoration Services, a Funding and Technical Assistance Guide. http://www.dnr.state.md.us/bay/services/summaries.html#BIP
Maryland Code: Natural Resource, Title 5 (Forests and Parks), Subtitle 4 (Trees and Forest Nurseries)

Nontidal Wetland Act (DNR)
Year: 1989
Description: Requires the use of BMPs for forest harvests affecting nontidal wetlands, and requires a 25 foot vegetated buffer around nontidal wetlands greater than 5,000 square feet. BMPs must be incorporated into the sediment control plan. This act also limits development within 25 feet of a nontidal wetland.

Objective: Wetland preservation
Approach: Regulatory
Source: McElfish and Wilkonson (2000)
Website: Maryland DNR, Summary of Nonpoint Source Pollution Control and Prevention Activities. http://www.dnr.state.md.us/bay/czm/nps/publications/summary.html
Maryland Code: Environment, Title 5 (Water Resources), Subtitle 9 (Nontidal wetlands)

Forest Conservation Act (DNR)
Year: 1991
Description: Requires each local government with planning and zoning authority to develop and adopt a forest conservation plan, which will apply to any public or private development on areas of at least 40,000 square feet (1 acre). The act requires forest stand delineation before the development plan can be approved and the development of a conservation, reforestation or afforestation plan. Forests should be retained in environmentally sensitive areas, contiguous or connective forests should be retained, as should large, rare or historic trees. Reforestation or afforestation must occur in riparian buffers, forest corridors, floodplains or contiguous forests. Commercial and industrial development must afforest 15%, agriculture and medium density development must afforest 20%. Areas cannot be deforested more than 50% for agriculture and natural resource areas, 25% for medium density development, 20% for high density development, and 15% for commercial and industrial development. If deforestation is above the critical threshold, reforestation must occur at a ratio of 1 acre reforested to every 0.25 acre deforested. Forested land covered by the conservation plan must be placed under local jurisdictional easement. The act does not apply to highway construction, agricultural or commercial timber activities. Reforestation can take place off site, or a developer must pay into the local or state Forest Conservation Fund.
Objective: Forest conservation
Approach: Regulatory
Source: McElfish and Wilkonson (2000), Galvin et al. 2000
Website: Maryland DNR, Forest Conservation Act. http://www.dnr.state.md.us/forests/healthreport/act.html
Maryland Code: Natural Resource, Title 5 (Forests and Parks), Subtitle 16 (Forest Conservation)

Economic Growth, Resource Protection and Planning Policy
Date: 1992
Description: This policy mandates that county comprehensive land use plans include provisions for concentration of development, protection of sensitive areas, conservation of resources, and stewardship of the Chesapeake Bay.
Objective: Growth management

Approach: Regulatory
Source: McElfish and Wilkonson (2000)
Website: Maryland Department of Planning, The Economic Growth, Resource Protection, and Planning Act of 1992. http://www.mdp.state.md.us/planningact.htm
Maryland Code: State Finance and Procurement, Title 5 (State Planning), Subtitle 7A. State Economic Growth, Resource Protection, and Planning Policy.

Maryland's Stream ReLeaf Plan (DNR)
Year: 1996
Description: Leverages existing programs, including the Conservation Reserve Enhancement Program, the Forest Conservation Act, and the Critical Area Law, to increase riparian buffer protection 600 miles by 2010. Riparian buffers include areas within 35 feet of a stream bank.
Objective: Riparian buffer BMPs
Approach: Non-regulatory plan
Source: Maryland DNR, Stream ReLeaf. http://www.dnr.state.md.us/forests/streamreleaf.html

Priority Development Funding Act
Year: 1997
Description: State funding of growth related projects is contingent on local authorization that the project exists within a Priority Funding Area, which are locally designated growth zones.
Objective: Growth management
Approach: Regulatory
Source: McElfish and Wilkonson (2000)
Website: Maryland Department of Planning, Smart Growth Priority funding Areas Act of 1997. http://www.mdp.state.md.us/fundingact.htm
Maryland Code: State Finance and Procurement, Title 5 (State Planning), Subtitle 7B (Priority Funding Areas)

Community Forestry Council
Year: 1997
Description: A non-profit volunteer network to increase public awareness and promote the formation of networks. The Council also manages the PLANT awards program.
Objective: Urban forestry
Approach: Outreach and education
Source: McElfish and Wilkonson (2000)
Website: Maryland DNR, Maryland Community Forest Council. http://www.dnr.state.md.us/forests/programs/urban/mcfc.html

Rural Legacy Program (DNR)
Year: 1997
Description: State funds are provided to local governments and land trusts for the acquisition of land and easements to protect agriculture and forest lands.
Objective: Land acquisition
Approach: Land acquisition
Source: McElfish and Wilkonson (2000)
Website: Maryland DNR, Maryland's Rural Legacy. http://www.dnr.state.md.us/rurallegacy/
Maryland Department of Planning, Rural Legacy. http://www.mdp.state.md.us/legacy_rural.htm
Maryland Code: Natural Resource, Title 5 (Forests and Parks), Subtitle 9A (Rural Legacy Program)

Maryland Conservation Reserve Enhancement Program (CREP) (USDA and DNR)
Year: 1997
Description: Uses a combination of state, federal and nonprofit contributions to provide up to 100% reimbursement for installation of BMPs, with a focus on buffer establishment, wetland restoration, and retiring highly erodable agricultural lands that are adjacent to water bodies that drain into the Chesapeake Bay.
Objective: BMPs
Approach: Non-regulatory cost share
Source: McElfish and Wilkonson (2000)
Website: Maryland DNR, The Conservation Reserve Enhancement Program (CREP). http://www.dnr.state.md.us/wildlife/milo.asp

Non-profit land trusts (MET and DNR)
Year: 1998
Description: Counties are authorized to offer property tax credits for nonprofit land trusts. Trusts must be certified by the MET, with a renewal every 5 years.
Objective: Land conservation
Approach: Non-regulatory property tax exemption
Source: McElfish and Wilkonson (2000)
Maryland Code: Tax Property, Title 7 (Property Tax Exemptions), Subtitle 3 (State Property Tax Exemption)

Smart Codes (Maryland Departments of Planning and Housing and Community Development)
Year: 2000
Description: Authorizes counties to adopt the state rehabilitation building code to facilitate rehabilitation and reuse of existing buildings. The state gives financial incentives to adopt Smart Codes.
Objective: Redevelopment
Approach: Non-regulatory

Source: McElfish and Wilkonson (2000)
Website: Maryland Department of Planning, Community Design. http://www.mdp.state.md.us/cd.html
Maryland Code: State Finance and Procurement, Title 5 (State Planning), Subtitle 7B (Priority Funding Areas)

Greenprint Program (DNR)
Year: 2001
Description: This program leverages state resources, land trusts, and conservation groups to stimulate additional activities and funding sources to protect important natural resource lands. Lands are identified and prioritized using the Strategic Forest Lands Assessment, which identifies ecological and economic values of the forest land base, and in the Green Infrastructure, which identifies core and corridor areas.
Objective: Decision support
Approach: Decision support
Source: McElfish and Wilkonson (2000), Maryland Department of Natural Resources (2003c)
Website: Maryland DNR, Maryland's GreenPrint Program. http://www.dnr.state.md.us/greenways/greenprint/greenprint.html
Maryland Code: Natural Resource, Title 5 (Forests and Parks), Subtitle 15A (Maryland Greenprint Program).

Income tax incentives (MET and DNR)
Year: 2001
Description: Provides income tax incentives for MET easements (minimum 15 years).
Objective: Land conservation
Approach: Non-regulatory income tax incentives
Source: Maryland Environmental Trust, State Income Tax Credit. http://www.dnr.state.md.us/met/sitc.html

Maryland Environmental Quality Incentive Program (EQIP) (NRCS)
Year: 2003
Description: A cost share of 50 – 90% is provided for forest stand improvements, forested riparian buffer establishment, tree planting and other non-forest related BMPs. State funding allocations are split between practices related to animal waste management and cropland, grazing land, forest, irrigation, and nurseries.
Objective: BMPs
Approach: Non-regulatory cost share
Website: Maryland DNR, Forest Management Notes on Cost Share Assistance – EQIP. http://www.dnr.state.md.us/forests/programapps/eqip.html

Chesapeake Bay School Reforestation Program (DNR)
Year: Unknown
Description: Provides grants to school to support reforestation efforts on school property.
Objective: Tree planting
Approach: Non-regulatory grants
Source: McElfish and Wilkonson (2000)

A.4 State Policies in Virginia

Acts of Assembly 1914, Office of State Forester
Year: 1914
Description: Established the Office of the State Forester and the State Forest Service. Early objectives included fire management and suppression, information, education, assistance to landowners, and land acquisition.
Objective: Forest management
Approach: Regulatory
Source: Commission to Study the Forestry Conditions of Virginia (1932)

Tree nursery (US Forest Service (USFS))
Year: 1917
Description: Establishment of nursery maintained by the USFS to provide trees for planting in Virginia.
Objective: Tree planting
Approach: Non-regulatory
Source: Commission to Study the Forestry Conditions of Virginia (1932)

Timber Services to Landowners Act (Department of Forestry (DOF))
Year: 1946
Description: Permitted the State Forester to, upon request by a landowner, examine timber property, make recommendations, and designate trees for cutting.
Objective: Outreach/education/decision support
Approach: Outreach and education
Source: Sanders, et al. (1955)

Use Value Assessment Ordinance
Year: 1950
Description: Allows counties to assess land for a lower property tax rate based on its use in agriculture (>5 acres), horticulture (> 5 acres), forest (>20 acres) or open space (>2 or > 5 acres). Agricultural and horticultural properties must be involved in the commercial production of plants or animals, forests must meet stocking and productivity standards, and open space can include parks, conservation lands, wetlands, riparian buffers, and historic

or scenic areas. Open space must also be located in a designated agricultural or forestal district and must be under easement.
Objective: Farmland preservation
Approach: Non-regulatory property tax incentive
Source: McElfish and Wilkonson (2000)

Seed Tree Law (DOF)
Year: 1950
Description: Requires seed trees to be reserved or requires reforestation for commercial harvests on land at least 10 acres in size and on which white or loblolly pines constitute at least 25% of the area. At least 8 seed trees per acre must be reserved. This law does not apply to areas where a management plan exists or when land is being cleared for agriculture or for development, or to land that has been zoned for more intensive use. The act also explicitly states that local governments may not limit any forest management activity or require permits or fees.
Objective: Forest management
Approach: Regulatory
Source: McElfish and Wilkonson (2000)
Website: Virginia DOF, Seed Tree Law and Reforestation of Timberlands. http://www.dof.virginia.gov/mgt/va-seed-tree-law.shtml

Open Space Land Act
Year: 1966
Description: Authorizes counties to use their own funds to acquire easements for preserving open space.
Objective: Open space preservation
Approach: Acquisition
Source: McElfish and Wilkonson (2000)
Virginia Code: Title 10.1 (Conservation), Chapter 17 (Open-Space Land Act)

Virginia Outdoors Foundation (VOF)
Year: 1966
Description: A land trust that owns and administers lands and easements, and administers the Open Space Lands Preservation Trust Fund.
Objective: Land acquisition
Approach: Land acquisition
Source: McElfish and Wilkonson (2000)
Website: VOF. http://www.virginiaoutdoorsfoundation.org/

Reforestation of Timberlands Program (DOF)
Year: 1971
Description: Cost share to support pine restoration and management on commercial forest land greater than 500 acres.
Objective: Forest management
Approach: Non-regulatory cost share

Source: McElfish and Wilkonson (2000)
Website: Virginia DOF, Virginia's Reforestation of Timberlands Program. http://www.dof.virginia.gov/mgt/rt-04-new.shtml

Comprehensive Land Use Planning
Year: 1975
Description: Required all counties to develop a comprehensive land use plan. Also, this legislation allowed counties to develop zoning ordinances to protect natural areas and promote provisions to discourage "sprawl" development. Counties were also allowed to adopt agricultural and forestal zones within which lower property tax rates can be applied. Counties are not permitted to inhibit forest management activities through zoning restrictions.
Objective: Planning
Approach: Regulatory
Source: McElfish and Wilkonson (2000)
Virginia code: Title 15.2 (Counties, Cities and Towns), Chapter 22 (Planning, Subdivision of Land and Zoning)

Agricultural and Forestal Districts Act
Year: 1977
Description: Commercial agricultural and forest lands are automatically considered for use value assessment. Lands must have a core area of 200 contiguous acres, although additional non-contiguous land can be included. Districts also have some protection from condemnation for utilities or other public development activities except road building.
Objective: Farmland preservation
Approach: Non-regulatory property tax credit
Source: McElfish and Wilkonson (2000)
Website: Virginia DOF, Agricultural and Forestal Districts. http://www.dof.virginia.gov/mgt/ag-for-districts.shtml
Virginia code: Title 15.2 (Counties, Cities and Towns), Chapter 43 (Agricultural and Forestal Districts Act)

Local Agricultural and Forestal Districts Act
Year: 1982
Description: For counties with an urban executive government, districts of local agricultural or forestal significance can be designated for reduced property tax rates. At least 20 acres must be designated.
Objective: Farmland preservation
Approach: Non-regulatory property tax credit
Source: McElfish and Wilkonson (2000)
Website: Virginia DOF, Agricultural and Forestal Districts. http://www.dof.virginia.gov/mgt/ag-for-districts.shtml
Virginia code: Title 15.2 (Counties, Cities and Towns), Chapter 44 (Local Agricultural and Forestal Districts Act)

Chesapeake Bay Preservation Act

Year: 1988

Description: Requires a 100 foot riparian buffer in Chesapeake Bay Resource Protection Areas, which are primarily located within the Tidewater areas of Virginia. A recent amendment requires protection around all perennial streams and other sensitive lands.

Objective: Riparian buffer BMPs to protect water quality

Approach: Regulatory

Source: McElfish and Wilkonson (2000)

Website: Virginia Department of Conservation (DCR) and Recreation Chesapeake Bay Local Assistance, The Chesapeake Bay Act and the Chesapeake Bay Preservation Area Designation and Management Regulations. http://www.cblad.virginia.gov/bayact.cfm

Chesapeake Bay Local Assistance Department (CBLA)

Year: 1988

Description: This agency assists local governments in creating and updating regulations related to the Chesapeake Bay Act. It provides technical and financial assistance to local governments in the Tidewater areas of Virginia, provides technical advice to regional and state agencies on land use and water quality protection, and ensures that local government comprehensive plans are in compliance with the Chesapeake Bay Act regulations.

Objective: Decision support

Approach: Decision support

Source: Virginia DCR CBLA. http://www.cblad.virginia.gov/

Conservation Easement Act

Year: 1988

Description: Allows nonprofit organizations to hold easements if they have been in existence or operating in Virginia for at least 5 years. If a nonprofit has been in operation less than 5 years, it can co-hold with other eligible entity.

Objective: Land conservation

Approach: Non-regulatory

Source: McElfish and Wilkonson (2000)

Virginia code: Title 10.1 (Conservation), Chapter 10.1 (Virginia Conservation Easement Act)

Tree Ordinance Legislation

Year: 1989

Description: Authorizes local municipalities to adopt tree conservation ordinances for heritage, specimen, memorial or street trees. It also allows the establishment of an urban and community forestry department.

Objective: Tree preservation

Approach: Non-regulatory enabling legislation
Source: McElfish and Wilkonson (2000)
Virginia code: Title 10.1 (Conservation), Chapter 11.2 (Voluntary Environmental Assessment)

Replacement of trees during development
Year: 1989
Description: Localities with a population density greater than 75 people per square mile may adopt an ordinance to require planting or replacement of trees during the development process. Minimum tree cover guidelines are provided by land use class: 10% in commercial, industrial, or high density residential areas (>20 housing units/acre); 15% in medium density residential areas (10 – 20 housing units/acre; and 20% in low density residential (< 10 housing units/acre). The ordinance must require at least 20 years to reach the tree cover requirements, although municipalities established prior to 1780 can require 10 years. Local ordinances cannot exceed state specifications.
Objective: Urban forestry
Approach: Regulatory if adopted by local governments
Virginia code 15.2 (Counties, Cities and Towns), Chapter 9 (General Powers of Local Governments)

Urban Forest Council
Year: 1990
Description: Provides training and education and program development for urban forestry programs, and focuses on raising public awareness. The UFC also sponsors the state's Tree Stewards volunteer training and education program.
Objective: Urban forestry
Approach: Education and outreach
Source: McElfish and Wilkonson (2000)
Website: Trees Virginia, Virginia Urban Forest Council. http://www.treesvirginia.org/

Virginia Land Conservation Foundation
Year: 1992
Description: Plans state acquisition programs for open space, natural areas, parks, farmland and forest preservation, and historic preservation. The VLCF provides direct or matching funds to state agencies. Funds are appropriated annually.
Objective: Land acquisition
Approach: Land acquisition
Source: McElfish and Wilkonson (2000)
Website: Virginia DCR, The Virginia Land Conservation Foundation http://www.dcr.state.va.us/vlcf/

Water Quality Law (DOF)

Year: 1993

Description: Requires that they Department of Forestry be notified of commercial timber harvests within 3 days of commencing harvest. A self-inspection form must be completed to indicate whether the operator is participating in the Sustainable Forest Initiative or if there are inspections occurring on the land. The inspection form makes the operator aware of best management practice guidelines, the Seed Tree Law, and streamside management zones. This law requires a 50 foot vegetated buffer to remain along perennial streams. The DOF can also conduct inspections and the State Forester can stop harvesting practices that are determined to cause or likely to cause pollution of waterways. However, the State Forester may not stop activity if the operator has incorporated generally accepted measures to protect water quality, even if streams become impaired as a result of the timber harvesting activities.

Objective: Riparian buffer BMPs to protect water quality

Approach: Regulatory

Source: McElfish and Wilkonson (2000)

Website: Virginia DOF, Water Quality. http://www.dof.virginia.gov/wq/index.shtml

Virginia code: Title 10.1 (Conservation), Chapter 11 (Forest Resources and the Department of Forestry)

Virginia Forest Resource Assessment (DOF)

Year: 1995

Description: This statewide assessment, performed by the Department of Forestry, classifies forests as urban and rural and also makes an assessment of the vulnerability of commercial timber production.

Objective: Decision support

Approach: Decision support

Source: McElfish and Wilkonson (2000)

Website: Virginia DOF, 1995 Forest Resource Assessment. http://www.dof.virginia.gov/resinfo/fra-95-exec-summ.shtml

Open Space Land Preservation Trust Fund (VOF)

Year: 1997

Description: Provides funds to assist local governments in purchasing easements

Objective: Open space preservation

Approach: Non-regulatory easements

Source: McElfish and Wilkonson (2000)

Website: VOF, Open Space Lands Preservation Trust Fund. http://www.virginiaoutdoorsfoundation.org/ptf.html

Water Quality Improvement Act

Year: 1997

Description: Provides state and federal cost shares, funded through the Water Quality Improvement Act, for the installation of best management practices on private agricultural land. These voluntary BMPs address non-point source pollution into streams, and are distributed through the state soil and water conservation districts. Riparian buffers are included.

Objective: BMP implementation on agricultural land

Approach: Non-regulatory, voluntary, cost share

Source: McElfish and Wilkonson (2000)

Website: Virginia DCR, Water Quality Improvement Act. http://www.dcr.state.va.us/sw/wqia.htm

Riparian Buffer Implementation Plan (DOF)

Year: 1998

Description: A plan to increase vegetated riparian 610 miles by 2010. A buffer must be at least 35 feet on one side of a stream or 70 feet on both sides. Progress is tracked on the DOF website. The Chesapeake Bay Program initiated this plan.

Objective: Riparian buffer BMPs

Approach: Decision support

Website: Virginia DOF, Riparian Forest Buffers. http://www.vdof.org/rfb/

Agricultural best management practices

Year: 1998

Description: Provides a tax credit up to an amount equaling 25% of the first $70,000 expended for installing agricultural BMPs related to improving water quality and enhancing riparian areas. BMPs must meet the guidelines developed by the Virginia soil and water conservation districts.

Objective: BMPs

Approach: Non-regulatory tax incentive

Virginia code: Title 58.1 (Taxation), Chapter 3 (Income Tax)

Tree Planting for Virginia's Communities (DOF)

Year: 1999

Description: State grant funds for street tree plantings. This funding has likely been discontinued.

Objective: Street tree planting

Approach: Non-regulatory grant

Website: Virginia DOF, Annual Management Report 1999. http://www.dof.virginia.gov/mgt/annual-mgt-report-99.shtml

Tax increment financing

Year: 1999

Description: Property taxes can be forgiven for development and redevelopment projects in economically depressed areas if funds are redirected into public improvements, including open space.

Objective: Redevelopment, growth management

Approach: Non-regulatory tax incentive

Source: McElfish and Wilkonson (2000)

Conservation Land Coalition

Year: 1999

Description: A coalition of environmental groups, chaired by the Nature Conservancy, who advocate for a dedicated state funding source for land acquisition.

Objective: Advocacy

Approach: Education, advocacy, decision support

Source: Institute for Environmental Negotiation, IEN Project Archive. http://www.virginia.edu/ien/archive.htm

Virginia's United Land Trusts

Year: 2000

Description: A coalition of over 30 Virginia land trusts, which promote conservation efforts, build capacity, and coordinate trusts' activities.

Objective: Land conservation

Approach: Education, decision support, outreach

Website: Virginia DCR, Land Conservation, http://www.dcr.state.va.us/olc/whereto4.htm

Riparian buffer tax credit

Year: 2000

Description: Owners of forest land who forgo timber harvesting along a 35-300 foot stream buffer are eligible for an income tax credit of up to 15% of the timber value in the buffer area.

Objective: Riparian buffer BMPs

Approach: Income tax incentive

Source: McElfish and Wilkonson (2000)

Website: Virginia DOF, Riparian Buffer Tax Credit. http://www.dof.virginia.gov/rfb/rbtc-intro.shtml

Virginia Conservation Reserve Enhancement Program (CREP)

Year: 2000

Description: Cost share involving the USDA (up to 50%), the state of Virginia (up to 25%, and Ducks Unlimited and the Chesapeake Bay Foundation (CBF) (up to 25% for the installation of vegetated filter strips within 100 feet of stream banks; or forested riparian buffers within 300 feet of stream banks or around wetland up to 40 acres in size. To qualify, land must be under

10-15 year Conservation Reserve Program (CRP) contracts or under permanent easements.

Objective: Riparian buffer BMPs

Approach: Non-regulatory cost share

Source: McElfish and Wilkonson (2000)

Website: Virginia DCR, Virginia's Conservation Reserve Enhancement Program. http://www.dcr.state.va.us/sw/crep.htm

USDA Farm Service Agency, Conservation Reserve Program Virginia Enhancement Program. http://www.fsa.usda.gov/pas/publications/facts/html/crepva00.htm

Cluster subdivisions to protect open space

Year: 2002

Description: State enabling legislation that allows localities to permit and regulate cluster zoning.

Objective: Open space preservation

Approach: State enabling legislation

Virginia Code: Title 15.2 (Counties, Cities and Towns), Chapter 22 (Planning, Subdivision of Land and Zoning)

Urban and Community Forestry Program

Year: Unknown

Description: Provides funding for programmatic support for tree inventories, purchase of equipment, and training scholarships. This program is funded through the USDA Urban and Community Forestry Program.

Objective: Urban forestry

Approach: Decision support

Source: McElfish and Wilkonson (2000)

Website: Virginia DOF, Urban and Community Forestry. http://www.dof.virginia.gov/urban/index.shtml

Protection of Farm and Forest Lands Act

Year: Unknown (amended in 2000)

Description: Requires all state agencies to preserve farm and forest land. Each agency must show that it has considered the impacts of a project on farm and forest lands and has considered alternative or mitigation strategies. Forest lands eligible for protection are those in forestal districts, those that provide exceptional forest products, or those that are important for the local economy or character.

Objective: Land conservation

Approach: Regulatory for state agencies

Source: McElfish and Wilkonson (2000)

Virginia code: Title 3.1 (Agriculture, horticulture and food), Chapter 3.2 (Protection of Farm and Forest Lands)

Virginia Environmental Quality Incentive Program (EQIP) (Virginia NRCS)

Year: Unknown

Description: Provides cost share for forest stand improvements, including prescribed burning, riparian buffer establishment, fencing, firebreaks, stand establishment and site preparation.

Objective: Forest management

Approach: Non-regulatory cost share

Source: NRCS, Virginia 2005 EQIP Documents and Procedures. http://www.va.nrcs.usda.gov/programs/eqipdocs.html

A.5 Montgomery County, MD Policies

Montgomery County park system

Year: 1950

Description: Build and manage a network of county-owned park units for recreation, open space preservation and land conservation. The Montgomery County Department of Park and Planning manages the park system.

Objective: Land acquisition, management

Approach: Land acquisition

Website: Maryland-National Capital Park and Planning Commission, Montgomery County Parks. http://www.mc-mncppc.org/parks/index.shtm

Master planning

Year: 1969

Description: Comprehensive land use planning includes procedures for the development and adoption of land use plans, including the general countywide vision plan, master plans, sector plans, etc. Plans created by the Maryland National Capital Park and Planning Commission are reviewed by the Montgomery County Planning Board and approved by the Montgomery County Council. The general plan was adopted in 1969 and sets forth visions for urban and rural areas, as well as for the provision of public services. The plan, entitled *On Wedges & Corridors: A General Plan for the Maryland-Washington Regional District in Montgomery and Prince George's Counties*, is based on radial development corridors extending from the city of Washington, DC, conserving "wedges" of green space in between (Maryland-National Capital Park and Planning Commission 1964).

Objective: Comprehensive planning

Approach: Decision support

Source: Maryland-National Capital Park and Planning Commission (1964), Hiebert and MacMaster (1976)

Website: Montgomery County Park and Planning, Department of Park and Planning. http://www.mc-mncppc.org/department/index.shtm

Growth Policy (Adequate Public Facilities Ordinance)
Year: 1973
Description: The County Council must adopt an annual growth ceiling every year. Growth ceilings are developed based on the capacities of schools, transportation, and public facilities. A policy component is adopted every two years that contains guidelines for the Planning Board and other agencies for their administration of laws and regulations that affect growth and development.
Objective: Growth management
Approach: Regulatory
Montgomery County Code: Part II, Chapter 33A, Article II
Website: Montgomery County Park and Planning, Montgomery County Growth Policy. http://www.mc-mncppc.org/development/agp/agphome.shtm

Erosion, sediment control and storm water management
Year: 1974
Description: Requires a permit to disturb land for projects exceeding 5,000 square feet of surface area. If the activity is subject to Forest Conservation regulations, those requirements must be met before activity can occur and preliminary conservation plans must be approved. If the limits of the plan are violated, the permittee must develop a reforestation plan. The planning director may recommend regulations pertaining to the protection of specimen trees.
Objective: Erosion control
Approach: Regulatory
Montgomery County code: Part II (Local Laws, Ordinances, Resolutions, etc.), Chapter 19 (Erosion, Sediment Control and Storm Water Management)

Environmentally Sensitive Areas (Subdivision Regulations)M-NCPPC
Year: 1979
Description: Restricts subdivision on stream valleys and floodplains, or land that is prone to flooding or erosion, to meet protect environmentally sensitive areas, including critical wildlife habitat, steep slopes and/or erodable soils, wetlands, perennial and intermittent streams, and stream buffers.
Objective: Environmental preservation
Approach: Regulatory
Montgomery County code: Part II (Local Laws, Ordinances, Resolutions, etc.), Chapter 50 (Subdivision of Land), Sec. 50-32

Transfer of Development Rights
Year: 1980
Description: Helps preserve farmland in northern Montgomery County's Agricultural Reserve Rural Density Transfer (RDT) zone. Development rights are transferred from areas in the RDT zone to receiving areas, where the development density is then increased. In the RDT zone, building

density is 1 house per 25 acres, but transferable rights are equal to 1 house per 5 acres.
Objective: Farmland preservation
Approach: Non-regulatory
Source: Maryland-National Capital Parks and Planning Commission (2001)

Agricultural Easement Program
Year: 1988
Description: Landowners can place their land into a 25-year agricultural conservation easement, held by the county. Land does not have to be within a county agricultural district if it is zoned rural, rural density transfer or rural cluster. Otherwise, it must be in a county or state agricultural district. Priority is given based on price and whether it is in an agricultural area in the county master plan.
Objective: Farmland preservation
Approach: Non-regulatory, voluntary easement
Website: Montgomery County Department of Economic Development Agricultural Services Division, Agricultural Preservation. http://www.montgomerycountymd.gov/mcgtmpl.asp?url=/content/ded/AgServices/agpreservation.asp
Montgomery County code: Part II (Local Laws, Ordinances, Resolutions, etc.), Chapter 2B (Agricultural Land Preservation), Article II (Purchase of Easements by the County)

County agricultural districts
Year: 1988
Description: Creation of agricultural districts allows land within those districts to become eligible for certain tax benefits or easements. Land in a county district must be at least 50 contiguous acres, meet certain USDA soil or woodland classifications, and lie outside certain water and sewer categories. The County Council can circumvent these requirements if they feel it has significant agricultural value and if it determines that it is in the public interest. The landowner must request establishment of or inclusion in a district.
Objective: Farmland preservation
Approach: Non-regulatory, voluntary inclusion
Montgomery County code: Part II (Local Laws, Ordinances, Resolutions, etc.), Chapter 2B (Agricultural Land Preservation), Article II (Purchase of Easements by the County)

Conservation easements
Year: 1991
Description: Easements placed on environmentally sensitive lands, including streamside areas, wetlands, forests, and steep slopes.
Objective: Environmental preservation
Approach: Non-regulatory, except in designated Special Protection Areas

Website: Montgomery County Park and Planning, Conservation Easement. http://www.mc-mncppc.org/environment/SPA/easement.shtm

Montgomery Park Foundation

Year: 1992

Description: Allows private citizens to make donations of money, property or time to support the parks system. Funds can be designated to the general fund, Legacy Open Space or to the Sniper Victim Memorial Fund. The foundation also facilitates private sector partnerships to provide goods and services.

Objective: Land acquisition, support

Approach: Park fund

Website: Montgomery County Parks Foundation. http://www.montgomeryparksfnd.org/

Montgomery County Forest Conservation Law

Year: 1992

Description: Requires developers to submit a forest stand delineation and a forest conservation plan that must be approved with the development application before land clearing can begin. Existing trees must be preserved wherever possible, and planting of trees should occur to compensate for unavoidable loss. Includes the establishment of a tree fund where reforestation funds are paid if applicant cannot remediate on-site. This local law was developed in response to Maryland's Forest Conservation Act.

Objective: Forest and tree preservation

Approach: Regulatory

Source: Maryland-National Capital Parks and Planning Commission (1994)

Website: Montgomery County Park and Planning, Forest Conservation Program of Montgomery County. http://www.mc-mncppc.org/environment/forest/index.shtm

Montgomery County Development District Act

Year: 1994

Description: The County can provide financing for infrastructure costs for the development of high priority land for new development or redevelopment. Allows special assessments and/or special taxes and tax-exempt bond issuance. Development or redevelopment should be located in approved master plan areas where infrastructure support already exists. The Planning Board must review and approve.

Objective: Growth management

Approach: Non-regulatory, incentive

Montgomery County code: Part II (Local Laws, Ordinances, Resolutions, etc.), Chapter 14 (Development Districts)

Special Protection Areas

Year: 1994

Description: Special protection is applied to areas where streams, wetlands and related natural features are of high quality. Requires additional inventorying and permitting procedures, monitoring, and no net wetland loss as a result of development. Currently there are only three: Clarkesburg, Piney Branch, and Upper Paint Branch.

Objective: Environmental preservation, particularly streams and wetlands.

Approach: Regulatory once established

Website: Montgomery County Park and Planning, An Overview of Special Protection Areas (SPA). http://www.mc-mncppc.org/environment/SPA/index.shtm

Environmental Overlay Zone

Year: 1997

Description: Overlay zoning for the Upper Paint Branch SPA, which specifies that impervious surface cannot exceed 10%.

Objective: Environmental preservation, particularly streams and wetlands

Website: Montgomery County Park and Planning, 59-C-18.15 Environmental Overlay Zone for the Upper Paint Branch Special Protection Area. http://www.mc-mncppc.org/environment/SPA/paint_overlay.shtm

Legacy Open Space

Year: 2000

Description: A multi-million dollar program to expand existing park system in order to protect "exceptional" open space lands and heritage resources. Criteria for selection include: known or potential habitat for threatened or endangered species, "best example" of terrestrial or aquatic community, unique or unusual ecological communities, large area with diverse habitats, exceptional viewscapes or historic elements, protection of public water supply, part of a "critical mass" of similar ecological or heritage resources, provides human or ecological connectivity, provides a buffer, provides educational opportunity, increases access to open space in high density areas, or provides protection or improvement of open space in urbanized areas.

Objective: Land acquisition

Approach: Land acquisition

Website: Montgomery County Park and Planning, Legacy Open Space Summary. http://www.mc-mncppc.org/legacy_open_space/summary.shtm

Residential Cluster Subdivision (Subdivision Regulations)

Year: Unknown

Description: Cluster subdivisions to encourage the preservation of existing topography and to promote forest conservation and provide green or open space.

Objective: Open space preservation

Approach: Non-regulatory
Montgomery County code: Part II (Local Laws, Ordinances, Resolutions, etc.), Chapter 50 (Subdivision of Land), Sec. 50-39

A.6 Fairfax County, VA Policies

Fairfax County Park Authority
Year: 1950
Description: Manage and acquire County park lands for recreation, land conservation and open space preservation.
Objective: Land acquisition, recreation
Approach: Land acquisition
Website: Fairfax County Park Authority.
http://www.co.fairfax.va.us/parks/index.htm
Fairfax County, Parks and Recreation.
http://www.fairfaxcounty.gov/living/parks/default.htm

Northern Virginia Soil and Water Conservation Districts
Year: 1954
Description: County government organization that promotes clean streams and the protection of natural resources
Objective: Outreach and decision support, landowner education
Approach: Outreach, decision support
Website: Fairfax County, Northern Virginia Soil and Water Conservation District.
http://www.co.fairfax.va.us/nvswcd/

Northern Virginia Regional Park Authority (NVRPA)
Year: 1959
Description: The NVRPA oversees the acquisition and management of a network of parks throughout northern Virginia, including Fairfax, Arlington, Loudoun, Alexandria, Falls Church, and Fairfax City.
Objective: Land acquisition, recreation
Approach: Land acquisition
Website: Northern Virginia Regional Park Authority.
http://www.nvrpa.org/index.html

Cluster zoning
Year: 1963
Description: Developers are permitted to apply for cluster zoning to preserve open space. This zoning category was amended in 2004 to comply with recent state guidelines. Under cluster subdivision provisions, there are minimum open space requirements, minimum district size requirements, reduced lot size requirements and reduced yard size requirements.
Objective: Open space preservation
Approach: Non-regulatory, optional subdivision provisions for developers

Website: Fairfax County, Cluster Subdivision Amendments.
http://www.co.fairfax.va.us/dpz/projects/clustersubdiv.htm
Fairfax County code: Chapter 101 (Subdivision Provisions), Article 2 (Subdivision Application Procedures), Section 101-2-8

Open space requirements (Subdivision regulations)
Year: 1970
Description: The director of the Department of Public Works and Environmental Services (DPWES) can require the dedication of up to ten percent of the proposed subdivision to the County for recreational purposes.
Objective: Open space preservation
Approach: Chapter 101 (Subdivision Provisions), Article 2 (Subdivision Application Procedures), Section 101-2-2

Tree cover requirements (Subdivision regulations)
Year: 1970 Regulatory
Description: Original guidelines adopted in 1970, recently amended in 2002 to adopt state requirements. Tree cover requirements for subdivision and development are set to the maximum of state enabling legislation. This requires minimum tree cover of 10% for commercial, industrial, or high density residential (> 20 hu/acres) land uses, 15% for medium density residential (10 - <20 hu/acres), and 20 % for low density residential (≥ 20 hu/acre). In Fairfax County, requirements must be met within 10 years. On sites that were once agricultural land or otherwise devoid of trees prior to development, the director of DPWES can reduce tree cover requirements by 50%.
Objective: Tree cover conservation
Approach: Regulatory
Fairfax County code: Chapter 101 (Subdivision Provisions), Article 2 (Subdivision Application Procedures), Section 101-2-2

Vegetation Preservation and Planting
Year: 1970
Description: For new development, a conservation plan is required that indicates the existing vegetation, areas to be preserved, tree protection measures, limits of grading and clearing. "Every effort" shall be made to protect monarch trees; utilities shall be located to minimize protected vegetation.
Objective: Vegetation and tree conservation
Approach: Regulatory
Fairfax County code: Chapter 104 (Erosion and Sediment Control), Article 1 (Purpose and Administration), Section 104-1-2

Fairfax County planning

Year: 1974

Description: Comprehensive land use planning includes procedures for the development and adoption of land use plans, including the general countywide comprehensive plan and area plans. Plans created by the Fairfax County Department of Planning and Zoning are reviewed by the Fairfax County Planning Commission and approved by the Fairfax Board of Supervisors. The Planning and Land Use System (PLUS) was developed as part of the initial comprehensive planning efforts in the early 1970s. PLUS organizes the county into five planning areas, each of which comprises a section of the comprehensive plan, and also sets forth the framework within which plan preparation and approval occurs. The first comprehensive plan was adopted in 1975. The spatial vision of development, as described in the comprehensive plan, is based on urban, suburban, and commercial clusters.

Objective: Comprehensive planning

Approach: Decision support

Source: Fairfax County Department of Planning and Zoning (2002), Fairfax County Office of Comprehensive Planning (1990)

Website: Fairfax County Department of Planning and Zoning. http://www.co.fairfax.va.us/dpz/
Fairfax County Department of Planning and Zoning, The Comprehensive Plan. http://www.co.fairfax.va.us/dpz/comprehensiveplan/policyplan/

Local agricultural and forestry districts

Year: 1977

Description: Land within these districts is assessed at a lower rate. To qualify, land must be in agricultural use, be consistent with comprehensive plan, meet zoning requirements (i.e. low density), agricultural soil requirements, and have a soil management plan. Land with scenic vistas, historical/cultural significance, or practice effective water pollution control can also be considered. Land must be at least 20 acres in size, and be part of a larger (at least 100 acres) core area.

Objective: Farmland preservation

Approach: Non-regulatory tax incentive

Fairfax County code: Chapter 115 (Local Agricultural and Forestal Districts)

Erosion and Sediment Control

Year: 1982

Description: For new development, a plan for the control of erosion and sediment is required, indicating areas of unstable or highly erodable soils and tree preservation areas. Control measures include requirements that the development plan be fitted to the topography and soils, that land is developed in increments of workable size, that exposure is limited to a period of 120 days, that natural vegetation is retained wherever feasible, and that permanent vegetation be installed as soon as possible.

Objective: Erosion control
Approach: Regulatory
Fairfax County code: Chapter 104 (Erosion and Sediment Control), Article 3 (Erosion and Sediment Control Review Board), Section 104-3-1

Fairfax ReLeaf
Year: 1991
Description: A non-profit advocacy and educational group, run entirely by volunteers, that supports planting trees along roadsides, public parks, schools, retirement homes, etc., with specific aims to beautify derelict space in suburban settings.
Objective: Tree planting
Approach: Outreach, advocacy and education
Website: Fairfax ReLeaf. http://www.geocities.com/RainForest/5663/index.html

Chesapeake Bay Preservation Ordinance
Year: 1993 Regulatory
Description: The original legislation designated resource protection areas (RPAs) in Tidewater jurisdictions, which included tidal wetlands, tidal shores, and non-tidal wetlands connected to tidal wetlands and a 100-foot buffer around these features. Amendments in 2003 included water bodies with perennial flow, perennial streams, and buffer areas that include any land within a major floodplain or within 100 feet of the above features.
Objective: Riparian buffer BMPs, water quality
Approach: Regulatory
Fairfax County code: Chapter 118 (Chesapeake Bay Preservation Ordinance)

Northern Virginia Conservation Trust
Year: 1994
Description: A non-profit land trust that focuses on acquiring easements and land in northern Virginia for open space preservation.
Objective: Land conservation
Approach: Non-regulatory easements
Website: The Northern Virginia Conservation Trust. http://www.nvct.org/

Land Preservation Fund
Year: 2001
Description: Allows citizens to make a tax-deductible donation to a fund dedicated to land acquisition. Maintenance costs are covered by the annual operating budget of the Park Authority. Residents cannot specify the parcels on which they want their donations to be spent.
Objective: Land acquisition
Approach: Non-regulatory park fund
Website: Fairfax County Park Authority, Land Preservation Fund. http://www.fairfaxcounty.gov/parks/landfund.htm

Fairfax County Park Foundation
Year: unknown

Description: The Foundation raises money to support the Fairfax County park system, for which less than half of the annual operating budget comes from tax support. The remainder comes from grants and donations by private citizens, and donations go into the general operating budget.

Objective: Support the general operation of the park system

Approach: Non-regulatory park fund

Website: The Fairfax County Park Foundation. http://www.fairfaxcountyparkfoundation.com/pages/337807/index.htm

REFERENCES

Agterberg, F. P., G. F. Bonham-Carter, Q. Cheng and D. F. Wright. 1993. Weights of evidence modeling and weighted logistic regression for mineral potential mapping. In *Computers in Geology -- 25 Years of Progress*, ed. J. C. Davis and U. C. Herzfeld, 13-32. New York: Oxford University Press.

Almeida, C. M. d., M. Batty, A. M. V. Monteiro, G. Camara, B. S. Soares-Filho and G. C. Cerqueira. 2003. Stochastic cellular automata modeling of urban land use dynamics: empirical development and estimation. *Computers, Environment and Urban Systems* 27 481-509

American Forests. 1999. *Regional Ecosystem Analysis: Chesapeake Bay Region and the Baltimore-Washington Corridor*. Washington, D.C.: American Forests. http://www.americanforests.org/downloads/rea/AF_Chesapeake.pdf.

Anderson, D. G. 1970. *Effects of Urban Development on Floods in Northern Virginia*. 2001-C. Washington, D.C.: United States Geological Survey.

Anderson, J., E. E. Hardy, J. T. Roach and R. E. Witmer. 1976. *A land use and land cover classification scheme for use with remote sensor data*. U.S. Geological Survey Professional Paper 964. U.S. Geological Survey.

Axelsson, A.-L., L. Ostlund and E. Hellberg. 2002. Changes in Mixed Deciduous Forests of Boreal Sweden 1866-1999 Based on Interpretation of Historical Records. *Landscape Ecology* 17 403-418

Baker, M. 1966. The Politics of Planning in Montgomery County, Maryland. Master of Arts, Political Science. George Washington University: District of Columbia.

Bender, D. J., T. A. Conreras and L. Fahrig. 1998. Habitat Loss and Population Decline: A Meta-Analysis of the Patch Size Effect. *Ecology* 79 (2): 517-533

Berg, B. 2001. *Qualitative Research Methods for the Social Sciences*. Boston: Allyn and Bacon.

Bernard, H. R. 2002. *Research Methods in Anthropology*. Walnut Creek, CA: Altamira Press.

Bertolas, R. J. 1998. Cross-Cultural Environmental Perception of Wilderness. *Professional Geographer* 50 (1): 98-111

Besley, F. W. 1916. *The Forests of Maryland*. Baltimore, MD: Maryland State Board of Forestry.

Blaikie, P. and H. Brookfield. 1987. *Land Degradation and Society*. London: Methuen.

Bockstael, N. E. 1996. Modeling Economics and Ecology: the Importance of a Spatial Perspective. *American Journal of Agriculture and Economics* 78 (5): 1168-1180

Bonham-Carter, G. 1997. *Geographic Information Systems for Geoscientists*. Tarrytown, NJ: Elsevier Science, Inc.

Bonham-Carter, G. F., F. P. Agterberg and D. F. Wright. 1988. Integration of geological datasets for gold exploration in Nova Scotia. *Photogrammetric Engineering and Remote Sensing* 54 (11): 1585-1592

Bonnicksen, T. 1991. Managing Biosocial Systems: A Framework to Organize Society-Environment Relationships. *Journal of Forestry* 89 (10): 10-15

Bridge, G. 2000. The Social Regulation of Resource Access and Environmental Impact: Production, Nature and Contradiction in the US Copper Industry. *Geoforum* 31 237-256

Bromley, D. 1982. Land and Water Problems: An Institutional Perspective. *American Journal of Agricultural Economics* 84 (December): 834-844

Burchell, R. W., N. A. Shad, H. Phillips, A. Downs, S. Seskin, J. S. Davis, T. Moore, D. Helton and M. Gall. 1998. *The Costs of Sprawl-Revisited*. 39. Washington, DC: Transit Cooperative Research Program.

Bureau of the Census. 1927. *U.S. Census of Agriculture 1925, Part II The Southern States*. Washington, DC: Government Printing Office.

Bureau of the Census. 1946. *U.S. Census of Agriculture 1945, volume 1, part 14, Delaware, Maryland and the District of Columbia*. Washington, DC: Government Printing Office.

Bureau of the Census. 1956. *U.S. Census of Agriculture 1954, volume 1, part 14, Delaware and Maryland*. Washington, DC: Government Printing Office.

Bureau of the Census. 1967. *U.S. Census of Agriculture 1964, volume 1, part 23, Maryland*. Washington, DC: Government Printing Office.

Bureau of the Census. 1981. *U.S. Census of Agriculture 1978, volume 1, part 20, Maryland*. Report AC78-A-20. Washington, DC: Government Printing Office.

Bureau of the Census. 1989. *U.S. Census of Agriculture 1987, volume 1, part 20, Maryland*. Report AC78-A-20. Washington, DC: Government Printing Office.

Bureau of the Census. 2001. *U.S. Census of Agriculture 1997, volume 1, Geographic Area Series*. Washington, DC: Government Printing Office.

Carson, R. 1962. *Silent Spring*. Greenwich, CT: Fawcett Crest.

Castree, N. 1997. Nature, Economy and the Cultural Politics of Theory: the "War Against the Seals" in the Bering Sea, 1870-1911. *Geoforum* 28 (1): 1-20

Chesapeake Bay Commission. 1995. *An Analysis of Riparian Forest Buffer Policies in Maryland, Virginia, and Pennsylvania*. Annapolis: Issues and Actions.

Chesapeake Bay Program. 2000. Chesapeake 2000. http://www.chesapeakebay.net/c2k.htm (last accessed August 10 2000).

Clarke, J. N. and H. J. Cortner. 2002. *The State and Nature: Voices Heard, Voices Unheard in America's Environmental Dialog*. Upper Saddle River, NJ: Prentice Hall.

Commission to Study the Forestry Conditions of Virginia. 1932. *Report of the Commission to Study the Forestry Conditions of Virginia to the General Assembly*. Senate Document No. 5. Richmond: Virginia General Assembly.

Cooksey, R. and A. Todd. 1996. *Conserving Forests of the Chesapeake: The Status, Trends, and importance of Forests for the Bay's Sustainable Future*. NA-TP-03-96. Annapolis: U.S. Department of Agriculture Forest Service, Northeastern Area.

Cortner, H. J. and M. A. Moote. 1999. *The Politics of Ecosystem Management*. Washington, DC: Island Press.

Dawson, G. 1977. *No Little Plans: Fairfax County's PLUS Program for Managing Growth*. Washington, D.C.: The Urban Institute.

Denny, G. D. 1997. *Proud Past, Promising Future: Cities and Towns in Prince George's County, Maryland*. Brentwood: Tuxedo Press.

Department of Conservation and Recreation. 2002. CBLA's Mission, Objectives and Goals. http://www.cblad.virginia.gov/mission.cfm (last accessed August 25 2004).

Duncan, J. 1980. The Superorganic in American Cultural Geography. *Annals of the Association of American Geography* 70 181-198

Duncan, J. 1990. *The City as Text: the Politics of Landscape Interpretation in the Kandyan Kingdom*. Cambridge: Cambridge University Press.

Duncan, J. S. and N. G. Duncan. 2001. The Aestheticization of the Politics of Landscape Preservation. *Annals of the Association of American Geographers* 91 (2): 387-409

Duncan, N. G. and J. S. Duncan. 1997. Deep Suburban Irony: The Perils of Democracy in Westchester County, New York. In *Visions of Suburbia*, ed. R. Silverstone, 161-179. New York: Routledge.

Dwyer, J. F., H. W. Schroeder and P. H. Gobster. 1991. The Significance of Urban Trees and Forests: Toward a Deeper Understanding of Values. *Journal of Arboriculture* 17 (10): 276-284

Eder, K. 1996. The Institutionalization of Environmentalism: Ecological Discourse and the Second Transformation of the Public Sphere. In *Risk, Environment and Modernity: Towards a New Ecology*, ed. S. Lash, B. Szerszeynski and B. Wynne, 203-223. London: Sage Publications Ltd.

Ernst, H. 2003. *Chesapeake Bay Blues: Science, Politics, and the Struggle to Save the Bay*. Lanham: Rowman and Littlefield Publishers, Inc.

Escobar, A. 1996. Constructing Nature: Elements for a Post-Structural Political Ecology. In *Liberation Ecologies: Environment, Development, Social Movements*, ed. R. Peet and M. Watts, 46-68. New York: Routledge.

Fairfax County Chamber of Commerce. 1928. *Historic, Progressive Fairfax County in Old Virginia*. Alexandria: Newell-Cole Co., Inc.

Fairfax County Department of Planning and Zoning. 2002. *The Fairfax Planning Horizons: The Fairfax County Comprehensive Plan*. Fairfax, VA: Fairfax County Department of Planning and Zoning.

Fairfax County Office of Comprehensive Planning. 1990. *Policy Plan: The Countywide Policy Element of the Comprehensive Plan for Fairfax County, Virginia*.

Fairfax County Planning Division. 1962. *The Vanishing Land: Proposals for Open Space Preservation*. Annandale: Fairfax County Board of Supervisors.

Fairfax Releaf. 2004. Fairfax Releaf Trees for Our Community: History. http://www.geocities.com/RainForest/5663/history.html (last accessed August 26 2004).

Felicisimo, A. M., E. Frances, J. M. Fernandez, A. Gonzalez-Dies and J. Varas. 2002. Modeling the potential distribution of forests with a GIS. *Photogrammetric Engineering and Remote Sensing* 68 (5): 455-461

Finz, S. A. 1974. *Proposed Land Banking Program for Fairfax County*. Fairfax: Fairfax County Office of Research and Statistics.

Forman, R. T. T. 1999. Horizontal Processes, Roads, Suburbs, Societal Objectives and Landscape Ecology. In *Landscape Ecological Analysis: Issues and Applications*, ed. J. M. Klopatek and R. H. Gardner, 35-53. New York: Springer-Verlag.

Fotheringham, S. A., C. Brunsdon and M. Charlton. 2002. *Geographically weighted regression: the analysis of spatially varying relationships*. New York: John Wiley and Sons, Inc.

Galvin, M. F., B. Wilson and M. Honeczy. 2000. Maryland's forest conservation act: a process for urban greenspace protection during the development process. *Journal of Arboriculture* 26 (5): 275-280

Gardner, R. H. 1999. RULE: Map Generation and a Spatial Analysis Program. In *Landscape Ecological Analysis: Issues and Applications*, ed. J. M. Klopatek and R. H. Gardner, 280-303. New York: Springer-Verlag.

Gardner, R. H., B. T. Milne and others. 1987. Neutral Models for the Analysis of Broad-scale Landscape Pattern. *Landscape Ecology* 1 (1): 19-28

Gardner, R. H., R. V. O'Neill, M. G. Turner and V. H. Dale. 1989. Quantifying Scale-dependent Effects of Animal Movement with Simple Percolation Models. *Landscape Ecology* 3 (3/4): 217-227

Garner, J. September 14 1996. Virginia's Forest - 2014. Virginia Forest Products Association. Virginia Beach, VA. Available from Virginia Department of Forestry, http://www.dof.virginia.gov/info/speech-96-Sept14.shtml.

Garner, J. December 11 2002. Personnel Conference. North Carolina Division of Forestry. Available from Virginia Department of Forestry, http://www.dof.virginia.gov/info/speech-02-Dec11.shtml.

GeoLytics Inc. 1996. Census CD + Maps, version 3.0. New Brunswick, NJ.

GeoLytics Inc. 2001. Census CD Neighborhood Change Database, 40 Year Tract Series. New Brunswick, NJ.

Gobster, P. and B. Hull. 1999. The Restoration and Management of Nature: A Conference and Forthcoming Book Explore Restoration from the Perspectives of the Social Sciences and the Humanities. *Ecological Restoration* 17 (1): 44-51

Gobster, P. H. 1995. Perceptions and Use of a Metropolitan Greenway System for Recreation. *Landscape and Urban Planning* 33 401-413

Gobster, P. H. 2000. Restoring Nature: Human Actions, Interactions, and Reactions. In *Restoring Nature: Perspectives from the Social Sciences and Humanities*, ed. P. H. Gobster and R. B. Hull, 1-20. Washington, DC: Island Press.

Goetz, S. J., C. A. Jantz, S. D. Prince, A. J. Smith, D. Varlyguin and R. Wright. 2004. Integrated Analysis of Ecosystem Interactions with Land Use Change: the Chesapeake Bay Watershed. In *Ecosystem and Land Use Change*, ed. R. S. DeFries, G. P. Asner and R. A. Houghton, 263-275. Washington, DC: American Geophysical Union.

Goetz, S. J., R. Wright, A. J. Smith, E. Zinecker and E. Schaub. 2003. Ikonos Imagery for Resource Management: Tree Cover, Impervious Surfaces and Riparian Buffer

Analyses in the Mid-Atlantic Region. *Remote Sensing of the Environment* 88 195-208

Green, D. W. 1994. Connectivity and Complexity in Landscapes and Ecosystems. *Pacific Conservation Biology* 1 194-200

Greenberg, J. B. and T. K. Park. 1994. Political Ecology. *Journal of Political Ecology* 1 1-12

Hajer, M. 1995. *The Politics of Environmental Discourse: Ecological Modernization and the Policy Process*. Oxford: Clarendon Press.

Hall, M. D., S. R. Donohoe, F. Williams, J. S. Pearson and M. E. Church. 1907. *Industrial and Historical Sketch of Fairfax County Virginia*. Alexandria: The County Board of Supervisors.

Harold, M., N. Goldstein and K. Clarke. 2003. The Spatiotemporal Form of Urban Growth: Measurement, Analysis and Modeling. *Remote Sensing of the Environment* 86 286-302

Harvey, D. 1996. *Justice, Nature and the Geography of Difference*. Cambridge: Blackwell Publishers Ltd.

Hawks, L. J., F. W. Cubbage, H. L. Haney, R. M. Shaffer and D. H. Newman. 1993. Forest water quality protection: a comparison of regulatory and voluntary programs. *Journal of Forestry* 91 (3): 48-54

Hiebert, R. E. and R. K. MacMaster. 1976. *A Grateful Remembrance: the Story of Montgomery County Maryland*. Rockville: Montgomery County Government and the Montgomery County Historical Society.

Hirt, P. W. 1994. *A Conspiracy of Optimism: Management of the National Forests since World War II*. Lincoln, NE: University of Nebraska Press.

Horton, T. 2003. *Turning the Tide: Saving the Chesapeake Bay*. Washington, DC: Island Press.

Huang, C., L. Yang, B. Wylie and C. Homer. 2001. A strategy for estimating tree canopy density using Landsat 7 ETM+ and high resolution images over large areas. Third International Conference on Geospatial Information in Agriculture and Forestry, November 5-7. Denver. http://www.mrlc.gov/mrlc2k_nlcd.asp.

Jackson, J. B. 1984. *Discovering the Vernacular Landscape*. New Haven: Yale University Press.

Jantz, C. A. 2000. Land Use History and Planning in Montgomery County, MD and Fairfax County, VA: Implications for Landscape Patterns and Forest

Fragmentation. *Occasional Publications of the Department of Geography* 2000-02 52

Jantz, P. A., S. J. Goetz and C. A. Jantz. In press. Urbanization and the loss of resource lands in the Chesapeake Bay watershed. *Environmental Management*

Jenerette, G. D. and J. Wu. 2001. Analysis and Simulation of Land-use Change in the Central Arizona-Phoenix Region, USA. *Landscape Ecology* 16 611-626

Johnston, R. J., P. J. Taylor and M. J. Watts, eds. 1995. *Geographies of Global Change: Remapping the World in the Late Twentieth Century*. Cambridge: Blackwell Publishers, Ltd.

Jones, K. B., K. H. Riitters, J. D. Wickham and J. Roger D. Tankersley. 1997. *An Ecological Assessment of the United States Mid-Atlantic Region: A Landscape Atlas*. Washington, D.C.: Environmental Protection Agency Office of Research and Development.

Kaimowitz, D. and A. Angelsen. 1998. *Economic Models of Tropical Deforestation: A Review*. Bangor, India: Center for International Forestry Research.

Kaplan, R. 1983. The Role of Nature in the Urban Context. In *Behavior and the Natural Environment*, ed. I. Altman and J. F. Wohlwill, New York: Plenum Press.

Kempton, W., J. S. Boster and J. A. Hartley. 1995. *Environmental Values in American Culture*. Cambridge: MIT Press.

Knox, P. L. 1993. The Postmodern Urban Matrix. In *The Restless Urban Landscape*, ed. P. Knox, 207-236. Englewood Cliffs: Prentice-Hall, Inc.

Kok, K., A. Farrow, A. Veldkamp and P. H. Verburg. 2001. A Method and Application of Multi-scale Validation in Spatial Land Use Models. *Agriculture, Ecosystems and Environment* 85 223-238

Kok, K. and A. Veldkamp. 2001. Evaluating the Impact of Spatial Scales on Land Use Pattern Analysis in Central America. *Agriculture, Ecosystems and Environment* 85 205-221

Kraft, M. E. and N. J. Vig. 1997. Environmental Policy from the 1970s to the 1990s: An Overview. In *Environmental Policy in the 1990s*, ed. M. E. Kraft and N. J. Vig, Washington, DC: Congressional Quarterly Inc.

Krummel, J. R., R. H. Gardner, G. Sugihara and R. V. O'Neill. 1987. Landscape Patterns in a Disturbed Environment. *Oikos* 48 (3): 321-324

Lammers, C. A. and M. P. Knapp. 1999. Illustrating the need for urban forest management. Proceedings of the 8th National Urban Forest Conference. Atlanta, GA. American Forests: Washington, DC.

Landis, J. D. 1995. Imagining Land Use Futures: Applying the California Urban Futures Model. *Journal of the American Planning Association* 61 (4): 438-457

Lee, S. and J. Choi. 2004. Landslide susceptibility mapping using GIS and the weight of evidence model. *International Journal of Geographical Information Science* 18 (8): 789-814

Leonard, T. and J. S. J. Hsu. 1990. *Bayesian Methods: an Analysis for Statisticians and Interdisciplinary Researchers*. Cambridge: Cambridge University Press.

Lewis, P. 1979. Axioms for Reading the Landscape: Some Guides to the American Scene. In *The Interpretation of Ordinary Landscapes*, ed. D. W. Meinig, 11-32. New York: Oxford University Press.

Lutz, A. R. and P. Simpson-Housley. 1999. Wilderness: Rural and Urban Attitudes and Perceptions. *Environment and Behavior* 31 (2): 259-266

Machlis, G. E. and J. E. Force. 1997. The Human Ecosystem Part I: the Human Ecosystem as an Organizing Concept in Ecosystem Management. *Society and Natural Resources* 10 (4): 347-368

Macionis, J. J. and V. N. Parrillo. 1998. *Cities and Urban Life*. Upper Saddle River: Prentice-Hall, Inc.

Manheimer, S. 1999. *Fairfax County Data: Fairfax County U.S. Census of Agriculture*. Richmond, VA: Virginia Agricultural Statistics Service. http://www.nass.usda.gov/va/censusest.htm.

Maryland Department of Natural Resources. 2000. History of Maryland State Parks. http://www.dnr.state.md.us/publiclands/sfpshistory.html (last accessed July 31 2000).

Maryland Department of Natural Resources. 2003a. Forest Service Vision, Mission and Goals. http://www.dnr.state.md.us/forests/mission.html (last accessed August 26 2003a).

Maryland Department of Natural Resources. 2003b. *Maryland's Land Conservation Programs: Protecting the Chesapeake Bay Watershed*. Annapolis: Maryland Department of Natural Resources. http://www.dnr.state.md.us/download/mdlandconprog.pdf.

Maryland Department of Natural Resources. 2003c. *Maryland's Strategic Forest Lands Assessment*. Annapolis: Maryland Department of Natural Resources Watershed Services and the Maryland Forest Service. http://www.dnr.state.md.us/forests/download/sfla_report.pdf.

Maryland Department of Natural Resources. 2004a. A Brief History of the Forest Service. http://www.dnr.state.md.us/forests/aghistory.html (last accessed August 26 2004a).

Maryland Department of Natural Resources. 2004b. Forestry Boards. http://www.dnr.state.md.us/forests/programapps/fboards.html (last accessed August 26 2004b).

Maryland Department of Natural Resources. 2004c. Maryland Seed Tree Law. http://www.dnr.state.md.us/forests/programapps/treelaw.html (last accessed August 2 2004c).

Maryland Department of Natural Resources. 2004d. Program Open Space. http://www.dnr.state.md.us/pos.html (last accessed August 2 2004d).

Maryland Department of Planning. 1999. MdProperty View Technical Specifications.

Maryland National Capital Parks and Planning Commission. 1957. *Inventory of Land Use: Maryland-Washington Regional District, Montgomery and Prince George's Counties, Maryland*. Riverdale: Maryland-National Capital Park and Planning Commission.

Maryland-National Capital Park and Planning Commission. 1964. *On Wedges and Corridors...A General Plan for the Maryland-Washington Regional District in Montgomery and Prince George's Counties*. Riverdale: The Maryland-National Capital Park and Planning Commission.

Maryland-National Capital Parks and Planning Commission. 1964. *On Wedges and Corridors...Updated General Management Plan for Maryland-Washington Regional District in Montgomery County Maryland*. Montgomery County Department of Parks and Planning.

Maryland-National Capital Parks and Planning Commission. 1994. *Trees: Approved Technical Manual*. Silver Spring: Maryland-National Capital Parks and Planning Commission. http://www.mc-mncppc.org/environment/forest/trees/toc_trees.shtm.

Maryland-National Capital Parks and Planning Commission. 2001. *Plowing New Ground: Questions and Answers Agricultural and Rural Open Space Preservation Program, Montgomery County Maryland*. Silver Spring: Community Based Planning - Rural Team. http://www.mc-mncppc.org/community/plan_areas/rural_area/related_reports/plowing_newground/toc.shtm.

Matlack, G. R. 1993. Sociological Edge Effects: Spatial Distribution of Human Impact in Suburban Forest Fragments. *Environmental Management* 17 (6): 829-835

McElfish, J. M. and J. B. Wilkonson. 2000. *Forests for the Bay*. Washington, DC: Environmental Law Institute.

McGarigal, K. and B. J. Marks. 1994. FRAGSTATS: Spatial Pattern Analysis Program for Quantifying Landscape Structure, 2.0.

McHugh, F. D. 1954. *Land Uses-1953 Fairfax County, VA*. Fairfax: Fairfax County Planning Commission.

Meadows, D. H. and et. al. 1972. *The Limits to Growth: a Report for the Club of Rome's Project on the Predicament of Mankind*. New York: Universe Books.

Mitchell, D. 1996. Sticks and Stones: The Work of Landscape (A Reply to Judy Walton's "How Real(ist) Can you Get?"). *Professional Geographer* 48 (1): 94-96

Montgomery County Commission on Zoning and Planning Law Procedure. 1965. *Report of the Commission on Zoning and Planning Procedures*. Silver Spring: Montgomery County Council.

Montgomery County Planning Board. 1973. *Managing Our Future: An Approach to Urban Growth Policy for Montgomery County*. 1. Silver Spring: The Maryland-National Capital Parks and Planning Commission.

Netherton, N. and D. Sweig. 1978. *Fairfax County, Virginia: A History*. Fairfax: Fairfax County Board of Supervisors.

Obeysekera, J. and K. Rutchey. 1997. Selection of Scale for Everglades Landscape Models. *Landscape Ecology* 12 (1): 7-18

Office of the County Attorney Fairfax County Government. 1974. *A Brief History of Planning, Zoning and Environmental Constraints in Fairfax County, Virginia*. 1. Fairfax: County of Fairfax.

O'Neill, R. V., J. R. Krummel, R. H. Gardner, G. Sugihara, B. Jackson, D. L. DeAngelis, B. T. Milne, M. G. Turner, B. Zygmunt, S. W. Christensen, V. H. Dale and R. L. Graham. 1988. Indices of Landscape Pattern. *Landscape Ecology* 1 (3): 153-162

Paehlke, R. C. 1997. Environmental Values and Public Policy. In *Environmental Policy in the 1990s*, ed. N. J. Vig and M. E. Kraft, Washington, DC: Congressional Quarterly Inc.

Peet, R. 1996. Discursive Idealism in the "Landscape-as-Text" School. *Professional Geographer* 48 (1): 96-98

Peet, R. and M. Watts, eds. 1996. *Liberation Ecologies: Environment, Development, Social Movements*. London: Routledge.

Peters, T. S. 1974. *The Politics and Administration of Land Use Control: The Case of Fairfax County, Virginia*. Lexington: Lexington Books.

Platt, R. H. 1991. *Land Use Control: Geography, Law, and Public Policy*. Englewood Cliffs, NJ: Prentice Hall.

Prichard, E. A. and G. A. Riegle. 1999. Searching for Certainty: Virginia's Evolutionary Approach to Vested Rights. *George Mason Law Review* 7 983

Prudham, S. 2003. Taming Trees: Capital, Science, and Nature in Pacific Slope Tree Improvement. *Annals of the Association of American Geographers* 93 (3): 636-656

Prudham, W. S. 1998. Timber and Town: Post-War Federal Forest Policy, Industrial Organization, and Rural Change in Oregon's Illinois Valley. *Antipode* 30 (2): 177-196

Purcell, M. 2001. Neighborhood Activism among Homeowners as a Politics of Space. *Professional Geographer* 53 (2): 178-195

Reichman, O. J. and H. R. Pulliam. 1995. The Scientific Basis for Ecosystem Management. *Ecological Applications* 6 (3): 694-696

Risser, P. G. 1999. Landscape Ecology: Does the Science Only Need to Change at the Margin? In *Landscape Ecological Analysis: Issues and Applications*, ed. J. M. Klopatek and R. H. Gardner, 3-10. New York: Springer-Verlag.

Rowntree, L. B. 1996. The Cultural Landscape Concept in American Human Geography. In *Concepts in Human Geography*, ed. C. Earle, K. Mathewson and M. S. Kenzer, 127-160. Lanham, MD: Rowman and Littlefield Publishers, Inc.

Sanders, P. D., W. H. King, G. Gray, R. S. Burruss, J. Glick, L. J. Spangler and J. H. Wheeler. 1955. *Forest Resources of Virginia: Report of the Commission to the Governor and the General Assembly of Virginia*. Senate Document No. 6. Richmond: Virginia General Assembly.

Sauer, C. O. 1969 (1925). The Morphology of Landscape. In *Land and Life: a Selection from the Writings of Carl Ortwin Sauer*, ed. J. Leighly, 315-350. Berkeley: University of California Press.

Sauer, C. O. 1969 (1956). The Education of a Geographer. In *Land and Life: a Selection from the Writings of Carl Ortwin Sauer*, ed. J. Leighly, 389-406. Berkeley: University of California Press.

Scheffer, V. B. 1991. *The Shaping of Environmentalism in America*. Seattle: University of Washington Press.

Schein, R. M. 1997. The Place of Landscape: A Conceptual Framework for Interpreting an American Scene. *Annals of the Association of American Geographers* 87 (4): 660-680

Setright, N. 1954. *Land Use: Upper Montgomery County Planning District, Maryland*. Rockville: Upper Montgomery County Planning Commission, Upper Montgomery County Planning Division.

Slocombe, D. S. 1993. Implementing Ecosystem-based Management. *BioScience* 43 (9): 612-622

Smedley, T., J. W. White and Student Legal Research Group of the University of Virginia Research Group. 1962. *Preserving Open Space in Fairfax County*. Fairfax County: Fairfax County Planning Division, Master Plan Section.

Smith, N. 1984. *Uneven Development: Nature, Capital, and the Production of Space*. Oxford: Blackwell.

Soares-Filho, B. S., G. C. Cerqueira and C. L. Pennachin. 2002. DINAMICA--a Stochastic Cellular Automata Model Designed to Simulate the Landscape Dynamics in an Amazonian Colonization Frontier. *Ecological Modeling* 154 217-235

Stamps, A. E. 1997. Some streets of San Francisco: preference effects of trees, cars, wires, and buildings. *Environment and Planning B: Planning and Design* 24 81-93

State Department of Forestry. 1932. *Maryland Forest Laws*. Leaflet 15. Baltimore: University of Maryland.

Stream Releaf Coordinating Committee. 1998. *Maryland Stream Releaf Implementation Plan*. Annapolis: Maryland Department of Natural Resources. http://www.dnr.state.md.us/forests/streamreleaf.html.

Taylor, P. D., L. Fahrig, K. Henein and G. Merriam. 1993. Connectivity is a Vital Element of Landscape Structure. *Oikos* 68 (3): 571-573

The Chesapeake Bay Program. 2004. *The State of the Chesapeake Bay and its Watershed: A Report to the Citizens of the Bay Region*. CBP/TRS 273/05 EPA 903-R-04-009. Annapolis: The Chesapeake Bay Program.

Thompson, J. T., D. Feeney and R. J. Oakerson. 1992. Institutional Dynamics: The Evolution and Dissolution of Common-Property Resource Management. In *Making the Commons Work: Theory, Practice and Policy*, ed. D. W. Bromley, San Francisco: Institute for Contemporary Studies.

Trees Virginia. 2004. Virginia Urban Forest Council. http://www.treesvirginia.org/ (last accessed August 2 2004).

Trenk, F. B. 1929. *Profitable Management of the Young Forest*. Baltimore: University of Maryland State Department of Forestry.

Turner, M. G. 1990. Landscape Changes in Nine Rural Counties in Georgia. *Photogrammetric Engineering and Remote Sensing* 56 (3): 379-386

Turner, M. G., R. H. Gardner and R. V. O'Neill. 2001. *Pattern and Process: Landscape Ecology in Theory and Practice*. New York: Springer-Verlag.

Turner, M. G., D. N. Wear and R. O. Flamm. 1996. Land Ownership and Land-Cover Change in the Southern Appalachian Highlands and the Olympic Peninsula. *Ecological Applications* 6 (4): 1150-1172

U.S. Department of Agriculture. 1963. *Farm Taxes on the Rural-Urban Fringe: A Case Study of Fairfax County, Virginia*. ERS-102. Washington, D.C.: Farm Production Economics Division, Economic Research Service.

U.S. Environmental Protection Agency. 1991. *Guidance for Water-Quality-Based Decisions: The TMDL Process*. EPA 440/4-91-001. Washington, DC: U.S. Environmental Protection Agency Watershed Branch Assessment and Watershed Protection Division. http://www.epa.gov/OWOW/tmdl/decisions/.

U.S. Environmental Protection Agency. 2002. Introduction to the Clean Water Act. http://www.epa.gov/watertrain/cwa/ (last accessed January 1, 2003 2002).

Verburg, P. H., J. R. R. v. Eck, T. C. M. d. Nijs, M. J. Dijst and P. Schot. 2004. Determinants of Land-use Change Patterns in the Netherlands. *Environment and Planning B: Planning and Design* 31 (1): 125-150

Verburg, P. H., H. G. J. d. Koning, k. Kok, A. Veldekamp and J. Priess. 2001. The CLUE Modeling Framework: An Integrated Model for the Analysis of Land Use Change. In *Land Use and Cover Change*, ed. R. B. Singh, J. Fox and Y. Himiyama, Enfield, NH: Science Publishers.

Virginia Department of Forestry. 2004. Seed Tree Law and Reforestation of Timberlands. http://www.dof.virginia.gov/mgt/va-seed-tree-law.shtml (last accessed August 2 2004).

Virginia Riparian Forest Buffer Panel. 1998. *Riparian Buffer Implementation Plan*. Charlottesville: Virginia Department of Forestry. http://www.dof.virginia.gov/rfb/rfb-98-imp-plan.shtml.

Virginia State Forester. 1942. *Major Forest Problems in Virginia and a Plan to Maintain Forest Lands in the State in a More Productive Condition*. Richmond: Virginia Forest Service.

Waggoner, P. E. and J. D. Ovington. 1962. *Proceedings of the Lockwood Conference on the Suburban Forest and Ecology*. Bulletin 652. New Haven, CT: The Connecticut Agricultural Experiment Station.

Walker, R. and W. Solecki. 2004. Theorizing Land-Cover and Land-Use Change: The Case of the Florida Everglades and Its Degradation. *Annals of the Association of American Geographers* 94 (2): 311-328

Wallace, M. G., H. J. Cortner, M. A. Moote and S. Burke. 1996. Moving Toward Ecosystem Management: Examining a Change in Philosophy for Resource Management. *Journal of Political Ecology* 3 1-36

Walton, J. 1995. How Real(ist) Can You Get? *Professional Geographer* 47 (1): 61-65

Weaver, T. 2000. Changes in Forestry Policy, Production, and the Environment in Northern Mexico: 1960-2000. *Journal of Political Ecology* 7 1-18

Weiland, P. S. 1999. Preemption of Local Efforts to Protect the Environment: Implications for Local Government Officials. *Virginia Environmental Law Journal* 18 467

Wickham, J. D., R. V. O'Neill and K. B. Jones. 2000. Forest Fragmentation as an Economic Indicator. *Landscape Ecology* 15 171-179

Wiens, J. A. 1989. Spatial Scaling in Ecology. *Functional Ecology* 3 385-397

Wiens, J. A. 1992. What is Landscape Ecology, Really? *Landscape Ecology* 7 149-150

Wiens, J. A. 1999. The Science and Practice of Landscape Ecology. In *Landscape Ecological Analysis: Issues and Applications*, ed. J. M. Klopatek and R. H. Gardner, New York: Springer-Verlag Inc.

Williams, M. 1989. *Americans and Their Forests: A Historical Geography*. Cambridge: Cambridge University Press.

With, K. A., R. H. Gardner and M. G. Turner. 1997. Landscape Connectivity and Population Distributions in Heterogeneous Environments. *Oikos* 78 (1): 151-169

Zube, E. H. 1987. Perceived Land Use Patterns and Landscape Values. *Landscape Ecology* 1 (1): 37-45

CURRICULUM VITAE

CLAIRE A. JANTZ

May 2005

RESEARCH INTERESTS

Forest use and policy; land use change modeling; socio-economic factors of land use change; political ecology; spatial analysis; the application of Geographic Information Systems (GIS) and the integration of remotely sensed data to study social-environmental problems.

EDUCATION

Ph.D. (2005), Geography, University of Maryland, College Park

Dissertation title: Analyzing forest change and policy in Washington, DC suburban counties

M.A. (2000), Geography, University of Maryland, College Park

Concentrations: Cultural ecology, biogeography

Scholarly paper: Land use history and planning in Montgomery County, MD and Fairfax County, VA: Implications for landscape patterns and forest fragmentation

B.A. (1997), Summa Cum Laude, University of Tennessee, Knoxville

Major: College Scholar Program, concentration in Ecology and Anthropology

Senior thesis: Cades Cove: an environmental history

EMPLOYMENT

- Research Associate, The Woods Hole Research Center. Woods Hole, MA (July 2003-present).
- Research Assistant, Mid-Atlantic Regional Earth Science Applications Center (RESAC). College Park, MD (August 1999-July 2003)
- Teaching Assistant, Department of Geography, University of Maryland. College Park, MD (August 1998-July 2003).
- Undergraduate Advisor, Department of Geography, University of Maryland. College Park, MD (August 2000-May 2004).
- Social Science Aide, Great Smoky Mountains National Park. Gatlinburg, TN (June 1997-August 1997).
- Field Assistant, University of Tennessee. Knoxville, TN (May 1996-August 1996).

PEER REVIEWED PUBLICATIONS

Jantz, P.A., S. J. Goetz and C.A. Jantz (in press). Urbanization and the loss of resource lands in the Chesapeake Bay watershed. *Environmental Management.*

Jantz, C.A. and S.J. Goetz (2005). Analysis of scale dependencies in an urban land use change model. *International Journal of Geographical Information Science* 19 (2): 217-241.

Dougherty, M, R.L. Dymond, S.J. Goetz, C.A. Jantz and N. Goulet (2004). Evaluation of impervious surface estimates in a rapidly urbanizing watershed. *Photogrammetric Engineering and Remote Sensing* 70 (11): 1275-1284.

Claggett, P.R, C.A. Jantz, S.J. Goetz, and C. Bisland (2004). Assessing development pressure in the Chesapeake Bay watershed: an evaluation of two land use change models. *Environmental Monitoring and Assessment* 94: 129-146.

Jantz, C.A., S.J. Goetz, and M. K. Shelley (2003). Using the SLEUTH urban growth model to simulate the impacts of future policy scenarios on urban land use in the Baltimore-Washington metropolitan area. *Environment and Planning B* 31 (2): 251-271.

BOOK CONTRIBUTIONS

Elvidge, C., P. C. Sutton, T. W. Wagner, R. Ryznar, S. J. Goetz, A. J. Smith, C. Jantz, K. C. Seto, M. L. Imhoff, Y. Q. Wang, C. Milesi, and R. Nemani. (2004). Urbanization. In *Land Change Science: Observation, Monitoring, and Understanding Trajectories of Change on the Earth Surface*. Eds. G. Gutman, D. Skole, and C. Justice. Springer, New York.

Goetz, S. J., D. Varlyguin, A. J. Smith, R. K. Wright, S. D. Prince, M. E. Mazzacato, J. Tringe, C. Jantz, and B. Melchoir. 2004. Application of multitemporal Landsat data to map and monitor land cover and land use change in the Chesapeake Bay watershed. In *Analysis of Multi-temporal Remote Sensing Images*, pp. 223-232. Eds. P. Smits and L. Bruzzone. World Scientific Publishers, Singapore.

Goetz S. J., Jantz C. A., Prince S. D., Smith A. J., Wright R. and Varlyguin D. 2004. Integrated analysis of ecosystem interactions with land use change: the Chesapeake Bay watershed. In *Ecosystems and Land Use Change*, pp. 263-275. Eds. R. S. DeFries, G. P. Asner & R. A. Houghton. Geophysical Monograph Series, American Geophysical Union, Washington DC.

Jantz, C.A. (2002). "Cades Cove: reconstructing human impacts on the environment prior to Euroamerican settlement." In *Culture, Environment and Conservation in the Appalachian South*. Ed. Benita J. Howell. University of Illinois Press, Champagne.

CONFERENCE PROCEEDINGS

Jantz, C.A., S.J. Goetz, P.A. Jantz and B. Melchior (2005). Resource land loss and forest vulnerability in the Chesapeake Bay Watershed. Proceedings of the 4th Southern Forestry GIS Conference, 15-19 December.

Goetz, S.J., A.J. Smith, C. Jantz, R.K. Wright, M.E. Mazzacato, and B. Melchoir (2003). Monitoring and modeling urban land-use change using multi-temporal satellite data. Proceedings of the International Geoscience and Remote Sensing Symposium (IGARSS), 21 July.

RESEARCH GRANTS

Goetz, S.J. and C.A. Jantz (co-investigator) (2003). Modeling the effects of land use policies on urban land use patterns in Maryland. National Center for Smart Growth Research and Education Small Grants Program, University of Maryland, College Park, MD. $20,000.00.

Goetz, S.J. and C.A. Jantz (co-investigator) (2004-2006). Modeling the rates and spatial patterns of future land use change in the Chesapeake Bay watershed. Chesapeake Bay Program, US Environmental Protection Agency. $100,000.

RECENT PRESENTATIONS

Jantz, C.A. and M.E. Geores (2005). Defining the suburban forest across space and time: a multi-scale analysis of forest management policies in the Washington, DC suburbs. Association of American Geographers Annual Meeting. Denver, CO.

Jantz, C.A., S.J. Goetz, J. Opton-Himmel (2005). Vulnerability of National Parks to "sprawl:" a regional analysis in the eastern United States. George Wright Society. Philadelphia, PA.

Jantz, C.A., S.J. Goetz, P.A. Jantz, and B. Melchoir (2005). Resource land loss and forest vulnerability in the Chesapeake Bay Watershed. Ecological Society of America, Mid-Atlantic Division. Baltimore, MD.

Jantz, C.A., S.J. Goetz, P.A. Jantz, and B. Melchoir (2004). Resource land loss and forest vulnerability in the Chesapeake Bay Watershed. Southern Forestry and GIS Conference. Athens, GA.

Jantz, C.A. and S.J. Goetz (2004). Modeling and assessing urban land use change in the mid-Atlantic region. The International Association of Landscape Ecology United States Regional Association, 19th Annual Symposium. Las Vegas, NV.

Jantz, C.A., S.J. Goetz, and N. Bockstael (2004). Towards an integrated approach to modeling sprawl in the mid-Atlantic region. Association of American Geographers Annual Meeting. Philadelphia, PA.

Jantz, C.A., S.J. Goetz, N. Bockstael, and B. Melchior (2003). Prediction of future growth in the Chesapeake Bay watershed using models calibrated with satellite observations. Mid-Atlantic Land Use/Land Cover Conference. Towson, MD.

Jantz, C.A. (2003). Using aerial photographs to analyze the changing suburban landscape, 1937-1998. Social Science History Association. Baltimore, MD.

Claggett, P.R., C.A. Jantz, S.J. Goetz, S. Painton-Orndorff, and M. Martinez (2003). Assessing the vulnerability of resource lands in the Chesapeake Bay watershed. EPA ReVA-MAIA Conference: Using Science to Assess Environmental Vulnerabilities. King of Prussia, PA.

Jantz, C.A., S.J. Goetz, and A.J. Smith (2003). Mapping and modeling land use change in the Baltimore-Washington, DC area: tools for regional planning in the Chesapeake Bay watershed, USA. Framing Land Use Dynamics International Conference. Utrecht University, Netherlands.

STUDENT PAPER AWARDS

First place winner, student paper competition. Jantz, C.A. (2000). Land use, history and planning in Montgomery County, MD and Fairfax County, VA: implications for landscape patterns and forest fragmentation. Annual Meeting, Mid-Atlantic Division of the Association of American Geographers. Washington, D.C.

Second place winner, student paper competition. Jantz, C.A. (2001). Understanding forest change in northern Virginia: a case study. Annual Meeting, Mid-Atlantic Division of the Association of American Geographers. Frostburg, MD.

Third place winner, student paper competition. Jantz, C.A. (2001). Land use, history and planning in Montgomery County, MD and Fairfax County, VA: implications for landscape patterns and forest fragmentation. 11th Annual Graduate Research Interaction Day, University of Maryland. College Park, MD.

SCHOLARSHIPS AND AWARDS

Recipient of the College of Behavioral and Social Sciences Outstanding Advisor Award (2003). University of Maryland, College of Behavioral and Social Sciences.

Recipient of the Outstanding Teaching Assistant of the Year Award (2000). University of Maryland, Department of Geography.

Recipient of the Alvin H. Nielsen Scholarship in Arts and Science (1996). University of Tennessee, Knoxville, TN.

SERVICE

Graduate Student Representative for the Geography Undergraduate Committee, University of Maryland, 2001-2003.

Graduate Student Representative for the Geography Faculty Search Committee, University of Maryland, 2000 and 2001.

Graduate Student Representative for the Geography Chair Search Committee, University of Maryland, 2000.

Graduate Student Representative for the Geography Faculty Committee, University of Maryland, 2000.

PROFESSIONAL MEMBERSHIPS AND HONOR SOCIETIES

Association of American Geographers (AAG)
American Geophysical Union (AGU)
International Association for Landscape Ecology (IALE)
Social Science History Association (SSHA)
Phi Beta Kappa National Honor Society
Golden Key National Honor Society
Phi Kappa Phi National Honor Society