EXPLORING INTERACTIONS BETWEEN LANDSCAPE CHANGE AND LAND PRESERVATION

by

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ABSTRACT OF THE DISSERTATION

Exploring Interactions between Landscape Change and Land Preservation

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The creation of land preservation policies are, in part, a response to real and perceived landscape changes. Those landscape changes continue after the preservation policies are implemented. This study examines the interaction between landscape change and land preservation in the context of assessing how ongoing land use/land cover change may be impacting the capacity of land preservation programs to meet their goals. It focuses on two New Jersey counties, Hunterdon and Burlington, using multiple years of land use/land cover data (1986, 1995, 2002 and 2007) to assess change.

Major findings include:

- In both counties, agricultural land is developed more than expected at random, and upland forest developed less than expected
- A small but significant proportion of land in each county transitions from agriculture to upland forest before being developed
- 45% of agricultural land loss in Hunterdon and 16% in Burlington is the result of agricultural converting to upland forest, which impacts the amount land eligible for farmland preservation

- Simple measures of landscape change underestimate the amount flux in upland forest, meaning that mature upland forests are more threatened than those simple measures suggest
- Measures of landscape fragmentation show that upland and wetland forests are suffering from fragmentation, which decreases their ecological integrity
- Preserving and establishing the contiguity of farmland, parkland and wildlife habitat- all major goals of land preservation – are being made more difficult by the patterns of development in both counties
- In both counties, a significant percentage of preserved emergent wetland are found on preserved farmland
- Certain areas targeted for preservation are developing faster than other targeted areas in both counties – grasslands and conservation areas in Hunterdon, greenway target areas in Burlington, and farmland eligible for preservation in both counties

The study shows how pre – and post-implementation assessment of land use/land cover change provides important information that can be used to adjust the targets and goals of land preservation policies to make them more effective. Furthermore, the study confirms the importance of having multiple, commensurate sets of land use/land cover data spanning a multi-decade period. Further research will include integrating new land use/land cover data into the analysis.

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Portions of Chapter 2 appeared in Myers (2005).

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Chapter 1 – Introduction

Landscape change is rapidly becoming an important area of inquiry in many fields. Researchers from disciplines as varied as geography, ecology, economics and planning have examined the causes and consequences of landscape change over a range of scales and at locations around the world (Antrop 2004, Muir 2003, Osaragi and Kurisaka 2000, Zebisch et al. 2004) . Such attention is the result of a confluence of factors. Landscape change has continued to accelerate with increasing human population (Krausmann et al. 2003). Compounding the increase in human population is an increase in per capita land consumption. In urbanizing areas the increasingly extensive nature of land use manifests itself most visibly as the diffuse form of development colloquially known as sprawl (Theobald 2001), while deforestation and conversion of natural vegetation to agricultural production is common in rural areas (Turner 2002). Growing awareness of landscape change and its consequences has also resulted from recent technological advances that have increased our capacity to monitor and analyze landscape change (Marceau et al. 2001). Satellite imagery provides a relatively inexpensive and continually updated source of land cover data. Geospatial technologies such geographic information systems allow this data to be analyzed both alone and in conjunction with other data sources. New approaches to modeling landscape change have grown out of these new technologies as well (e.g. Bradshaw and Muller 1998, Brown et al. 2002).

A variety of social and political responses to landscape change have been implemented. Land preservation programs that preserved undeveloped land by purchase of the land or its development rights are particularly common in the United States (Alterman 1997, Bengston et al. 2004). These programs often focus on preserving farmland to retain agricultural capacity or on preserving undeveloped open space for recreation or conservation purposes. By purchasing properties or their development rights, these programs permanently preserve land and have long term effects on the landscape. This suggests that the relationship between landscape change and land preservation is not one-way, with land preservation programs simply being implemented because of landscape change. Rather, there exists a two-way interaction between landscape change and land preservation. Initially, land preservation programs may simply be responses to landscape change, but as they are implemented they themselves becomes drivers of landscape change.

There are a number of reasons why the consequences of land preservation programs and their interactions with landscape change should be studied. The amount of public funds being directed at land preservation exceeds several billion dollars annually and has been steadily increasing in the previous decade (Landvote 2004). This figure does not include the value of lands or conservation easements donated to governments or non-profit groups, for which significant tax-savings are usually received. The public, of course, expects to accrue benefits from these programs (Kline and Wichelns 1998). Given the magnitude of the expenditure, research that answers basic questions of effectiveness as well that which examines more subtle ramifications is warranted. Furthermore, since they are, in part, a response to landscape change, land preservation programs play an important role in many growth management plans (Bengston et al. 2004). While managing growth, many land preservation programs are also designed to produce numerous environmental benefits, such as protecting groundwater and surface water quality and quantity, preserving rare habitats and species and providing aesthetic value. Evaluating whether land preservation programs are meeting these goals obviously demands a spatially based analysis. The potential for interaction between landscape change and land preservation programs means that landscape change must be considered when analyzing the consequences of these programs.

This study seeks to further our understanding of the interactions between landscape change and land preservation by pursuing an in-depth study of these interactions in two New Jersey counties. The central hypothesis of this study is that ongoing landscape change has an impact on land preservation programs' capacity to meet their goals. To explore this hypothesis, the study examines landscape change in Hunterdon and Burlington counties in New Jersey and details how that change is adversely impacting areas targeted for land preservation. The possibility of preserved land attracting development to its margins is also examined. A case is also made for the need to develop policy specific indicators of landscape change that directly measure change relevant to the policy analyzed based on the specific goals of the policy.

- Chapter 2 explores general issues of landscape change and its measurement, and presents a conceptual model for exploring landscape change and land preservation interactions.
- Chapter 3 argues the need for policy relevant indicators of landscape change, and outlines a process for generating such indicators.

- Chapter 4 introduces the study areas and discusses the various land preservation policies implemented in them.
- Chapter 5 details the landscape changes in the study areas by examining in detail the land use/land cover changes that have occurred in the past 30 years.
- Chapter 6 investigates the evidence of interactions between landscape change and open space preservation over the past 30 years
- Chapter 7 investigates the evidence of interactions between landscape change and farmland preservation over the past 30 years.
- Chapter 8 synthesizes the results of the previous chapters and assess the potential for the measured landscape change to impact land preservation policies.
- Chapter 9 offers conclusions and suggestions for future research.

It is hoped that the analyses conducted will result in a clearer picture of how landscape change impacts the implementation of land preservation programs in Hunterdon and Burlington. Furthermore, it is hoped that the results and conclusions can be utilized to make land preservation more efficient and effective at countering any negative impacts they suffer from the landscape change that occurs during their implementation. Because of the structure of land preservation in New Jersey, the methodologies, conclusions and recommendations will be applicable to the other counties in New Jersey. They should also be extensible to other areas if those areas have similar land preservation processes and land use/land cover data.

Chapter 2 – Landscape Change and Land Preservation

2.1 Introduction

Exploring the interactions between landscape change and land preservation requires an interdisciplinary perspective that incorporates theories, concepts and methods from landscape change science, environmental policy analysis and geographic information science. This chapter discusses the important theoretical and conceptual underpinnings of the research and reviews the relevant literature. It also introduces a conceptual model of the interactions between landscape change and land preservation that is used to structure the research.

2.2 Landscape Change

Studies of landscape change consider a variety of temporal scales, from millennial scale geomorphological (e.g., Kammerbauer and Ardon 1999) studies to decadal scale land-use studies (e.g., Schneider and Pontius 2001). The spatial scale of studies varies widely as well. Many studies that cover millennia look at change at a regional or subcontinental scale, because their data sources have limited spatial or temporal resolution and/or the processes being studied operate over large areas. In contrast, many studies that examine changes of one or several centuries are usually more limited in their extent (e.g., Skanes and Bunce 1997). This again is the result of processes of interest – land use impacts of specific human settlements, for example – and the spatial and temporal resolution of data sources (Luque 2000a). It also results from the fact that data sources describing landscape change at these scales can be difficult to find, time-consuming to extract information from and not commensurable with the data sources found in other areas for the same time period or in the same area for other time periods (Russell 1997).

The advent of geographic information and remote sensing technologies has allowed the spatial extent of short-term studies to significantly increase (Luque 2000a, Wickham et al. 1999). Relatively inexpensive satellite imagery now allows for decadal and even yearly analysis of land cover change at scales from the local to the global. This decoupling of the relationship between the spatial and temporal resolution of landscape change data has led to a profusion of new research focused on short-term landscape change (e.g., Ammissah-Arthur et al. 2000, Franklin et al. 2000, Lathrop and Bognar 2001). These studies are generally limited to change which has occurred over the past 3 decades, since that period marks the advent of readily available satellite imagery, although aerial photography or property records can provide commensurable information from the pre-satellite era.

Coincident with this scale shift and emphasis on remotely sensed data has been an increasing concern with anthropogenic landscape change. The time period for which suitable satellite imagery is available has seen a dramatic increase in human impacts on land cover, as well as increasing concern over their effects (Himiyama et al. 2002, Steffan et al. 2002). In the past decade the increasing capacity of geographic information technologies to integrate data from different sources has led to the combining of remotely sensed data with other sources of geographic information to produce more nuanced investigations that not only delineate landscape change but also incorporate additional data to model its causes and consequences (e.g., Amissah-Arthur 2000, Smits and Annoni 1999).

Landscape change studies that focus on anthropogenic change usually focus on accomplishing one or more of the following tasks:

- Quantifying change – Temporally successive and adequately commensurable sources of land cover data such as satellite and aerial photo imagery are analyzed (e.g. LaGro and DeGloria 1992, Franklin et al. 2000) to generate both simple and complex measures of change (O'Neill 1999). Important changes are not always categorized by complete modification of the landscape, for instance intensification of land use may be as important as a change in land cover (Lambin et al. 2000).

- Determining impacts of previous change – After quantifying landscape change, the impact of that quantified change is assessed for any number of characteristics, such as species and species habitat or higher level processes such as ecosystem function, stability and resilience, and aesthetic qualities of landscape (e.g. Luque 2000b).

- Determining causes of change – Empirical modeling techniques are often used to determine important variables associated with change in a particular area. The variables that are thought to be important are tested for significance using statistical methods (e.g. Kline and Alig 1999, Levia and Page 2000, Schneider and Pontius 2001).

- Modeling future change – Once the variables that seem to be driving landscape change have been tested for significance, empirical models are often extended to predict future change (e.g. Levia 1998, Verberg and Velkamp 2001). Baker (1989) differentiated between distributional and spatial models of landscape change. Distributional models summarize change over the study area but are not explicitly spatial. Since Baker's review, increasingly sophisticated geospatial technologies have resulted in the increasing prevalence of spatial explicit models. Cell (Li and Yeh, 200x) and agent based modeling (Pianjowski et al. 2001) have been used to model future change, requiring a rule-based or hybrid quantitative/rule-based approach. Agent and cell based models have also been hybridized to study landscape change (Parker et al. 2003). Alternatively, future change may be projected using current conditions as a starting point and current or potential constraints on change as rules governing change. Build-out analyses and many other spatially explicit policy analyses (Bradshaw and Muller 1998, Espejel et al. 1999, Musacchio and Coulson 2001) are examples of this type of substantially more qualitative landscape change modeling (Mcintosh 2003).

- Modeling impacts of future change – Models that predict or project future landscape change are often applied to assess impact of changes on entire landscape or components of interest (e.g. Musacchio and Coulson 2001).

Landscapes are dynamic in part because they are open systems, receiving inputs of energy, materials and organisms from beyond their boundaries (Wood and Handley 2001). Landscape change is an umbrella term that covers many different types of changes to different components of landscapes. The term covers alterations in the geomorphology of landscapes such as river channel migration, erosion and deposition. Many studies that investigate landscape changes focus on ecological considerations related to habitat extent, location and configuration. The forces which drive landscape changes can be either natural or anthropogenic in origin.

Changes in land use/land cover are among the most studied and most recognizable types of landscape change. Land use refers to the use to which humans put a particular area of land (e.g. residential, commercial, agricultural) while land cover refers to the nature of what is covering the earth's surface in a given area (forest, human development, grassland, emergent wetland) (Jensen 1996). Land use results from the interaction of physical, social, economic and legal factors within specific geographic contexts (Mather 1982). Alterations to land use and land cover constitute the primary way humans are modifying the environment (Turner 2002). Although only small areas may be affected by individual conversion episodes, the cumulative impact of these changes is enormous.

Land use/land cover (LULC) change can be described in a number of ways. Gross amounts or percentages of land use changes (e.g. development increased by 20% over a 20 year period) provide an idea of the magnitude of change in a given area, but they omit important information concerning the nature of the changes reported.

Transition matrices, for instance, show not just the gross magnitude of change, but also provide an indication of the trajectories of LULC (Pontius et al. 2004). These matrices show how much of one LULC type converted into another type during the period between two temporally distinct LULC mappings.

However, neither transition matrices nor gross changes describe the spatial components of the change. These components can be broken down into the spatial elements of the change itself and the spatial consequences of the change. Spatial elements of change include simple location (i.e. where has change occurred) as well as more complex spatial measures. Among these are descriptions of pattern or distribution of change (e.g. diffuse, linear, concentrated) without reference to other land use types. Some spatial elements of change describe the relationships between LULC change and existing landscape types (e.g. development occurring along roadways, or on formerly agricultural lands). The spatial consequences of the change are typically measured in relation to areas which did not change over the study period. These may include such consequences as reduced connectivity between forest patches or increased agricultural/development interface.

2.3 Landscape Metrics

In order to better understand the spatial patterns of land use and land use change, landscape ecologists and geographers have developed a number of landscape metrics. Landscape metrics are computed from the type, geometry and arrangement of land use patches. They can be computed on a per patch or per land use/cover class basis, or over the landscape as a whole. Landscape metrics can be categorized into four main types

(Herzog and Lausch 2001): patch metrics, edge-shape metrics, diversity metrics and landscape configuration metrics. Patch metrics measure the characteristics of contiguous areas of homogenous land use. These characteristics include size and number. Edge-shape metrics measure characteristics related to the amount of edge of a patch, class or landscape relative to its area, providing information about the fractal dimension of patches and classes. Diversity metrics use common measures of diversity derived from information science to determine the diversity and evenness of the land use classes present in a landscape. Landscape configuration metrics measure interspersion, dispersion and contagion among and between classes and over the landscape as a whole.

Landscape metrics have been widely adopted for use in many studies of landscape structure and function. However, their use is not without problem. Many landscape indices are significantly correlated with one another, producing similar values when measured in the same landscape. Riiters et al. (1995) crosscorrelated 55 landscape metrics measured across 85 landscapes, and then grouped metrics together that had correlations coefficients of 0.9 or greater. This resulted in 26 groups. After performing a principal components analysis on 26 variables (one from each group of correlated metrics), they concluded that 5 metrics, each of which had the highest loading on one of the first five principal components, could be used to capture much of the information found in the original 55 metrics considered.

Another concern with the use of landscape metrics lies in understanding the implications of what they measure. Landscape ecologists have been concerned about how to interpret the ecological and environmental significance of many landscape metrics (Li and Wu 2004). This is the methodological manifestation of one of the fundamental theoretical struggles of landscape ecology, the linking of pattern to process. Metrics are one very important way to measure landscape pattern but there has been much debate over the ecological consequences of the patterns they measure. Some metrics, such as patch size, have been shown to accurately predict the occurrence of edge-sensitive species (Bender et al. 1998) In her recent review of landscape ecology, Turner (2005) warns that metrics and the measurement of spatial pattern are tools, not ends to themselves, and that analysts must be careful to specify the objectives of the analysis a priori and must justify why the metrics they use the metrics they choose.

In areas where adequate LULC data exists or can be generated, landscape metrics can be an important tool for monitoring the impacts of landscape change. Applying metrics to time-series LULC data allows for more sophisticated measures of LULC change than examining only the rates of transition between LULC classes. For example, Hasse and Lathrop (2003) develop a set of land resource impact indicators for measuring urban sprawl. Their indicators include simple measures such as loss of wetlands and loss of prime farmland. These simple indicators are supplemented by more complex measures, including the density of new urbanization and the loss of core forest habitat. By making use of more sophisticated metrics (which in certain cases rely on ancillary data such as population soil quality data), Hasse and Lathrop (2003) conclude that a more detailed and nuanced interpretation of the impacts of LULC change is possible.

In general, metrics should be chosen that capture the structural properties of the landscape under study (Lausch and Herzog 2002). In most cases, remote sensing methods will need to be used to generate data, given the typical size of landscapes investigated. To ensure spatial and temporal compatibility, the metrics should be derived from remotely sensed data that has been generated and processed by a standardized methodology. Specific inquiries, of course, will require metrics that reflect the underlying reasons for the study as well. For instance, ecologically oriented studies will need to consider ecological relevant metrics (Gustafson 1998).

Landscape metrics are ideally suited to aid in the spatial analysis of the impact and efficacy of land policies and management. Controlling, restricting and reducing the negative impacts of LULC change is an important policy goal in many areas. Luque (2000b) provides an example of the utility of this approach. In her investigation of landscape change in the New Jersey Pinelands National Reserve, she found that forest area had increased in the most protected areas of the reserve, in accordance to management objectives in the reserve. At the same time, however, fragmentation of forested areas increased, which is not a desirable outcome. Using just landscape change data that specified to-from change between land use/cover classes alone would have lead to the conclusion that the management plan for the reserve was adequately controlling the adverse ecological impacts of landscape change. Examining fragmentation shows that this may not be the case. Chapter 3 discusses the development of policy relevant metrics of landscape change in further detail. The remainder of this chapter considers one of the primary social responses to real or perceived landscape change – the development and implementation of policies designed to prevent land from becoming developed.

2.4 Land Preservation Policies

The land preservation policies enacted to combat landscape change are among the suite of techniques for open space protection available to communities. Open space is a nebulous term that requires precise definition to be operational. In its most general sense, open space refers to any land that has not been converted to any human use that involves significant construction of buildings or the creation of large areas of impervious surface. In their review of open space preservation and urban growth management policies, Bengston et al. (2004) define open space as

> "natural resource lands such as farmland and timberland, environmental resources such as wildlife habitat and wetlands, and a variety of other socially valued landscapes such as scenic sites, wilderness areas, historic and cultural resources and recreation areas."

Other authors use to the term to refer specifically to areas of natural vegetation, areas in agricultural use, or a combination of both.

Such general definitions make no reference to the specific properties comprising the open space or to their ownership. They also fail to take into consideration the regulatory framework governing development, most notably zoning regulations. In some cases it is easy to determine whether a property could be considered open space. If a property is completely undeveloped and is covered in natural or semi-natural vegetation, clearly it is open space. Similarly, the traditional farm landscape of farmhouse, barn and outbuildings surrounded by fields and pasture is open space. Conversely, a residential subdivision of houses on 1 acre lots would not be considered open space under most definitions.

Many cases are not so easily classified, however. What about a residential development in a forested area consisting of 10 acre lots, or a farm where much of the farm consists of greenhouses and associated structures (see The Star Ledger 2/14/2008 for a case involving the leveling and removal of soil on preserved farmland for the construction of greenhouses)? In the case of large-lot developments it may be reasonable not to consider them open space since they usually represent the minimal lot size allowable by the zoning regulations in effect during the planning and building of the development. The greenhouse-covered farm represents an even more difficult case to classify. While clearly agricultural in purpose and use, and therefore meeting one of the criteria of generic definitions of open space (such as Bengston et al.'s (2004) above) it certainly doesn't fit the common public perception of open space. Also, such use has negative impacts one of the primary natural resources found on agricultural land, namely soils with agricultural utility. It also likely limits other on-farm environmental amenities such as the capacity to provide wildlife habitat and promote infiltration of rainwater into the soil.

General definitions of open space such as the one given above also conflate properties that are of interest because they are essentially undeveloped and those that are of interest because of cultural and/or historical significance. These later types of properties may be substantially or completely developed, and may be so small that there preservation would have little impact on open space preservation goals related to landscape aesthetics or ecological integrity. At this point, it becomes necessary to more formally consider programs that seek to preserve properties.

2.5 Land Preservation Programs

The research presented here focuses on programs that permanently protect land from significant development and the land so preserved. There is significant variation in how land preservation programs are designed and implemented. This, in part, reflects the fact that preservation programs serve a variety of purposes. Managing urban growth, protecting wildlife habitat, maintaining water quality, providing recreational opportunities and preserving farmland are among the myriad of purposes served by land preservation programs (Bengston et al. 2004). A single open space preservation program may attempt to serve one or, more likely, several of these purposes.

In order to differentiate between types of land preservation activities, a hierarchical definition of land preservation can be constructed. The most inclusive, subsequently referred to as preservation, covers any activity that prevents or substantially restricts the development of a parcel of land, including the preservation of properties that have historic and cultural significance because of the structures present. Activities comprising preservation can be classified as either land preservation activities or cultural/historical preservation activities. Cultural/historical preservation activities focus on properties that have significance because of events that took place and/or structures that are located on the property. In contrast, land preservation activities seek to preserve properties because of their resource, recreational or aesthetic value. These activities can be further separated into open space preservation and farmland preservation. Open space preservation will refer to preservation undertaken to provide active or passive recreational opportunities or protect from development land that has scenic, rare or otherwise desirable physical or biological characteristics. Farmland preservation will be used to refer to preservation of agricultural land for the purpose of maintaining agricultural as a viable industry.

In general, land preservation activities preserve both larger properties and larger total areas than cultural/historical preservation activities. However, cultural/historical preservation may sometimes preserve large tracts of land, such as battlefields or military encampments. These preserved areas may be of considerable local importance even though land preservation activities may be responsible for much more preserved in a regional perspective. Cultural/historical activities may be also very important in preserving properties in urban areas. There are two main reasons for this. First, there is often a concentration of suitable properties in urban areas. Secondly, traditional land preservation programs often target property characteristics unlikely to be found in urban areas.

2.6 Mechanisms for Preserving Land

Bengston et al. (2004) distinguishes three broad categories of mechanisms used to preserve land for open space and farmland preservation: public acquisition, regulatory approaches and landowner incentives. Public acquisition involves the purchase (in some cases donation) and management of land by a public entity. Regulatory approaches include excluding certain sensitive areas such as slopes and wetlands from development. Zoning approaches such as clustered development and downzoning fall into this category as well. Incentive approaches include right-to-farm laws, agricultural districts, and purchase or transfer of development rights.

Of these, public acquisition is the most permanent form of preservation. However, the management objectives for a public property can change over time, and they may come to conflict with or undermine the original purpose behind the preservation. The acquisition or transfer of development rights is theoretically a permanent preservation technique, since the restrictions on development are usually written into the property deed. Furthermore, specific management goals and techniques, as well as use restrictions, may be part of the easement that restricts development. Deed restrictions and conservation/preservation easements do face two significant problems. Their strength and permanence has not been fully tested in court (Merenlander et al. 2004), and they are not always monitored well for compliance.

2.7 Preserved Land and Landscape Change

Land preservation programs prevent land under their protection from extensive development for human use. This does not mean all change is absent from preserved lands, however. Management plans and activities for preserved properties can institute significant changes to the land use, land cover and associated values such as habitat quality on preserved lands. In some cases, wholesale clearing of vegetation is undertaken, often for the purposes of initiating a plan for ecological restoration of native plant communities. Even in the absence of significant changes initiated by management activities, natural processes such as ecological succession and colonization by invasive species can considerably alter the character of preserved land. If a formerly agricultural area is preserved without the institution of a mowing regime, the agricultural fields will, over the course of a few decades, become forest.

The area surrounding preserved land can have a significant impact on the changes that occur on preserved lands. Abrupt changes in ownership and management, such as between a preserved forest property and an actively farmed field or dense residential area, create high-contrast edges between plant communities. These high-contrast edges often have negative impacts on natural vegetation communities and the animal species that rely on them for habitat. Negative impacts caused by nearby human-dominated areas can occur even if those areas are not directly adjacent. Residential development near preserved land may increase the direct human impact on that land by increasing the amount of use that land is subject to. Conversion of lands to developed uses often entails the installation of ornamental plants. Some of these plants are invasive, and may colonize nearby preserved areas. Alterations in the environment around preserved land can increase population of native organisms that may deleterious effects on preserved lands. Populations of white-tailed in the eastern United States often increase when some forested areas are converted to residential developments. High populations of deer can suppress reproduction and survival of native plant species, which in turn could alter the composition of native plant communities on preserved land. Development also degrades surface water quality, which can impact preserved areas some distance downstream.

Dwyer and Childs (2004) characterize the spatial relationship between people, development and natural resource lands as either interface or intermix environments. Interface environments are areas where natural resource lands and development are adjacent but separate. In contrast, intermix environments are characterized by interspersion of development and natural resource land. The difference between the two can be attributed to the extent and consolidation of the natural resource land relative to the extent and consolidation of the developed areas. Large tracts of natural resource land with development at its margins is an interface environment, while small tracts of natural resource land interspersed among developments represents a intermix environment.   It can be extended to encompass landscape change as well, if areas of potential development are considered along areas actually developed.

This terminology can be used to characterize the relationship between development and preserved land. Most preservation programs that acquire land on a voluntary basis result in intermix environments with pockets of preservation interspersed with development and other unpreserved land. Preservation programs that acquire very large tracts of land or that institute stringent growth controls over large areas are capable of producing interface environments. An example of the later is the Comprehensive Management Plan, which governs land use the New Jersey Pinelands Reserve.
The plan delineates a preservation core, with severely restricted development potential, surrounded by buffer and growth areas (New Jersey Pinelands Commission 2012). At a broad scale, this plan creates an interface environment. However, within the buffer and growth areas, the plan creates an intermix environment, suggesting these definitions are somewhat dependent on the scale at which they are applied.

2.8 Interactions between Landscape Change and Land Preservation

When studying how landscape change interacts with land preservation, a conceptual model of the interactions can be very useful for structuring the investigation. A number of authors have grappled with the more general issue of how land use policy impacts land use and landscape change, while comparatively few have addressed the more specific relationship between land preservation and landscape change. This section reviews previous studies of these interactions and proposes a new conceptual model of interaction between landscape change and land preservation.

2.8.1 General studies of land use policy and landscapes

A number of studies have examined the impact of various land use policies and landscape change. Most of these studies use an implicit or explicit model of policy/landscape interactions in order to generate research questions and interpret their results. Recent work by Munroe et al. (2005) that investigates how landscape fragmentation varies with zoning regulations is representative of studies that use an implicit model. Their model is encapsulated in their statement that “land use policy shapes land use patterns, which are in turn influenced by the biophysical and socioeconomic environment.” This casual formulation of the interactions between policy and landscape poses problems for adequately accounting for the complexities of the possible interactions, even if it is sufficient for the research question that was examined.

A simple relationship depicting interactions between landscape change and land preservation programs (Fig. 2.1) allows for both elements to affect each other. Existing studies examining the spatial consequences of land preservation programs on landscapes are sparse, but they do not seem to have recognized the potential for such interaction. For example, Brabec and Smith (2002) investigate how different farmland preservation mechanisms affect the fragmentation of agricultural land. They limit their study to the examination of how preservation mechanisms have influenced the current spatial configuration of agricultural lands. They clearly show that land preservation programs influence spatial patterns of land use where they are implemented. By influencing spatial patterns, these programs influence subsequent landscape change. Brabec and Smith (2002) briefly mention the implications of these patterns with respect to future change and preservation, but do not fully consider the consequences of landscape change on the capacity of the preservation programs to meet their goals.

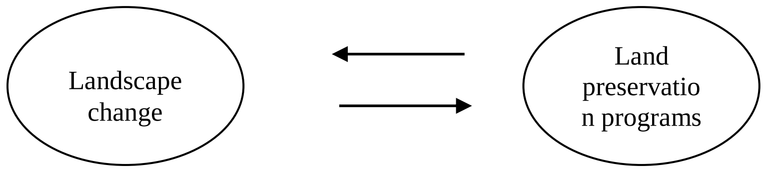

Figure 2.1. Conceptual model illustrating a bi-directional relationship between landscape change and land preservation programs.

Some of the research that has begun to explicitly explore how land preservation and smarth growth policies may be influencing landscape change come out of the tradition of economic modeling. Irwin and Bockstael (2002, 2004) approach the issue as economic modelers using geographic information systems as a tool for exploring how spatialized economic models can help explain landscape change. Using data from Maryland (Irwin and Bockstael 2004), they found evidence that suggested certain types of clustered zoning policies may increase the likelihood that undeveloped parcels near land preserved through clustering will be developed. They found no evidence that parcels near publically preserved open space developed faster than other land, however. They attribute this latter finding partially to limitations in their methodology, which used parcels as the unit of analysis and calculated distance to open space based on the distance of a parcel to the centroid of open space parcels. If open space parcels are large, neighboring parcels will have large distances to the centroids of the open space parcels, even if they are nearby.

Why have no studies explicitly and fully considered how landscape change and land preservation programs interact? Some clues to this omission may be found in the literature concerning the evaluation of land-use plans. Brody and Highfield (2005) discuss some of the problems surrounding the empirical evaluation of plans and their implementation. They posit four main obstacles to plan evaluation: difficulty of determining plan outcomes, difficulty of measuring plan effectiveness, lack of agreement on what constitutes plan success, and lack of longitudinal datasets and agreed-upon research methods. Because land preservation programs implemented by governments tend to have specific goals and criteria for preserving land, the first three issues should not pose significant difficulties when studying land preservation programs.

The last issue raised by Brody and Highfield (2005), however, is of great concern when investigating any aspect of landscape change. Without multitemporal landscape data, such as land-use/land-cover information, it is impossible to substantially address the causes or impacts of landscape change. Multitemporal land-use/land-cover data sets require expertise and resources to create, limiting their availability. Even if commensurable multitemporal land-use/land-cover data is available, it must also be from appropriate time periods for studying the policies under investigation. For example, if a researcher wishes to investigate how a particular land preservation policy has influenced the nature of landscape change, at least three land-use/land-cover data sets would be needed: one from before the policy is implemented, one concurrent with policy implementation, and one sufficiently long after implementation for policy effects to be noticeable. The first two land-use/land-cover data sets provide a baseline for landscape change that can be compared to the post-implementation change provided by the latter two data sets.

2.8.2 Separating Implementation from Policy

The model in Figure 2.1 provides a useful starting point for conceptualizing interactions between landscape change and land preservation programs. However, representing land preservation programs as a monolithic entity prevents the model from achieving its full analytical potential. As Brody and Highfield (2005) point out, the impact of a plan's implementation may or may not achieve the policies of the plan that were laid out when it was formulated. This suggests the necessity of considering their implementation separately from their policies.

This potential disjuncture between land preservation goals and their implementation arises from the nature of the implementation. The land preservation programs discussed here are implemented through the acquisition of property or development rights from property owners. These acquisitions are directed by goals and criteria that were generated during the program's formulation. Usually these goals include a target total acreage for acquisition, and the criteria include desirable environmental conditions, proximity to currently preserved land, usefulness for active or passive recreation and other such property characteristics (e.g. Hunterdon County Planning Board 2000). However, barring the use of eminent domain, the acquisitions are contingent on the presence of a willing seller. This means that land preservation programs result in spatial configurations of preserved and unpreserved land that cannot be predicted from the program goals and criteria alone. Furthermore, the precise impacts of the acquisitions on both the program goals and on continuing landscape change are a direct consequence of the specific characteristics of the lands preserved. Therefore separating implementation from preservation (Fig. 2.2) provides a more complete understanding of landscape change – land preservation interactions.

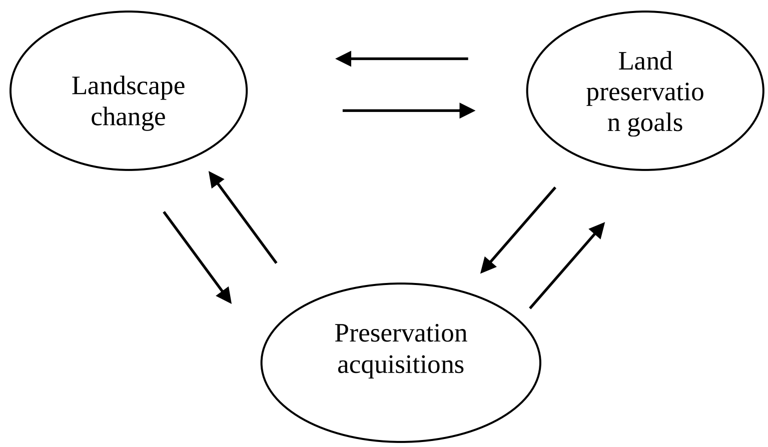

Figure 2.2. A conceptual model separating land preservation program policies from their implementation (acquisitions).

The management of preserved lands is another important component of program implementation. It can influence landscape change both on the preserved lands and beyond its borders. For example, preserved land managed for active recreation may attract or dissuade different types of proximal landscape change than preserved land managed for biodiversity protection. Potential management regimes may also impact acquisition decisions. If forced to choose between two equivalent available properties, land preservation organizations are likely to choose the one that presents fewer management challenges and lower management costs. Management considerations may also influence the goals of land preservation policies. For instance, budgetary constraints may preclude the preservation of areas in need of extensive restoration or other costly management techniques. These constraints may shape policy goals by preventing the inclusion of restoration requiring goals. These examples demonstrate that it is necessary to include the management of preserved lands in the conceptual model in such a way that it interacts with all the other components. This is shown in Figure 2.3.

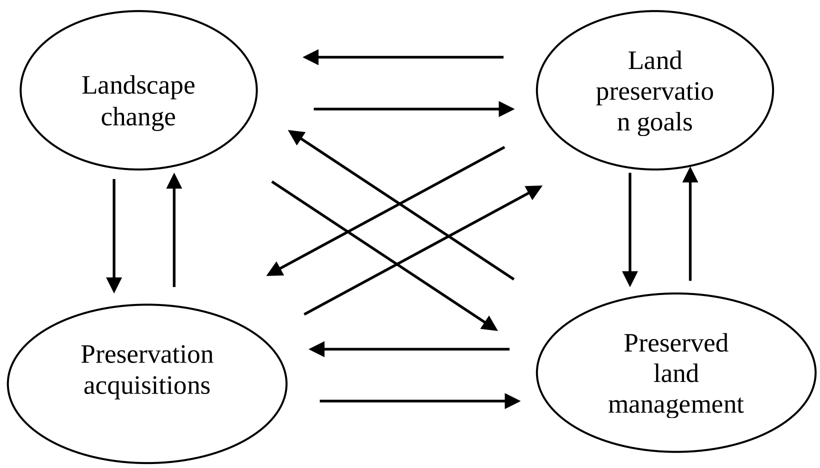

Figure 2.3. A conceptual model including management of preserved lands.

Creating a conceptual model of how landscape change and land preservation programs interact provides a structure for developing research questions and a framework for data analysis. This section provides examples to illustrate the interactions between landscape change, land preservation program goals and land preservation implementation. In doing so, it provides justification for the separation of program goals from program implementation, as represented by acquisition and management of preserved lands.

Landscape change can impact policy responses in number of ways. Perhaps most fundamentally, changes or the perception of the changes in the landscape are one of the initiators of preservation programs. Different types of real or perceived change can lead to different program goals and criteria. The type of landscapes perceived to be most at risk from landscape change will most likely receive the strongest efforts and protections. For example, agricultural lands in rapidly developing locales in New Jersey were the focus of locally sponsored systematic preservation programs before such programs were developed for conservation areas.

Another important consideration is the impact of landscape change that occurs after program formulation, during the implementation period. Such landscape change is often overlooked by the planners and citizens that create preservation programs. It has the potential, however, to have significant impacts on preservation programs. Ongoing landscape change can make the goals of preservation programs more difficult to attain. Consider a forest land preservation program in an area with significant residential development. Over the lifespan of the preservation program, ongoing conversion of forest land to residential use may reduce the area of forest available for preservation to levels below the goals of the preservation program. More subtly, residential development may tend to occur in areas with characteristics that make them especially attractive for preservation.

The goals, structure and criteria of a preservation program can influence landscape change independent of the implementation of the program through land acquisition. By targeting for acquisition one type of land use, such as agriculture, or properties with particular characteristics such as proximity to preserved open space, programs can influence property values and land owner decisions concerning property management or transfer. Property values can have an influence on landscape change, encouraging speculation and development or even preservation. Management decisions such as mowing regimes, forest management plans and fallowing schedules can have an impact on landscape change on natural and agricultural lands.

Preservation program goals and structure have an obvious impact on the implementation of the program through land acquisition. Ideally, the goals lead to criteria that properties should meet before they are eligible for preservation. This could be a codified, quantitative scoring system based on property attributes, as in Tulloch et al. (2003), or more simply the presence of desirable property attributes such as rare species habitat, or even just location within a specific geographic area of concern. Goals and criteria therefore affect implementation by restricting the set of properties eligible for acquisition.

Preservation goals are impacted by implementation in several ways. The most straightforward manner is that the specific properties acquired through implementation determine whether the goals of a program are met. If progress assessments are made during the course of a program there is another way that implementation can impact goals. The assessment of the acquisitions may indicate that some goals are not being met. If so, it may be necessary to adjust the goals of a program. The need for a model that fully considers interactions between goals, implementation and landscape change is highlighted by the fact programs may not be meeting their goals because of changes in landscape structure or composition.

It is not surprising to find that program implementation has impacts on landscape change, given the intent of the land preservation programs. Assessment of landscape change during the course of a program is one method of testing whether a program is having the intended effect. However, the potential exists for more problematic impacts to arise, even ones that may be contrary to the goals of the program. For instance, many preservation programs seek to build large blocks of contiguous preserved land. Unfortunately for preservation programs, preserved open space has been found to increase the value of nearby properties (Correll et al. 1978, Riddel 2001) and many people find preserved open space to be a desirable neighbor. This may lead to open space acquisitions attracting development to their margins, undermining the ability of the preservation program to build large blocks of contiguous open space.

Finally, landscape change can impact implementation in a number of ways. Conversion to residential development or other uses not conducive to preservation removes land from consideration for preservation. Landscape change adjacent to a property worthy of preservation may make that property more or less desirable for preservation. They could also increase the value of that property, making more difficult to acquire for preservation in light of limited program budgets and other acceptable but cheaper properties. An often overlooked impact of landscape change is on the preserved land itself. Ongoing change may alter the preservation value of a property after it is acquired. This is especially true considering that many preserved properties, at least in New Jersey, are subject to minimal management.

The above examples make it clear that the model requires the separation of program implementation from program goals in order to achieve maximal utility. The fully articulated model provides a very useful analytical framework for exploring interactions between open space preservation and landscape change. By making clear the pathways for interaction between its elements, the model aides in the interpretation of research results. Importantly, the model also suggests new avenues for research that might not be so readily developed in its absence. The question of whether open space preservation attracts development is a relatively obvious one. However, by noting that landscape change can impact preservation goals, the model also leads us to ask whether such development might be undermining one the main goals of many preservation programs, that of building contiguous blocks of preserved land.

2.9 Contextualizing the Study within Land Change Science and Geography

In recent years, scholars have sought develop a theory of land change science to tie the disparate strands discussed above together into a more cohesive, theoretically grounded and practically focused whole. Turner et al. (2007) describe land change science "as an attempt to understand the dynamics of land cover and land use as a coupled human–environment system to address theory, concepts, models, and applications relevant to environmental and societal problems, including the intersection of the two." The work undertaken in this study, which seeks to explore interactions between landscape change and land preservation policies, falls firmly within this definition of land change science. The model of those interactions (illustrated in Figure 2.3) used to guide this study is clearly a model of an explicitly coupled human-environment system (see Liu et al. 2007) for a discussion of these systems), with interactions between human factors, land preservation programs, and landscape change.

Breaking down the components of land change science (in a way similar to the goals of landscape change studies as described in section 2.2 above), Turner et al. (2007) identify four main ones: observation and monitoring of land changes, the use of coupled human-environmental systems to understand land change, the spatially explicit modeling of land change and analysis of system level effects of land change such as vulnerability, sustainability and resilience. The work presented here falls mainly within the first two components listed above. The monitoring of land change in and of itself it is an important component of land change science. Exploring how land change uncovered through monitoring interacts with policies implemented to affect land change represents an exploration of one facet of the coupled human-environmental system that drives changes in the land. Attempts to understand the ecological effects of landscape changes, and what they mean for land preservation, begin to address the system level outcomes of land change addressed in the final component.

In response for calls from Turner et al. (2007) and others to link land cover and land use change to broader issues of sustainability, resilience and its general landscape consequences, a number of researchers (e.g. Verburg et al. (2009)) have explored how land change research can shift its focus to study not just land use/land cover change but also the impact of that change on land functions. Land functions are defined as the goods and services provided by the land. Explicitly addressing the impacts of change on functions is necessary for effective land management, which includes policies aimed at shaping land use. As will be described later, the land preservation programs considered in this study can be seen as trying to ensure the continuing operation of selected land functions (agricultural viability, provisioning of wildlife and rare species habitat, protection of water resources) by preserving land that currently fosters these functions from being converted to uses which do not. One of the purposes of this study to assess how well these policies are achieving that goal in light of the impacts of ongoing land change on land function.

In a broader sense, the work presented here fits within the human-environment and the spatial traditions of geography, both longstanding core components of the discipline. The human-environment tradition stretches back to the earliest examples of modern geography, such as Marsh's *Man and Nature*, which appeared in 1864. More recently, the centrality of human-environment studies as well as spatial analysis to geography have been reaffirmed in various reviews of geography's purview. Pattison's 1964 exploration of the four themes of geography includes the spatial tradition and the human-environment tradition (labeled "man-land", the other two are the areas study and earth science traditions (Pattison 1964)). Later efforts such as the five themes of geography (from 1984, see Natoli (1994) for a review) and the 1994 National Geography Standards (reviewed in Bednarz ((2003) have also included human-environment interaction and spatial analysis as central components to geography.

More recent research oriented efforts dealing with geography's scope, such as the National Research Council's effort to set an agenda for geographical research (National Research Council 2010), look to define how geographical sciences can best contribute to society and address major issues confronting the planet in the early parts of this century. Included among their strategic directions are an examination of how to understand and respond to environmental change, how to promote sustainability, and how to leverage technological change for the betterment of society and environment. The work presented here bears directly on these questions by quantifying changes in the environment, exploring how these changes interact with our efforts to respond to those changes. Those efforts can be viewed, in part, as way to promote sustainability since maintaining farmland and ecological integrity are part of the goals of the land preservation programs examined. Finally, one of the points of this project is to use geospatial technologies to assess land preservation programs in a way that can make those programs more effective at achieving their goals.

2.10 Conclusions

Landscape change and land preservation programs can interact in ways that affect both the trajectories of change and the impacts and implementation of the programs. Given the importance of land preservation programs as an element of growth management plans and resource conservation, a more thorough understanding of these interactions is necessary, which is the goal of this study. In order to gain this understanding, the investigation of these interactions must be structured around measures of landscape change that have relevance to the various components of the policies under examination. As will be shown in the next chapter, this distinguishes this study from non-specific examinations of landscape change.

Chapter 3 - Policy Specific Metrics and Indicators for Landscape Change and Land Preservation Policies

3.1 Introduction

This chapter introduces the idea of policy specific metrics for landscape change. It defines what policy specific metrics and indicators are, and argues for their development in contrast to other approaches of measuring landscape change. It then introduces a model for the development of such indicators, and describes in detail the individual steps of the process. The primary types of policies are discussed are those intended to manage urban growth or preserve land as open space. These policies are directly concerned with ameliorating or influencing the effects and trajectories of landscape change. However, the methods discussed are applicable to any policies that have goals or implementations that could be affected by landscape change.

3.2 The Need for Policy Specific Metrics

If, as Gustafson (1998) suggests, ecologically oriented studies need to use ecologically oriented indicators, then studies focused on the impact of the land use policies on landscape structure and change must use indicators specific to the policies studied. This approach stands in direct contrast to the that suggested by Letao and Ahern (2002). They develop a core set of landscape metrics for planning and assessment based on the need to capture as much of the variability of a landscape as is possible using a small set of metrics. Such an approach has the advantage of providing a turn-key toolkit that can be easily implemented by planners and researchers that do not have the skills required to modify existing metrics or develop their own. It can also allow for easy cross-landscape comparisons, assuming the data from landscapes being compared is commensurable and metrics used can be compared between landscapes as well as within. Both of these aspects make the approach attractive for general landscape planning and policy assessment. However, a suite of metrics designed to capture the maximum amount of information about the spatial pattern of a landscape with as few metrics as possible has no value for policy assessment if the metrics fail to capture the features or patterns that the assessed policy is trying to influence.

Policy specific metrics can range from basic derivations of rates or percentages of change of policy relevant land use classes to more complicated analyses of landscape pattern and structure to very sophisticated models of the impact of changes on policy targets. Many land use policies seek to slow or stop the loss of certain LULC classes or habitat types. Metrics for such policies would need to measure the existing amounts of the LULC classes or habitat types at several time periods so that the rates of change before and after policy implementation could be compared. Peccol et al. (1996) adopt this approach to assess the impact of different types of countryside designations in England. Areas of countryside can be subject to more stringent planning controls on development if they receive one of several possible designations. The authors compared rates of change within these designated areas to the landscape outside of them to assess the effect of the designations on landscape change. Such comparison creates what is perhaps more properly termed an indicator (change in rates of change), since it does not represent a direct measurement (metric) of the landscape. Since simple metrics can also be considered indicators, I will adopt the more inclusive terminology for the rest of this study.

More complex indicators are required when policies aim to influence the structure and pattern of the landscape instead of or in addition to its composition. Policies promoting the retention of agricultural lands often seek to establish concentrations of proximal farmlands. Evaluating the effectiveness of this policy goal would require a metric that shows whether areas of farmland are concentrated on the landscape. Standard landscape metrics (such as those calculated by Fragstats (McGarigal et al. 2002)) fail to provide useful indicators for this policy goal. They typically deal strictly with adjacencies and have no good mechanisms for taking nearness into account. This is problematic because it is not the direct adjacency of farmland that is necessarily or exclusively promoted by many agricultural retention policies but the density of agricultural land within a given area. This is compounded by the fact that in agricultural settings, cultivated fields are usually interspersed and separated by forest and wetlands belonging to the same owner or neighboring farmers. The farms these areas comprise are adjacent or proximal from an agricultural retention perspective, but a land use or land cover map of these farms might consider the cultivated areas as individual polygons or patches isolated by intervening land cover or land use classes. A buffer based analytical approach that measures farmland area within a given distance of each contiguous patch of farmland would overcome the reliance on adjacency exhibited by standard metrics.

Another strategy that deals with the limitations of basing metrics on LULC classes is to use parcels instead of pixels or patches as a unit of analysis. This is intuitively appealing when developing indicators to assess the impact of land use or preservation policies, since the parcel is the basic decision making unit for many land use and preservation decisions. Brabec and Smith (2002) uses parcels as their unit of analysis to overcome the problems outlined above with regard to measuring the contiguity of farmland. They measured contiguity by calculating the aggregate size of adjacent preserved farmland parcels, not agricultural land use patches, to assess the success of various agricultural preservation policies in creating continuous tracts of preserved farmland. To solve the problem of calculating density of farmland outlined above, farm parcels could be used as the center point from which the total area of other farmland parcels within a certain distance could be determine. This value, averaged over all of the farmland parcels in the study area and measured for at least two different times, could detect whether policies that promote farmland concentration were working.

3.3 Developing Policy Relevant Indicators

Developing policy relevant indicators of landscape change is a multi-step process. First, the policies under evaluation must be examined to determine what their target areas are and which goals have landscape consequences amenable to measurement through GIS based analysis. As explored above, these goals can be assessed through simple measures of area or more complicated measures of landscape structure and pattern. Once the nature of policy goals are understood with respect to landscape change and measurable impacts on the landscape, the indicators to be measured can be determined. Then the required data can be created or acquired. Some data processing such as reclassification, reprojection or data overlay is likely to be necessary at this stage in order to ensure the data can be used to measure the relevant indicators. After this metrics can be generated and analyzed. This process is summarized in Figure 3.1

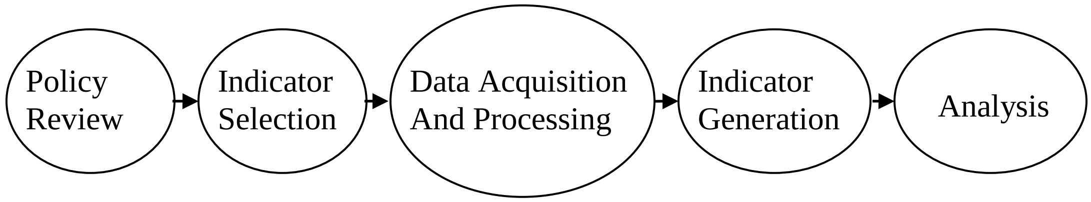

Figure 3.1. Generating policy relevant indicators of landscape change.

3.3.1 Policy Review

The first step in developing policy relevant indicators of landscape change is to review the policy or policies under consideration in order to be able to spatially delineate their target areas and identify their quantifiable or otherwise measurable goals. Policies that attempt to protect land from development can be broken down into two groups: those that attempt to direct development to suitable areas and away from unsuitable areas through statutory measures, such as incentives, taxes and regulation, and those that seek to prevent development through acquisition of property or development rights. Zoning is the primary example of the first type of policy. Areas suitable for development are zoned to encourage it while areas that are not have restrictions placed on the amount and type of development allowed. This group also includes regulations aimed at preventing development in areas with specific and sensitive characteristics, such as wetlands. Examples of the second type of policy include farmland and open space preservation plans. The main distinguishing factor between these two types of policy is that the first delineates areas that receive different levels of regulatory protection, while the second delineates areas that receive consideration for preservation without gaining protected status through regulatory means.

Such a distinction roughly corresponds to the typology derived by Bengston et al. (2003) of policies intended to protect open space (undeveloped land, by the authors' definition). The typology first distinguishes between policies intended to manage urban growth and those intended to protect open space directly. The categories are not mutually exclusive, nor do they directly correspond to the distinction between growth directing and acquisition policies made above. For example, the direct acquisition of open space is considered to be both a technique for urban growth management, since it constrains where growth can occur, and for protecting open space directly through acquisition. In the Bengston et al. typology, the regulatory protection of lands based on its characteristics, such as wetlands, is considered to be a means of protecting open space. This seems a more appropriate choice than considering such regulatory approaches as means of managing urban growth (although in localized instances wetland protection and similar regulations do serve this purpose, albeit perhaps unintentionally). However, for classifying policies based on how they delineate space and therefore can be analyzed spatially, it makes considerably more sense to group zoning policies and regulatory protections together.

Developing indicators for either type of policy is similar. For zoning policies and some others of the first type, it usually entails a relatively simple process of determining how much landscape change is occurring in the areas delineated by the policy. Significantly more interpretation and data generation may be required to develop indicators of landscape change for evaluating policies focused on regulatory protection or acquisition. It is important to note that both types of policy are usually operating in a given landscape and it may be of interest to examine how these policy types interact with one another as well as with landscape change. For instance, exploring whether zoning actively supports preservation policies by directing development away from areas where preservation is targeted would prove useful for assessing the efficiency of overall land use planning in a given landscape.

In a few cases, the target area may exactly correspond to the extent of the government entity enacting the policy. Usually, however, the policies will differentiate between different subsections of the enacting government unit. The policies delineate target areas by either directly specifying the area of interest or by outlining characteristics which properties must have in order to be considered target areas. Zoning regulations are perhaps the most familiar type of the first method of target area definition. Also included in these group are policies that specify geographic areas because they contain unique natural or cultural resources that will be negatively impacted by conversion of these areas to development. These areas may be recognized regions within the area the policy is operating (such as the New Jersey Highlands) or they may defined by their proximity to notable features (e.g. river corridors). The second method specifies characteristics that properties must have in order to be considered important for inclusion as a target area. In this case, it is not merely enough to be located within a certain broadly defined geographic area, the properties themselves must have certain characteristics, such as endangered species habitat or unique plant communities before they are considered. This distinction is important because analyzing policies which use the second method may require digital parcel data for property boundary definition. Such data is very difficult to develop and may require significant analytical compromises if it is not available.

As with the different policy types, these ways of specifying areas of interest are not mutually exclusive and often operate in conjunction with one another. Areas containing a concentration of valuable natural resources may be zoned for less development than areas not containing those resources. Importantly, however, individual properties within a natural resource may not contain any of those natural resources, yet they are subject to the constrained zoning all the same. In the case of preservation programs, it is common for farmland preservation to limit preservation to areas where agriculture is likely to be economically viable, delineated as relatively broad geographical areas. Properties within these broad areas of interest usually need to meet certain criteria in order to be eligible for preservation, usually related to their agricultural capacity.

Once the target areas that can be spatially represented have been identified, the next step is to consider the data needed to represent them. This can be relatively straight forward when policies target their interventions on well-defined areas, such as zoning policies. In these cases, there usually exist digital or paper maps that already spatially represent the area of interest to policy goals. Even if no spatial data, digital or otherwise, exists, the target areas might be well-specified verbally. This is likely if, as in the case of zoning, there are legal implications to the definitions of the target areas. For policies that provide regulatory protection to areas based on the presence of wetlands, endangered species habitat and similar land characteristics, a valid delineation of the area under the impact the regulation may require extensive site visits and data collection by experts. It may be possible to develop digital products that approximate the areas impacted by the regulation, such as the United States Fish and Wildlife Service's National Wetlands Inventory (USFWS 2006) and the New Jersey Endangered Species Program's critical habitat mapping project known as the Landscape Project (NJENSP 2006). However, it is extremely unlikely that the exact areas could be derived without site visits or similarly intensive procedures. It may still be very useful for policy analysis and landscape change studies to use such proxy derivations of the areas impacted by such regulation, indeed they may be the only means available for doing so, but the inadequacies inherent in most such derivations requires the analysts using them to scrupulously avoid conflating their results with the actually policy impacts.

In other cases, spatially representing the target areas may not be so straightforward. For instance, if a policy calls for protecting river corridors, representing the target area spatially becomes a several step process. First, it must be determined if all rivers corridors are targeted by the policy. If not, it must be determined which ones are. Once the rivers whose corridors will receive consideration under the policy are determined, then it must be decided what constitutes a river corridor. Sometimes this is specified in the policy but sometimes it will not. If not, it must be determined how far from the target rivers the corridors extend. Can corridors be represented by simple, single distance buffers around the rivers, or are areas exhibiting certain characteristics or possessing certain qualities excluded or included in the delineation of corridors? Are corridors areas of natural habitat only, or are agricultural areas considered important as well, or are developed areas? Should natural areas contiguous with corridors but not within the specified distance for the corridors be included in the corridor?

If such questions are not answered by the policy, several options exist for spatially representing them. The best option is for those implementing the plan to be contacted to see if they have an operational definition of the target area that answers such questions. If they do not, or have not considered them, it might be possible to infer the answers from other policy targets. In the case of the river corridor definition considered above, if the policy is primarily concerned with preserving natural habitat, it might make sense to exclude agricultural or at least heavily cultivated areas from the definition of river corridors. If there is little information on which to base judgments regarding the operationalization of target areas that are vaguely defined in the policy, it may be best to define them as simply as possible (such as with a simple distance buffer in the case of the river corridors). Adopting several definitions and testing their effects on the indicators is another option, although such a sensitivity testing type approach could be time consuming if they are many vaguely specified target areas involved.

In addition to target areas, the policy review portion of the indicator development process should also determine what goals a policy is attempting to achieve and it which target areas it is trying to achieve them. These goals can range from preserving a particular amount or percentage of certain existing LULC types to increasing the contiguity of preserved areas. It is the goal or goals for each target area that will define what indicators should be used to measure interactions between landscape change and the policy under review. This process is addressed in the next section.

3.3.2 Indicator Selection and Development

Once the target areas of the policy under review have been spatially represented, the next step is to determine what indicators are needed to assess the interactions between landscape change and the policy. The most obvious indicators would measure the amount and types of landscape change that have occurred in the target areas, most likely as changes to land use/land cover. Although basic, such indicators can provide useful information for a variety of policies in a number of contexts. For instance, basic indicators of landscape change can assess the efficacy of zoning policies by testing whether they appear to be successfully promoting development in suitable areas and restricting it in unsuitable areas. It may also be very useful to know the type and amount of landscape change occurring in the target areas of open space acquisition policies. If agricultural areas are being converted to development more rapidly than forested areas, it may be worthwhile for agencies tasked with implementing preservation to consider prioritizing agricultural areas.

However, many times policy goals will require the use of more sophisticated indicators, such as those that consider adjacency, contiguity and density. Policy goals concerning spatial arrangements may concentrate on the characteristics of the target areas or the nature of preserved properties. An example of the first would be a zoning policy that zones for large lots in a forested area in order to minimize forest fragmentation. Examples of the second include an agricultural preservation policy that seeks to concentrate preserved farmland in small areas and an open space preservation policy that promotes preservation of properties adjacent to currently preserved properties. Indicators for the first type of policies need to measure spatial arrangements of the habitat or LULC type targeted by the policy, and appropriate indicators can often be found in off-the-shelf landscape metric generation software such as Fragstats (McGarigal et al. 2002). Indicators for the second type of policies must measure arrangement of the preserved areas. They often require considerable technical skill to manually generate using a geographic information system software application such as ArcGIS, although the ability to write scripts or macros in such software means that complicated procedures can be automated and that someone in the large user community may have already created a script or macro that can assist in the indicator generation. Such user-generated tools are available on a number of websites, often accessible through the website of the producer of the base GIS software. A consideration of the different data requirements engendered by different types of policies and indicators is included in the next section.

3.3.3 Data Acquisition and Processing

Once the target areas and goals of the policy in question are known and the necessary indicators have been selected, the data needed to generate the indicators must be acquired, generated and/or processed. Since the indicators are specifically concerned with measuring the interactions between landscape change and land preservation policies, data about landscape change in the target areas is an obviously necessary component. A detailed description of the process of generating LULC data from satellite imagery or aerial photography is beyond the scope of this analysis (see Jensen (1996) for an introduction to image processing and classification). Briassoulis (2001) provides an overview of the data needs for policy-oriented integrated analysis LULC that extensively covers issues of compatibility, consistency and reliability.

Several elements of the process are relevant to the discussion at hand and will be explicitly considered here, however. Although it may be ideal to create LULC or other necessary data detailing landscape change for each project, the financial, technical and temporal constraints of the data creation process means that many times analysis will make use of pre-existing data. The creation of nationwide LULC by a consortium of government agencies (Multiresolution Land Characteristics Consortium 2006) means that most areas of the United States should have at least two time periods of LULC data available for them. Many states supplement this nationwide data with their own LULC mapping programs.

The temporal resolution necessary to generate indicators is dependent on the policy under consideration. At a minimum, it is necessary to have landscape data for three dates: a date before policy implementation, a data very close to policy implementation, and a date after policy implementation. The amount of time between the before and after implementation dates and the implementation date must be sufficient to detect policy relevant landscape changes. The data sets before implementation and at implementation provide an indication of landscape changes in absence of the policy, while the data sets at implementation and after implementation provide an indication of landscape changes after the policy. Comparing the two sets of change measurements allows for an assessment of the impacts of the policy on landscape change. The need for data sets from three (or more) dates suggests that the analysis of policy relevant landscape change is an exercise in analyzing landscape change trajectories. These trajectories show trends in landscape change over time instead of simply measuring change between two dates (Mertens and Lambin 2000).

The amount of time necessary to detect the effect of policies on landscapes has not received significant investigation, and is likely to vary depending on the policy type, method of implementation and nature of landscape changes occurring in the policy target areas. Hence, recommendations for the minimum time period between landscape data sets are difficult to make with certainty. A general rule of thumb is that the faster that landscape changes relevant to the policy are occurring, the shorter the minimum period between dates of landscape data collection. Familiarity with the nature and pace of landscape change in the study is necessary to make a reasonable estimation of this minimum period. A minimum of 5 years is suggested for areas where agricultural practices and/or urbanization are responsible for the majority of landscape change, while longer periods might be required if activities with longer-term turn-over times (such as commercial forestry) are driving forces of landscape change (Brandt et al. 2002).

Successful analysis of the interactions between landscape change and land policies depends on having data of the appropriate spatial as well as temporal resolution. The required spatial resolution depends on the landscape change indicators being measured. For example, if the size of building footprints was a necessary component of the indicator being calculated, high resolution aerial photography would be required. Measuring an indicator such as natural habitat contiguity should require only medium resolution data such as the Landsat TM/ETM 30 meter resolution satellite data. In general, the spatial resolution must be sufficient to distinguish the ground features relevant to the indicator. A pixel resolution of half the size of the smallest ground feature is usually considered sufficient for this purpose (Jensen 1996). Standard metrics used as landscape change indicators may be sensitive to changes in spatial resolution of the data they are generated from (Haines-Young and Chopping 1996), which can be problematic if resampling of data is required to make data from different sources commensurable. However, Luque (2000) found that one of the common data resampling transformations (resampling 30 m Landsat TM data to 80 m in order to match earlier Landsat MSS data) had no significant effect on several common landscape metrics in the forested environment she studied.

One of the most important determinations that must be made is whether the assessment requires parcel data, and if so, whether parcels are needed for the entire study area or just a portion. The analysis performed by Brabec and Smith (2002) to measure contiguity of preserved farmland required digital parcel data for only those properties that were preserved. Boundaries of the preserved properties are usually generated during the preservation process by agency coordinating the preservation, and are usually publically available if the agency is governmental or preserving property using public funds. If a similar measure of contiguity was undertaken for both preserved and unpreserved farmland, parcels for all the area would needed. This could pose a significant impediment to analysis, since parcel data is expensive and time consuming to create, and hence not available for large portions of the United States. Absent survey or similar information, an LULC data set that could be used to distinguish farm parcels from non-farm parcels would also be required. If policy goals were oriented toward maintaining a certain area or percentage of an area in active cultivation or pasture, then only LULC data would be necessary.

3.3.4 Indicator Generation

Indicators are typically generated within GIS software packages. If landscape change-policy interactions can be measured using common landscape metrics such as mean patch size, contagion or edge measurements, pre-written landscape metric generation packages such as Fragstats (McGarigal et al. 2002) can used within the GIS software to easily generate metrics. If the analysis requires the use of custom metrics, then the analytical capabilities of the GIS software will need to be used in a much more technically sophisticated manner.

3.3.5 Analysis of Indicators

If change of LULC or other categorical data is being measured as an indicator, it is customary to display the results of change as a transition, contingency or cross-tabulation table. This provides information detailing the area occupied by each category and the amount of change between category pairs for the time periods studied. While such "from-to" change detection may be a common approach, it fails to distinguish two important facets of landscape change: where the change is occurring and class-to-class persistence (Pontius et al. 2004). Creating maps that detail the location of change is an obvious way to understand where change is occurring. Generating separate statistics on change for areas inside and outside of policy target areas also to answer the question of where change is occurring in a policy relevant way.

Cross-tabulation tables can be extended to show how much of each land cover type remained unchanged, how much was lost to which other classes and how much was gained from other classes (Pontius et al. 2004). Such information is vitally important when assessing the interactions between landscape change and land policies, especially those policies that have conservation oriented goals. There are well-documented differences in the capacity of recently established habitat patches to sustain certain species as compared to older habitat patches (e.g. Barone and Frank 2003). In the context of assessing policies intended to protect those species, knowing which habitat patches have recently become established is just as important as knowing which have been lost. There may also differences in the aesthetic and recreation potential related to the date of patch establishment that could have bearing on the desirability of patches for preservation.

The analysis and interpretation of landscape metrics is less straightforward than that of simple measures of the extent of landscape change. As noted before, one of the major concerns regarding their use is how to link patterns to ecological processes (Li and Wu 2004). Fortunately, this particular concern is not as relevant for policy analysis as it is for landscape ecological studies. If the metric chosen accurately measures a component of landscape change which has policy relevance then the metric is sufficiently linked to the object under study. There may be difficulties in linking the landscape metrics to the processes generating landscape change, but the metrics would still suffice to shed light on how landscape change is interacting with land policies, which is likely to be the primary goal of most assessments. Examining the underlying processes that drive landscape change is likely to be beyond the scope of most landscape change-policy interaction studies.

3.4 Conclusion

The development and analysis of policy relevant indicators of landscape change is an integral part of this study. Analyzing landscape change through a lens that focuses attention on those pathways and patterns relevant to the land preservation policies being examined allows for a more effective investigation of how landscape change and land preservation policies interact than would a less focused approach. In order to best understand and analyze these interactions, a solid understanding of the geography and land preservation policies in the study areas is required. The next chapter introduces the study areas and the policies operating within in them.

Chapter 4 – Study Areas

4.1 Introduction

This chapter introduces the study areas by providing a brief description of their physical, environmental and cultural geographies. Hunterdon and Burlington Counties share a rural and agricultural past that has given way to significant urbanization over the past 30 years. The spatial pattern and character of this urbanization differ between the counties, however, and the reasons for this will be explored in this and the following chapter. These counties were chose for the study for a number of reasons. First, they both have significant agricultural and otherwise undeveloped areas coexisting with significant older and newer development. Second, they are both experiencing significant development pressure in their rural areas. Third, they both have longstanding farmland and open space preservation programs, which allows for a greater temporal depth to the analysis than would otherwise be possible. An overview of the land preservation policies operating within the counties is also given in this chapter, with special attention to the counties' own land preservation programs and those of selected municipalities within each county.

Figure 4.1 shows the location of the study counties within New Jersey. Hunterdon is located in New Jersey's wealth belt, a swath of mostly wealthy, mostly suburban or exurban development that stretches eastward from Hunterdon through Somerset and Morris counties. Burlington, meanwhile, is located in the generally less affluent southern portion of the state. Burlington also has older, more densely populated suburbs than Hunterdon, which is more exurban in character.

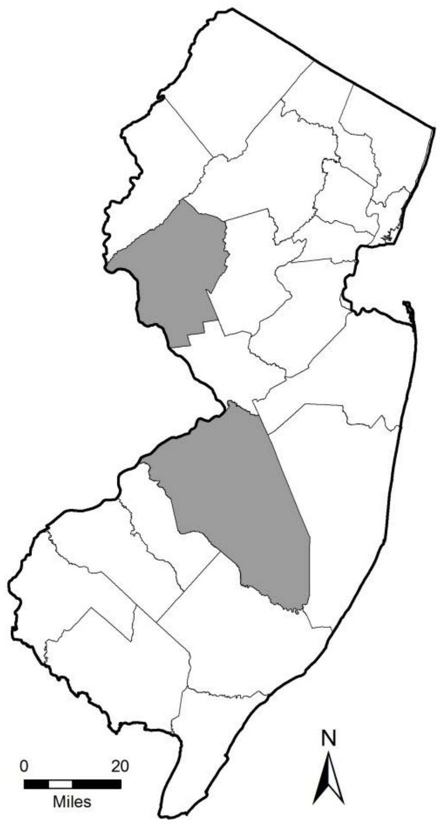

Figure 4.1 New Jersey counties, with Hunterdon (north) and Burlington shaded

Table 4.1 shows the per capita and median household incomes of New Jersey counties from the 2010 US census. Hunterdon County ranks first among New Jersey counties in per capita and median household incomes. Burlington ranks eighth among New Jersey counties. The relative disparity in incomes suggests that Hunterdon County may be better able to raise taxes to help fund land preservation than Burlington. This disparity may also be one of the reasons for the differences in scope between Hunterdon and Burlington's open space plans, as will be discussed later in the chapter.

Table 4.1 2010 New Jersey median household, per capita income and population by county, sorted by per capita income high to low

County	Median Household Income	Per Capita Income	Per Capita Income Rank	Population	Area (Sq. Miles)
Hunterdon County	100,980	48,489	1	128,349	430
Morris County	96,747	47,342	2	492,276	469
Somerset County	97,440	47,067	3	323,444	305
Bergen County	81,708	42,006	4	905,116	234
Monmouth County	82,265	40,976	5	630,380	472
Mercer County	71,217	36,016	6	366,513	226
Sussex County	83,089	35,982	7	149,265	521
Burlington County	76,258	34,802	8	448,734	805
Union County	66,791	34,096	9	536,499	103
Cape May County	54,292	33,571	10	97,265	255
Middlesex County	77,615	33,289	11	809,858	311
Warren County	71,364	32,985	12	108,692	358
Essex County	55,125	31,535	13	783,969	126
Gloucester County	72,664	31,210	14	288,288	325
Hudson County	55,275	31,024	15	634,266	47
Ocean County	59,620	29,826	16	576,567	916
Camden County	60,976	29,478	17	513,657	222
Salem County	59,441	27,296	18	66,083	338
Atlantic County	54,766	27,247	19	274,549	561
Passaic County	54,944	26,095	20	501,226	185
Cumberland County	50,651	21,883	21	156,898	489
New Jersey	**$69,811**	**$34,858**		8,791,894	7,698

4.2 Hunterdon County

Hunterdon County covers 430 square miles of northwestern New Jersey (Figure 4.2), and lies approximately 40 miles west of New York City and 30 miles north of Philadelphia. Founded in 1725, Hunterdon County originally consisted of part of what is now Mercer County as well as all of what is now Hunterdon County. The present boundaries were adopted in 1838. The US Census lists the 2010 population of Hunterdon County as 128,349.

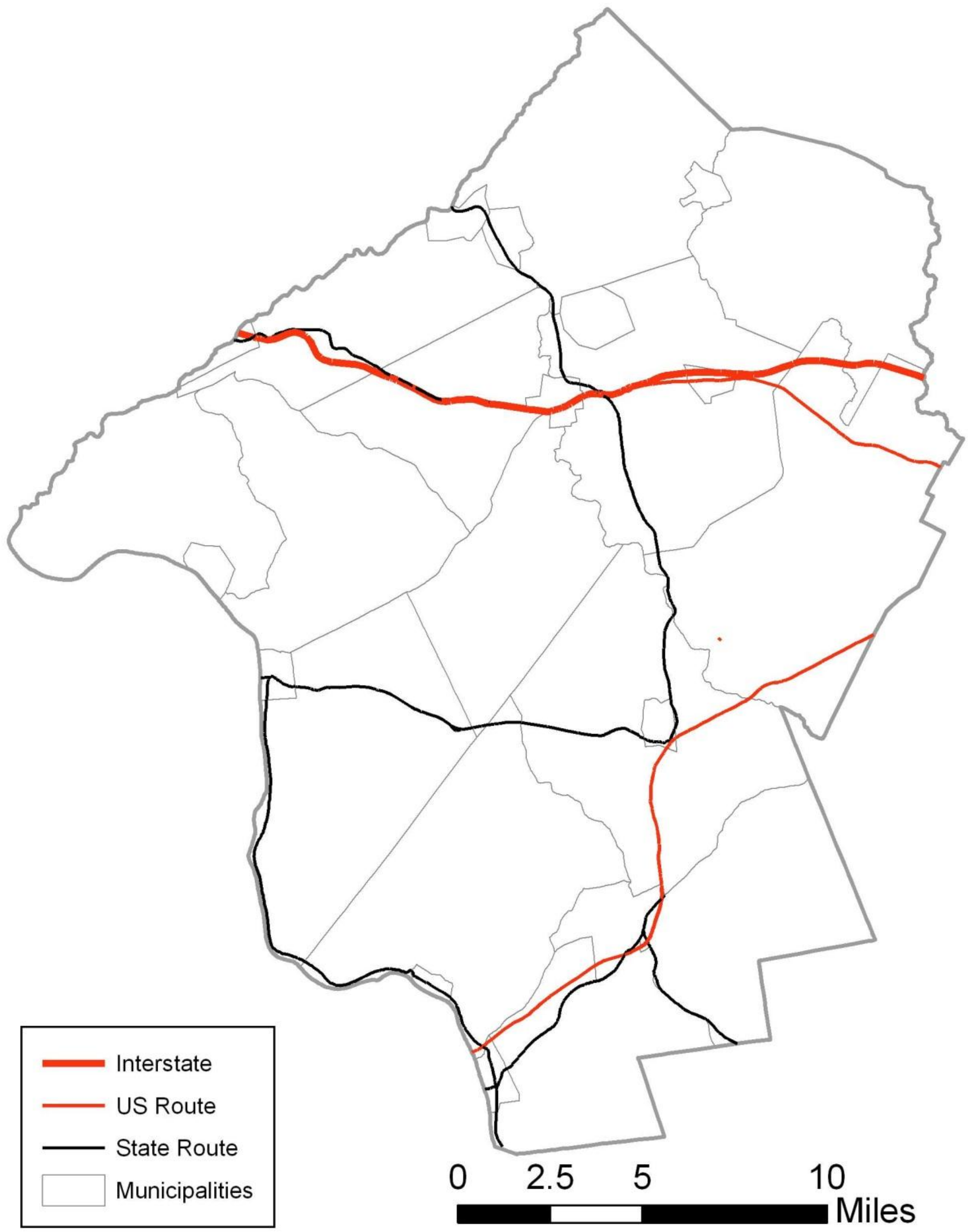

Figure 4.2 Hunterdon County, with major roads and municipalities

4.2.1 Physical Features

Hunterdon County resides within two physiographic provinces, the Highlands and the Piedmont. The broad ridges and steep valleys of the Highlands in the northern quarter of the county provide a contrast to the more gently rolling Piedmont landscape to the south. The Highlands ridges provide Hunterdon with its highest elevation, approximately 1050 feet above sea level. Productive farmland is generally absent in the granite ridges of the Highlands and the diabase ridges of the Piedmont. The limestone valleys of the Highlands and the gently rolling shale hills of the Piedmont can be farmed productively, however. The soil underlying 65% of Hunterdon's land area is classified as either prime soils (27%) or statewide important soils (38%) by the United States Department of Agriculture (Hunterdon County Board of Planning 2000). Prime soils represent the most productive soils in the nation, while soils of statewide importance reflect soils that may not be among the relatively most productive everywhere, but are economically important in New Jersey. Hunterdon County is divided by 2 major watersheds, the Raritan River watershed to the east and the Delaware River watershed to the northwest and west.

4.2.2 Biological Features

The naturally occurring vegetation of the county can best be described as mixed oak forest in most upland areas with chestnut oak forest occurring on dry ridge tops (Collins and Anderson 1994). These communities persist on steep hillsides or rocky ridges that were not conducive to cultivation, and in variously sized woodlots and abandoned fields interspersed between agricultural fields and development both new and old. In some of the Highlands valleys and steeply incised Piedmont stream cuts, hemlock-mixed hardwood forests can be found. Riparian corridors and other forested wetlands are characterized by red maple (*Acer rubrum*) and pin oak (*Quercus palustris*). Emergent wetland, usually found along streams or lakeshores, is predominantly cattail (*Typha* spp.) and phragmites (*Phragmites australis*).

A number of endangered species and rare plant communities can be found in Hunterdon County. Several unique plant communities exist along the bluffs overlooking the Delaware River in the western portion of the county, while large areas of cultivated grassland persist in the southern portion (NHP 2001). At least 20 endangered or threatened animal species have been found in Hunterdon (ENSP 2002). The endangered and threatened species present in the county reflect the diversity of habitats found there. For instance, barred owls (*Strix varia*), which require large tracts of forest and forested wetland, can be found along ridges of the county.   Many species of grassland birds such as bobolink (*Dolichonyx orzivorous*) breed in the cultivated grasslands found in the county's agricultural areas.

4.3 Burlington County

Burlington County, the largest in New Jersey, covers 827 square miles of southern New Jersey (Figure 4.3), and lies approximately 10 miles northwest of Philadelphia. Officially incorporated in 1694, Burlington County originally consisted of parts of what are now Mercer, Atlantic and Ocean County as well as all of what is now Burlington County. The present boundaries were finalized in 1891. Unlike Hunterdon County, Burlington County played a central role in the early history of New Jersey,

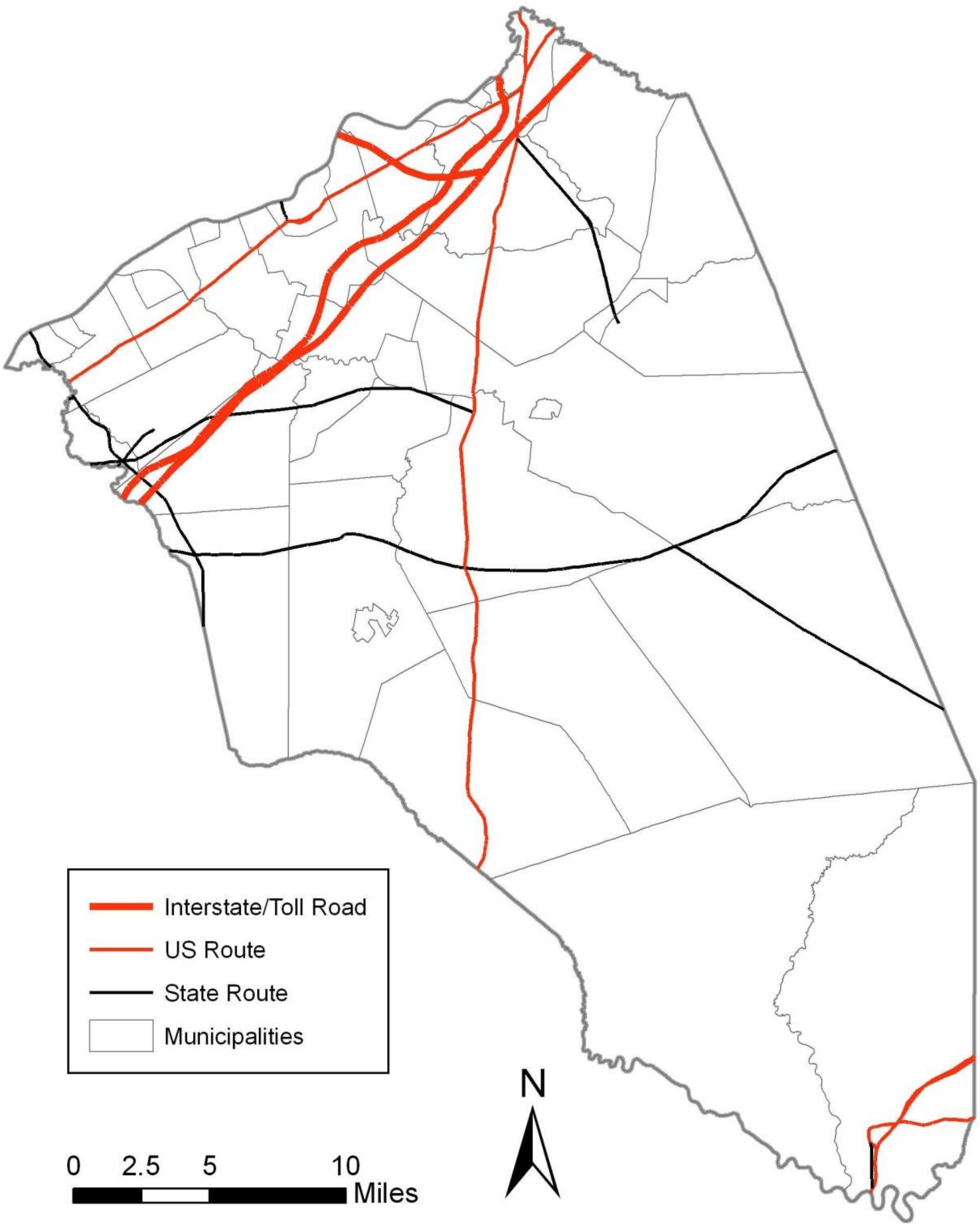

Figure 4.3 Burlington County with major roads and municipalities

serving as home to the provincial and colonial capital of West Jersey, one of the two originally chartered subdivisions that combined to become the state of New Jersey. The US Census lists the 2010 population of Burlington County as 448,734.

4.3.1 Physical Features

Burlington County lies within two physiographic provinces, the Inner Coastal Plain and the Outer Coastal Plain. Overall, the county has little relief or significant topography; the highest elevation in the county is 260 feet above sea level. The areas of the county within in the Inner Coastal Plain are characterized by fertile soils of clay and sand, with a very gently undulating terrain. The Inner Coastal Plain soils can be very productively agriculturally. In contrast, those areas within the Outer Coastal Plain have poor, sandy soils and are primarily flat. Despite their generally low fertility, the soils of the Outer Coastal Plain do support cranberry and blueberry farming. A small portion of the southeastern corner of the county has the organic, hydric soils associated with tidal estuarine marshes. Burlington County is divided by two main watersheds, the Delaware River basin in the west and Mullica River basin in the southeast.

4.3.2 Biological Features

The naturally occurring vegetation of the county differs significantly by physiographic region. In the Inner Coastal Plain, mixed-oak forest typifies the vegetation found in the upland areas with beech-oak forest occurring sporadically (Collins and Anderson 1994). Wetlands in the Inner Coastal Plain are typically red maple (*Acer rubrum*) and pin oak (*Quercus palustris*), if forested, or a number of herbaceous species if not. Upland sections of the Outer Coastal Plain, on the other hand, are dominated by a combination of pine and oak species. The entire region takes its common name, the Pine Barrens, from the predominance of several pine species, primarily pitch pine (*Pinus rigida*). Pine dominates frequently burned areas, transitioning to oak if fires are suppressed or otherwise less frequent. The freshwater wetland areas of the Outer Coastal Plain consist of Atlantic white cedar (*Chamaecyparis thyoides*) or diverse herbaceous wetlands. Saltmarsh vegetation compose of *Spartina* spp. can be found where the Outer Coastal Plain encounters saline or brackish water in the southeastern tip of the county.

The distinct contrasts between the Inner and Outer Coastal Plains provide a diversity of habitats that is home to many endangered, threatened or rare species and communities. Nearly 60 federal or state endangered or threatened species can be found throughout the county, 28 of them vertebrates. The Pine Barrens themselves are recognized as a Biosphere Reserve by United Nations and are substantially protected as the United States' only national reserve. The area contains many unique plant communities hosting a large number of rare plant species. Rare or threatened species are not restricted to the Outer Coastal Plain, however. The agricultural areas in the Inner Coastal Plain support populations of grassland birds similar to those found in Hunterdon County.

4.4 Land Preservation in New Jersey

Despite its reputation as an urbanized state, over 1.2 million acres of land has been permanently preserved in New Jersey through either open space or farmland preservation programs (Green Acres 2007). This represents 1/5 of the land area of the state. The state has been the most significant actor in this preservation. The state currently owns over 700,000 acres of land preserved as parks, wildlife areas, reservoirs and other miscellaneous areas. The rest of the preserved land in New Jersey is almost evenly split in ownership between counties, municipalities, nonprofit organizations and the federal government (Table 4.2). The state government serves a nexus for land preservation. Not only does it preserve a substantial amount of land through its own programs, it also administers substantial sums of money raised through bonds which it uses to assist counties, municipalities and non-profit groups in their preservation efforts.

Comparing the data in Table 4.1 to some of the figures provided in the previous paragraph highlights some of the difficulties of assessing the status of preserved land in New Jersey. The open space data in Table 4.2 is derived from the most recent geographic information system data detailing preserved open space that has been released by the Green Acres program through state Department of Environmental Protection, current as of 6/2005. The data for farmland preservation is more current (12/2006), and comes from the State Agricultural Development Committee (SADC 2007). The acreage cited in the previous paragraph comes from the Green Acres website (Green Acres 2007) and is assumedly more recent than the GIS data layer.

Problematically, the data available from Green Acres itself seems contradictory for reasons other than simple temporal mismatch. This may be the result of that agency using different definitions of ownership and preservation depending on the circumstance. Many recently preserved tracts may be owned jointly by one or more of the following – a state agency, a county, a municipality and one or more nonprofit groups. It is possible that Green Acres would include land owned jointly by the state and a local non-profit in tallies of both state-owned and non-profit owned preserved land. This is one of the reasons why the open space data derived from the GIS data layers will be used for analytical purposes in this study. In this data set, ownership is ascribed to single entity, usually the managing entity in the case of joint ownership. The other, of course, is that the GIS data layer contains the spatial data necessary for the spatial analyses that will be performed. Inconsistency may also arise because Green Acres may know of preservation but not include in their geographic data because they did not play a role in its preservation. Properties may be preserved through local agencies or non-profit groups without the involvement of Green Acres. Such acreage may be reported but properties may not be mapped and included in the geographic data set. The data for preserved farmland is much more consistent than the open space data because the farmland preservation process is much more centralized.

Table 4.2 - Preserved land in New Jersey.

	Acres	**Percent Total**
Open Space	**940565**	**86.12%**
State	686789	62.89%
County	74048	6.78%
Municipal	46021	4.21%
Non-Profit	24061	2.20%
Federal (non-military)	109646	10.04%
Farmland	**151543**	**13.88%**
Total Land Preserved	***1092108***	***100.00%***

Open space preservation has changed considerably in New Jersey over the last 100 years. Initial preservation efforts focused on preserving historic sites and preserving land for natural resource management activities such as forestry and wildlife. The emphasis towards more passive recreation and conservation oriented preservation began in the 1960s and gained considerable momentum in the subsequent decades. Concern for the diminishing agricultural character of the state led the creation of farmland preservation programs in the mid-1980s. Currently, open space preservation efforts in New Jersey also focus on conserving rare species and communities, while farmland preservation programs protect farmland in order to preserve agriculture as a viable industry. Both types of land preservation programs are seen as essential growth management tools, since they both remove land from pool of potentially developable properties.

Open space preservation efforts in New Jersey center around the Green Acres program, a state agency within New Jersey's Department of Environmental Protection. This program, started in 1961, purchases land for preservation on behalf of several state agencies. It also coordinates the disbursement of funds raised through the Garden State Preservation Trust Act, the legislative implementation of the landmark ballot initiative passed in 1998 that funds open space, farmland and historic preservation through bonds sales of up to $100 million per year for 10 years. Green Acres administers the forty per cent of this money that goes directly to land purchases for open space preservation. In addition to directly purchasing land for state programs, it partners with local and county governments as well as non-profit organizations to financially and administratively assist them with land purchases.

The Green Acres counterpart in farmland preservation is the State Agriculture Development Committee (SADC). Although some farmland was preserved in state parks or wildlife management areas and by some counties, statewide efforts aimed at retaining working farmland did not begin in New Jersey until 1985, with the implementation of the State Agriculture Retention and Development Act of 1983. This legislation permitted the use of permanent easements to prevent the development of farmland and tasked SADC with managing farmland preservation for the purpose of maintaining agriculture as a viable industry in New Jersey. Since 1985, the SADC has administered the preservation of 151,543 acres of farmland (SADC 2007). Most of this farmland is preserved through a hierarchical process. Land owners first apply to their county farmland preservation program, which ranks each applicant to determine the relative preservation value of the farm. The top applicants from each county are then passed on the SADC, which conducts its own ranking (usually very similar to counties' ranking scheme). The SADC then determines which farms will be preserved based its ranking and the willingness of the land owner to sell the development rights of their property below market value (SADC 2003b).

4.4.1 Non-Profit Organizations and Land Preservation in New Jersey

Although their effects are more difficult to trace, non-profit land trusts and conservation organizations have also played an important role in preserving land in New Jersey. It is, however difficult to generate a comprehensive portrait of the impact of these groups on land preservation. The number of non-profit groups involved in land preservation is large and their size and focus varies tremendously. They preserve land primarily through the donation or purchase of development rights or property. Many purchases are leveraged with funding from Green Acres, counties and/or municipalities, and are relatively easy to track because of the government involvement. However, the complexity of the purchases, in which 3 or more organizations might be involved, make it difficult to assign ownership to preserved land and to verify that preserved land with multiple owners is not being counted multiple times in summaries of preserved land. Donations and purchases made with privately raised funds are particularly difficult to track. In these cases, however, the organization may apply for tax exemption for lands so preserved if they wish to allow public access. Since this tax exemption is administered by Green Acres, it makes privately preserved land visible to Green Acres, which then means that it should appear at summaries of preserved lands compiled by that office. Unfortunately, this does not necessarily mean that good spatial data for lands preserved by non-profits will be available, although those preserved with state or local funding are much more likely to be represented in publicly available spatial data layers detailing preserved land.

4.4.2 The Garden State Preservation Trust Act

The involvement of non-profit organizations in land preservation in New Jersey has only increased since the passage of the Garden State Preservation Trust Act (GSPTA) in 1999. This act provides $98 million per year for land preservation in New Jersey, and gives the state authority to issue up to $1 billion in bonds for preservation over a 10 year period. Through the act, local and county governments as well as non-profit organizations are eligible to receive funding for preservation. If the experience of the

DFW holds true, the increased involvement of these groups may be one of the more important consequences of the GSPTA. As noted above, the involvement of Green Acres and public funds in acquiring land for DFW broadened the scope of activities seen as appropriate for WMAs. Along with the funding provided by the GSPTA comes the significant task of having to spend it. Green Acres is increasingly relying non-profit organizations and local or county governments to identify and preserve lands using money it provides (Green Acres 2002a). By virtue of this increasing involvement in permanent land preservation, such organizations play a significant role in shaping future landscapes.

The GSPTA is also likely to change the nature of open space preserved by counties and municipalities. Those counties and municipalities with significant amounts of undeveloped land are now in a position to focus more on conservation preservation rather than or in addition to creating parks for active recreation. The funding made available by the GSPTA also has the potential to change the way local governments plan open space and farmland preservation. In order to qualify for certain types of Green Acres preservation funding, local governments must have enacted an open space tax and an open space and recreation plan (Green Acres 2002b). Likewise, in order to be eligible for certain types of farmland preservation funding municipalities will need to have a farmland preservation component to their master plan (SADC 2003b). It seems likely that the potential to receive more money than previously anticipated will cause many local governments to reconsider their open space planning.

This hints at the larger issue of how the GSPTA will affect open space preservation and the future landscapes of New Jersey. Of course, a greater acreage of land will be preserved because of the legislation than would be otherwise. However, the legislation may very well have more subtle effects. Some of these potential effects worth future examination include changes in the characteristics of preserved land, alterations in the purpose and use of preserved land, and shifts in the geographic distribution of preserved land across a variety of spatial scales.

4.5 Land Preservation in Hunterdon County

The open space and farmland preservation programs administered by Hunterdon County are among the most active and longest established county programs in the state. Hunterdon's Parks and Recreation Department (HCPRD) has always given scenic and conservation preservation serious consideration. In three decades, the Parks and Recreation Department has acquired 26 areas totaling 8,280 acres (HCPRD 2012). Only two of these parks have facilities for active recreation. The rest are intended for passive recreation only. Future acquisition and development of Hunterdon County's parks seem likely to continue in this vein, since 90% of planned future acquisitions will target areas of conservation value and exclude active recreation from management plans (Hunterdon County 2000). Table 4.3 details the ownership/management of preserved land in Hunterdon County. Note the discrepancies between the preserved land data in the table, again derived from the Green Acres geographic data set, and the figures provided by the county above.

Comparing the percentages in Table 4.2 with those in Table 4.3 shows how Hunterdon's land preservation allocation differs proportionally from the state as a whole. Almost 41% of the preserved land in Hunterdon is preserved through farmland preservation, versus 13.9% for the state as whole. This reflects the longstanding county commitment to farmland preservation and the extent of the county's agricultural past. The county (13.3% vs. 6.8% statewide) and Hunterdon County's municipalities (7.8% vs. 4.2% statewide) are also overrepresented compared to the state as a whole. In contrast, the state owns considerably less land on a proportional basis in Hunterdon (34.0% vs. 62.9% statewide). Nonprofit organizations have preserved more of Hunterdon (4.7%) than of the state as a whole (2.2%). In total, 16% of the county is preserved compared to 20% of the state as a whole.

Table 4.3 - Preserved land in Hunterdon County

	Acres	**Percent Total**
Open Space	**24525**	**59.8%**
State	13938	**34.0%**
County	5452	**13.3%**
Municipal	3188	**7.8%**
Non-Profit	1946	**4.7%**
Farmland	**16460**	**40.2%**
Total Land Preserved	***40985***	**100.00%**

The relative importance of the county and municipalities in preserving open space in Hunterdon suggests that either these organizations may be responding to a relative lack of state involvement in the county or the state feels that its direct preservation efforts could be more effective elsewhere given the level of local involvement. It might also evidence a recognition by the state land preservation agencies that because the county receives a considerable amount of state resources for farmland preservation, resources for open space preservation might be more prudently applied elsewhere. If the county's goals for farmland and open space preservation come to pass (30,000 acres and 20,000, respectively) the county could conceivably eclipse the state as the primary shaper of preservation and manager of preserved land within the county's boarders.

Whatever the reason, this increased involvement of local governments puts Hunterdon in an interesting position. County and municipal open space preservation in Hunterdon is primarily focused on preservation for conservation and passive recreation (Hunterdon County 2000). Among New Jersey counties, Hunterdon may be in a unique position to concentrate park acquisition and development on conservation oriented goals. According to the 2000 US Census, Hunterdon County has a population density of 283.7 persons/sq. mile, giving it the third lowest population density in the state. Only Sussex and Salem Counties have lower population densities (276.6 and 190.3 persons/sq. mile, respectively). This is considerably below the state's mean density of 1,134.4 persons/sq. mile. Hunterdon's 121,989 residents enjoy the highest per household and third highest per capita income in the state. The low population density and high per capita income may combine to provide Hunterdon with resources to protect significant amounts of parkland without having significant pressure to develop it for active recreation.

4.5.1 Farmland Preservation in Hunterdon County

Although the exact formula used for ranking applicant farms varies from county to county, Hunterdon County's overall farmland preservation process and program can serve as a general model. In order to be eligible for preservation through Hunterdon's program, a farm must meet three criteria (Hunterdon County 2000). It must be equal to or greater than 40 acres, no more than 50% wooded and fall within both an Agricultural

Development Area (ADA) and agricultural district. ADAs are areas deemed likely to be able to support agriculture over the long term. They must contain a predominance of high-quality farming soils and not contain a large amount of new development. Originally delineated in the early 1980s, new ADAs have been added over time. An agricultural district is an area of farms totaling at least 250 acres that are within one mile of each other and have applied for or enrolled in the farmland preservation program.

The list of ranking criteria and their importance (Table 4.4) indicates that Hunterdon's program gives strong weight to high-quality farming soils, surrounding land uses that do not conflict with agriculture, size of the farm and proximity to preserved farmland. All of these factors were chosen to increase the probability of building core agricultural areas within ADAs that promote the economic viability of agriculture. Using these criteria, Hunterdon has permanently preserved 9190 acres of farmland since 1985, and had set the goal of preserving a total of 50,000 acres by 2010 (Hunterdon County 2000).

Table 4.4 – Summary of Hunterdon County's farmland preservation criteria

Criterion	**Points**
Soil	30
Boundaries and Buffers	20
Local Commitment	22
Size and Density	24
Farm and Family	10
TOTAL	**106**

Permanent preservation through easement purchase is not the only method available for farmland preservation in Hunterdon or the rest of the state. There is a temporary preservation program which provides incentives such as matching grants to land owners for 8 years if they agree to not to develop their farms for the duration of the program. Although not permanent, this type of preservation is important because it allows the creation of agricultural districts that can then become the nexus of permanent preservation efforts. Hunterdon currently has 838 acres of farmland in the 8-year program. Farms can also be preserved through fee simple acquisition, the outright purchasing of the farm by the county, or more likely, the state, with subsequent deed restricting and auctioning of the property. Finally, in cases where a family or business emergency necessitates the sale of a farm, the owner can apply to the SADC for emergency fee simple or easement purchase.

4.5.2 County Open Space Preservation in Hunterdon County

Hunterdon County has been preserving open space for conservation and recreational purposes since the county park system began 1966 with a donation of 80 acres of fields and forest to be used as a nature preserve (HCPRD 2012). Since then, the Parks and Recreation Department has acquired 26 areas totaling 8,280 acres (HCPRD 2012), the majority of which is used for passive recreation and conservation. As mentioned previously, future acquisition and development of Hunterdon County's parks seem likely to continue in this vein. The Hunterdon County Open Space, Farmland and Historic Preservation Trust Fund Plan calls for the acquisition of 12,300 additional acres of park land (Hunterdon County 2000). Only 1,100 acres of this planned acquisition falls into the General/Special Use category, which allows a combination of active and passive recreation as well as uses such as arboreta or similar special uses. The vast majority of remaining acquisitions (9,600 acres) are targeted at protecting representative or sensitive physiographic or biological features, with the remaining 800 acres providing linkages for trails and greenways.

The Hunterdon County Open Space, Farmland and Historic Preservation Trust Fund Plan (2000) details the characteristics of lands targeted by the county's general open space preservation program. This plan specifies seven open space preservation characteristics relevant to this study. These are conservation zones (e.g. areas of unique conservation value, including river corridors), fragile/rare flora habitat, habitat of endangered and threatened animals, properties adjacent to existing parks, properties in the viewshed of existing parks, and greenway linkages between parks and trail corridors. Maps showing the location of these areas can be found in Chapter 5. The continued value of these areas for preservation purposes is clearly contingent on the nature of future development in these areas, an issue left unaddressed by Hunterdon's plan.

4.6 Land Preservation in Burlington County

There are significant contrasts in land preservation efforts in Burlington County versus Hunterdon County. Burlington County's preserved land is overwhelmingly owned or administered by the state (Table 4.5), primarily in the form of large state parks and forests in the southeastern portion of the county. The percentage of state preserved is greater than the state as whole, while the other categories are less. The caveats about the data mentioned previously also apply the data for Burlington County.

Table 4.5 - Preserved Land in Burlington County

	Acres	Percent Total
Open Space	**146250**	**89.3%**
State	140705	**85.6%**
County	2536	**1.6%**
Municipal	593	**0.04%**
Non-Profit	2416	**1.5%**
Farmland	**18670**	**11.4%**
Total Land Preserved	***164920***	**100.00%**

The southeastern two thirds of the county is part of the Pinelands Management Area, an area designated in 1978 as part of the Pinelands National Reserve in recognition of the unique ecology of this area. This area is managed by the Pinelands Comprehensive Management Plan, which sets limits for development in ecologically important areas and attempts to foster development in designated centers (New Jersey Pinelands Commission 2008). The presence of both these large swaths of state owned land and the Pinelands Management Area has lead Burlington County to focus most of its land preservation efforts in the more populous northwestern third of the county, for several reasons. The first is that much of the southern two thirds of the county is already preserved. Secondly, that part of the county which isn't preserved is subject to the stricter growth controls of the Comprehensive Management Plan. Thirdly, several non-profit groups are actively preserving ecologically sensitive and valuable areas in this part of the county. Lastly, the county feels that its residents are better served by concentrating preservation efforts where the majority of those residents live, the northeastern third (Burlington County Department of Resource Conservation 2002).

4.6.1 Farmland Preservation in Burlington County

Burlington County preserved the first farm in the state in 1985. As of 2005, they have preserved over 14,000 acres of farmland and rank first among counties in acreage of farmland preserved. All of the farms preserved have been located in the northwestern third of the county, and only a few are located within the boundaries of the Pinelands Management Area. As of the mid 2000s, Burlington had adopted the same ranking scheme and eligibility requirements for farmland preservation used by Hunterdon County and the State Agricultural Development Committee.

4.6.2 County Open Space Preservation in Burlington

In contrast to the well-established, long standing farmland preservation program, the county's open space preservation program has been slow to acquire land. The county park system began by acquiring two historic properties in the 1960s and 1970s (Burlington County Department of Resource Conservation 2002). The park system concentrated on running and improving these facilities for several decades after acquisition. The county has since developed a master plan for acquisition that focuses on four project areas: Rancocas Creek Greenway, Delaware Raritan Greenway, Barker's Brook Project Area and the Mason's Creek/Rancocas Creek Southwest Project Area. These areas are located whole within the most populated and least protected northeastern half of the county. These areas were chosen because they support each support multiple goals the county has for open space preservation within a limited geographical area.

4.7 Conclusions

Both Burlington and Hunterdon have well developed and long standing farmland preservation programs that have preserved more farmland than other counties in New Jersey. They show a disparity in the open space preservation programs, however, with Hunterdon having a much more well developed open space preservation program than Burlington. This disparity may be the result of two factors. One, Hunterdon is much wealthier county than Burlington and can help fund county-led open space preservation more than Burlington can. Two Burlington has large swaths of preserved land occupying its southeastern half, both in and near the Pinelands National Reserve. This large reservoir of preserved open space may have influenced Burlington residents, and their county government, to forgo significant county-led open space preservation.

Chapter 5 – Landscape Change in Hunterdon and Burlington Counties, 1986 - 2002

5.1 Introduction

This chapter presents the methods and results of the analyses of landscape change in Hunterdon and Burlington. The analyses focus on the years 1986 to 2002, with land use/land cover datasets for 1986, 1995, and 2002. The importance of the results is also discussed, with an emphasis on the potential environmental impacts of the observed changes.

Land use/land cover change in Hunterdon and Burlington Counties was measured using land use/land cover data generated for the State of New Jersey's Department of Environmental Protection for the years 1986, 1995 and 2002. The LULC products distributed by the NJDEP are based on visual interpretation of aerial photography and classify LULC into more than 50 categories. These categories were combined into 7 LULC categories: developed, agriculture, upland forest, barren, wetland forest, emergent wetland and water (Table 5.1). These seven categories adequately capture the relevant natural and human-altered landscapes in the study areas while maintaining a reasonable area for each class. The reclassified vector data sets were then converted to ArcGrid format raster data with a resolution of 30 m. This was done to facilitate comparisons at between the data sets, each of which is based on different resolution aerial photography and has a different minimum mapping unit. The raster cell size was chosen because is large enough to eliminate many remnant polygons in the 2002 data formed by the update processes. The cell size also promotes comparison between this and other data, including Landsat derived 30 m LULC products. Also, many existing studies of landscape change utilize data derived from 30 m satellite imagery, and the behavior of indices and metrics generated from such imagery is reasonably well documented.

Table 5.1. Reclassification of orginal land use/landcover classes

Modified Anderson Classification	Reclassfication
AGRICULTURAL WETLANDS (MODIFIED)	EMER. WETLANDS
AIRPORT FACILITIES	DEVELOPED
ALTERED LANDS	BARREN LAND
ARTIFICIAL LAKES	WATER
ATHLETIC FIELDS (SCHOOLS)	DEVELOPED
BARE EXPOSED ROCK, ROCK SLIDES, ETC.	BARREN LAND
BEACHES	BARREN LAND
BRIDGE OVER WATER	WATER
CEMETERY	DEVELOPED
CEMETERY ON WETLAND	EMER. WETLANDS
COMMERCIAL/SERVICES	DEVELOPED
CONFINED FEEDING OPERATIONS	AGRICULTURE
CONIFEROUS BRUSH/SHRUBLAND	FOREST
CONIFEROUS FOREST (10-50% CROWN CLOSURE)	FOREST
CONIFEROUS FOREST (>50% CROWN CLOSURE)	FOREST
CONIFEROUS SCRUB/SHRUB WETLANDS	FOR. WETLANDS
CONIFEROUS WOODED WETLANDS	FOR. WETLANDS
CROPLAND AND PASTURELAND	AGRICULTURE
DECIDUOUS BRUSH/SHRUBLAND	FOREST
DECIDUOUS FOREST (10-50% CROWN CLOSURE)	FOREST
DECIDUOUS FOREST (>50% CROWN CLOSURE)	FOREST
DECIDUOUS SCRUB/SHRUB WETLANDS	FOR. WETLANDS
DECIDUOUS WOODED WETLANDS	FOR. WETLANDS
DISTURBED WETLANDS (MODIFIED)	EMER. WETLANDS
EXTRACTIVE MINING	BARREN LAND
FORMER AGRICULTURAL WETLAND (BECOMING SHRUBBY, NOT BUILT-UP)	EMER. WETLANDS
HERBACEOUS WETLANDS	EMER. WETLANDS
INDUSTRIAL	DEVELOPED
INDUSTRIAL/COMMERCIAL COMPLEXES	DEVELOPED
MAJOR ROADWAY	DEVELOPED
MANAGED WETLAND IN BUILT-UP MAINTAINED REC AREA	EMER. WETLANDS
MANAGED WETLAND IN MAINTAINED LAWN GREENSPACE	EMER. WETLANDS
MILITARY INSTALLATIONS	DEVELOPED
MIXED DECIDUOUS/CONIFEROUS BRUSH/SHRUBLAND	FOREST
MIXED FOREST (>50% CONIFEROUS WITH 10-50% CROWN CLOSURE)	FOREST
MIXED FOREST (>50% CONIFEROUS WITH >50% CROWN CLOSURE)	FOREST
MIXED FOREST (>50% DECIDUOUS WITH 10-50% CROWN CLOSURE)	FOREST
MIXED FOREST (>50% DECIDUOUS WITH >50% CROWN CLOSURE)	FOREST
MIXED RESIDENTIAL	DEVELOPED

MIXED SCRUB/SHRUB WETLANDS (CONIFEROUS DOM.)	FOR. WETLANDS
MIXED SCRUB/SHRUB WETLANDS (DECIDUOUS DOM.)	FOR. WETLANDS
MIXED URBAN OR BUILT-UP LAND	DEVELOPED
MIXED WOODED WETLANDS (CONIFEROUS DOM.)	FOR. WETLANDS
MIXED WOODED WETLANDS (DECIDUOUS DOM.)	FOR. WETLANDS
NATURAL LAKES	WATER
OLD FIELD (< 25% BRUSH COVERED)	FOREST
ORCHARDS/VINEYARDS/NURSERIES/HORTICULTURAL AREAS	AGRICULTURE
OTHER AGRICULTURE	AGRICULTURE
OTHER URBAN OR BUILT-UP LAND	DEVELOPED
PLANTATION	FOREST
RECREATIONAL LAND	DEVELOPED
RESIDENTIAL, HIGH DENSITY OR MULTIPLE DWELLING	DEVELOPED
RESIDENTIAL, RURAL, SINGLE UNIT	DEVELOPED
RESIDENTIAL, SINGLE UNIT, LOW DENSITY	DEVELOPED
RESIDENTIAL, SINGLE UNIT, MEDIUM DENSITY	DEVELOPED
STORMWATER BASIN	DEVELOPED
STREAMS AND CANALS	WATER
TRANSITIONAL AREAS	BARREN LAND
TRANSPORTATION/COMMUNICATION/UTILITIES	DEVELOPED
UNDIFFERENTIATED BARREN LANDS	BARREN LAND
UPLAND RIGHTS-OF-WAY DEVELOPED	DEVELOPED
UPLAND RIGHTS-OF-WAY UNDEVELOPED	DEVELOPED
WETLAND RIGHTS-OF-WAY	EMER. WETLANDS

5.2 Simple Measures of Landscape Change, 1986 to 2002

Figures 5.1a-c and 5.2a-c map the land use/land cover for each time period for Hunterdon and Burlington, respectively. Table 5.2a shows, in acres, the amount of land in each of the land use/land cover categories for 1986, 1995 and 2002 for Hunterdon County. Table 5.2b shows the same for Burlington County. Table 5.3a and 5.3b show the percentage change for each class over time periods 1986-1995, 1995-2002 and 1986-2002. Taken together, these tables show the gross landscape change in the study areas as measured by land use/land cover change. These figures can also be compared to statewide figures on landuse/landcover change generated by Hasse and Lathrop (2008) using the same data. This comparison facilitates an understanding of the similarities and differences in the LULCC processes occurring in the study areas versus the entire state.

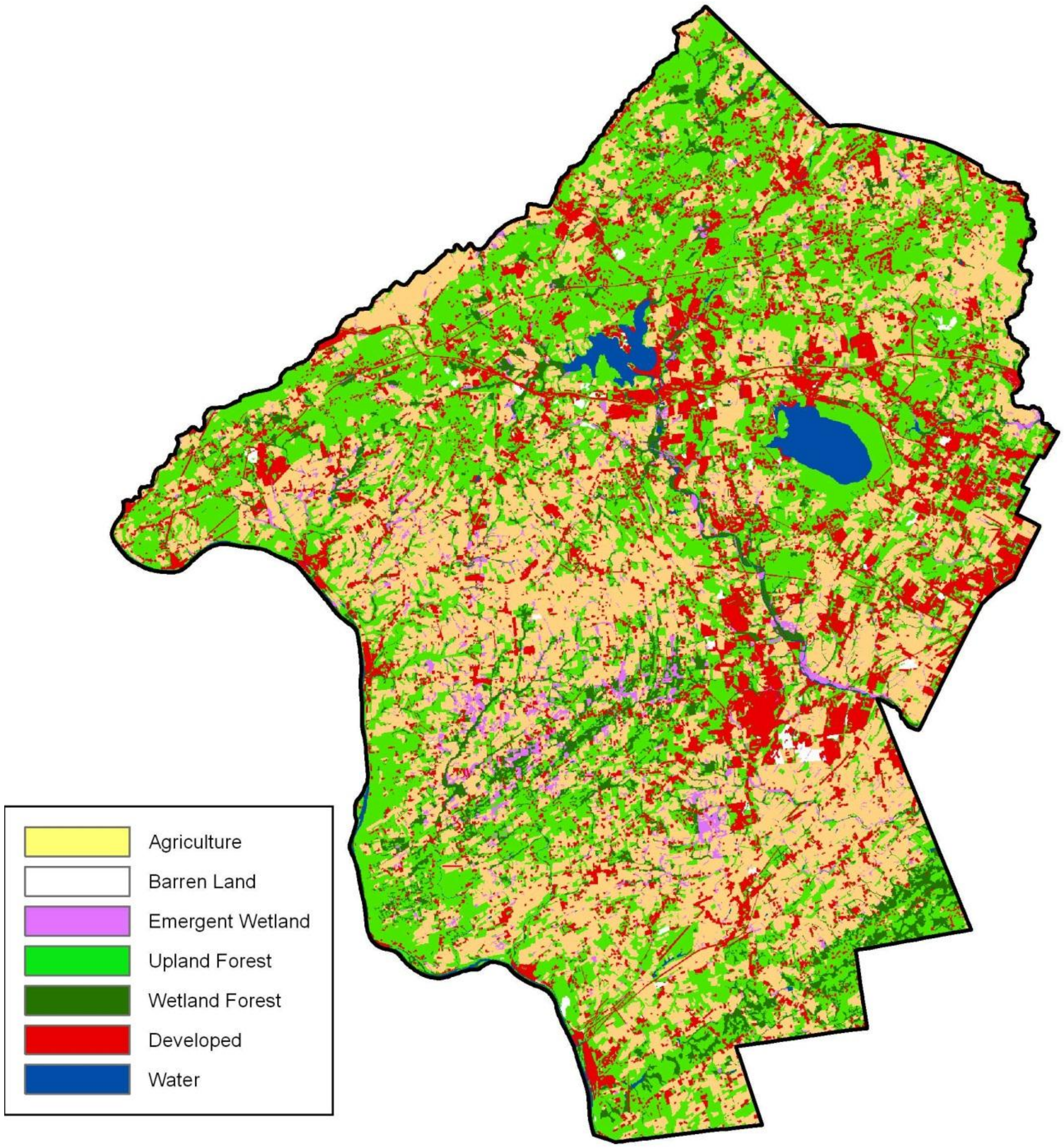

Figure 5.1a. Land Use/Land Cover in Hunterdon County, 1986

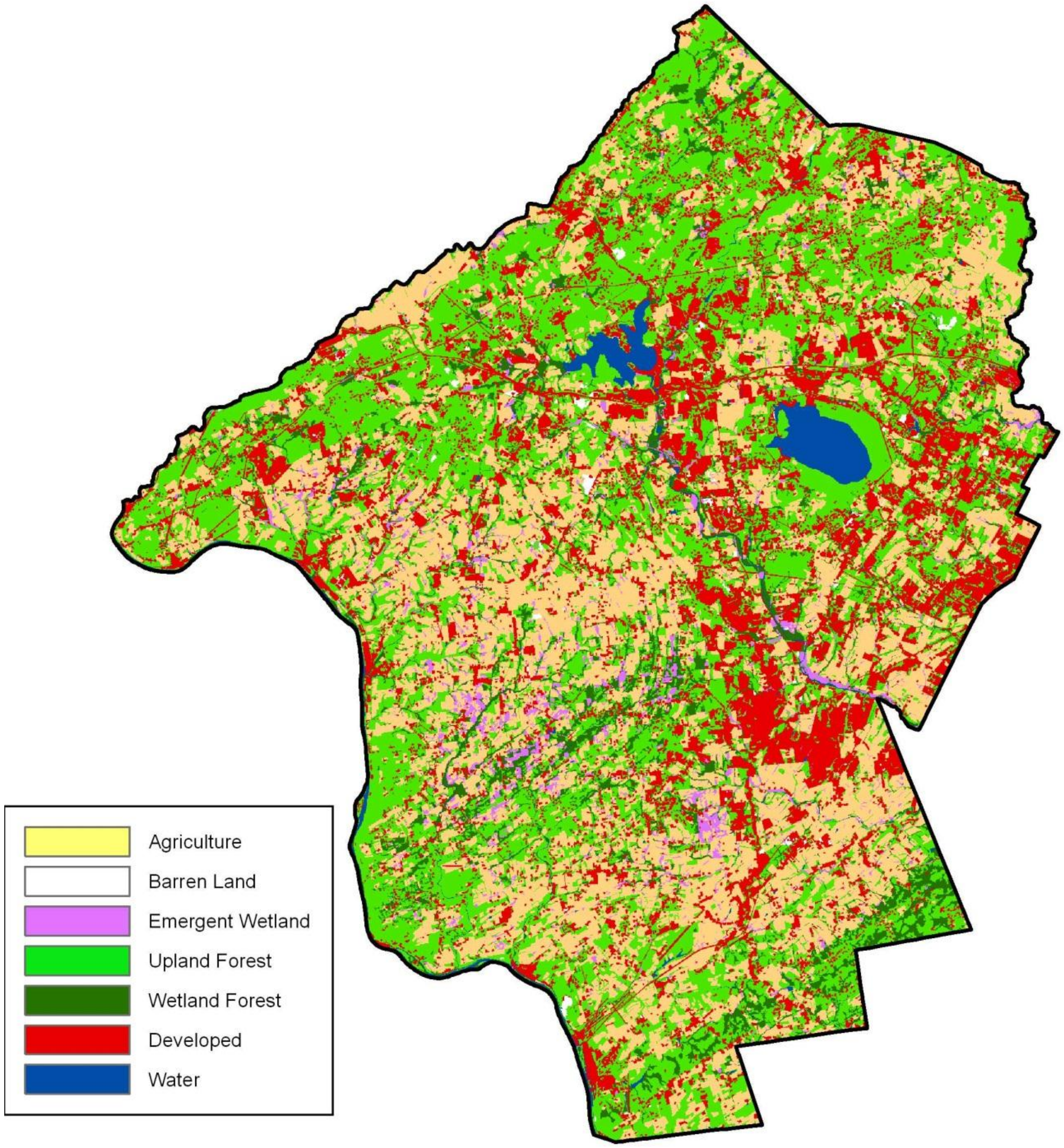

Figure 5.1b. Land Use/Land Cover in Hunterdon County, 1995

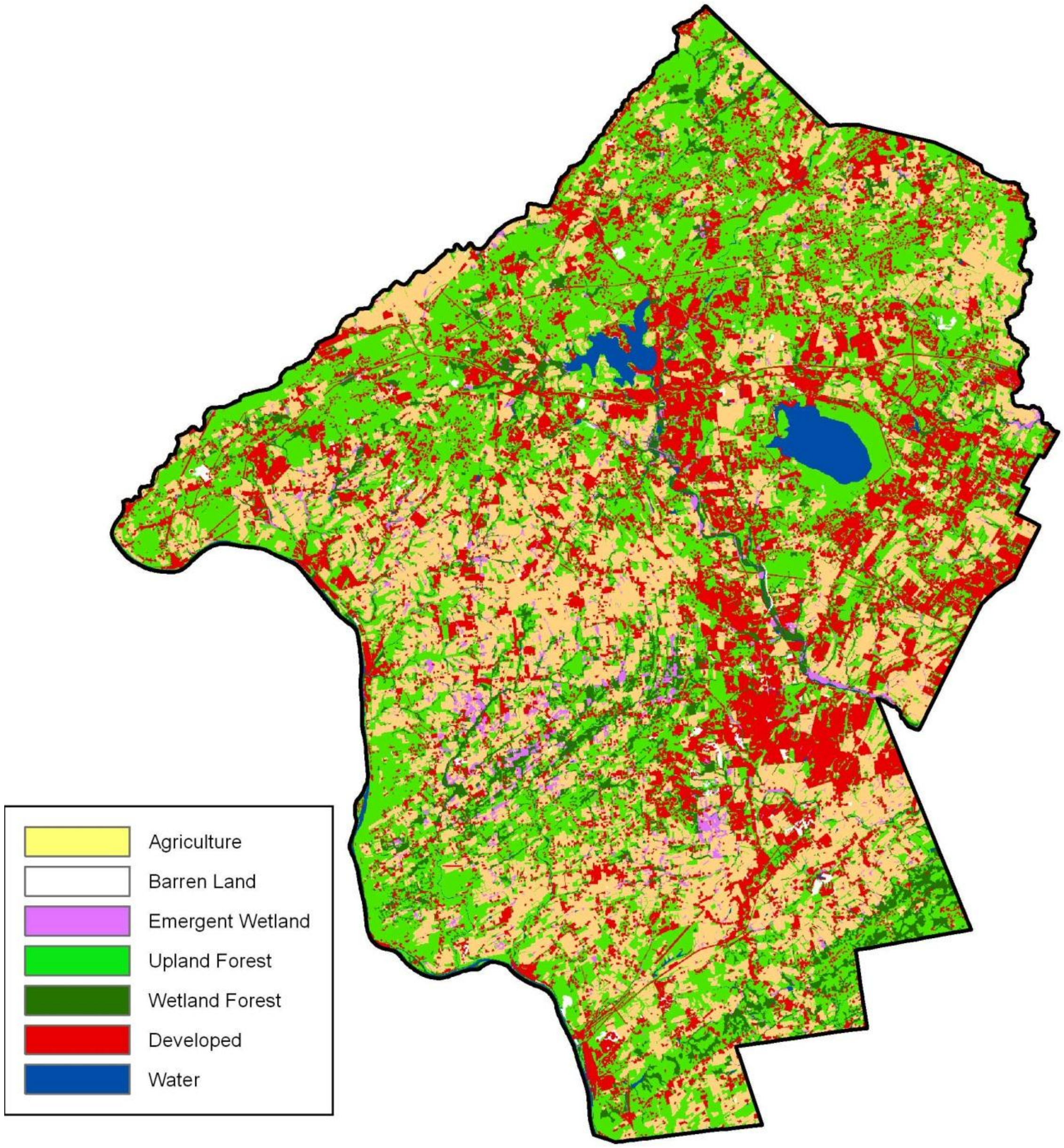

Figure 5.1c. Land Use/Land Cover in Hunterdon County, 2002

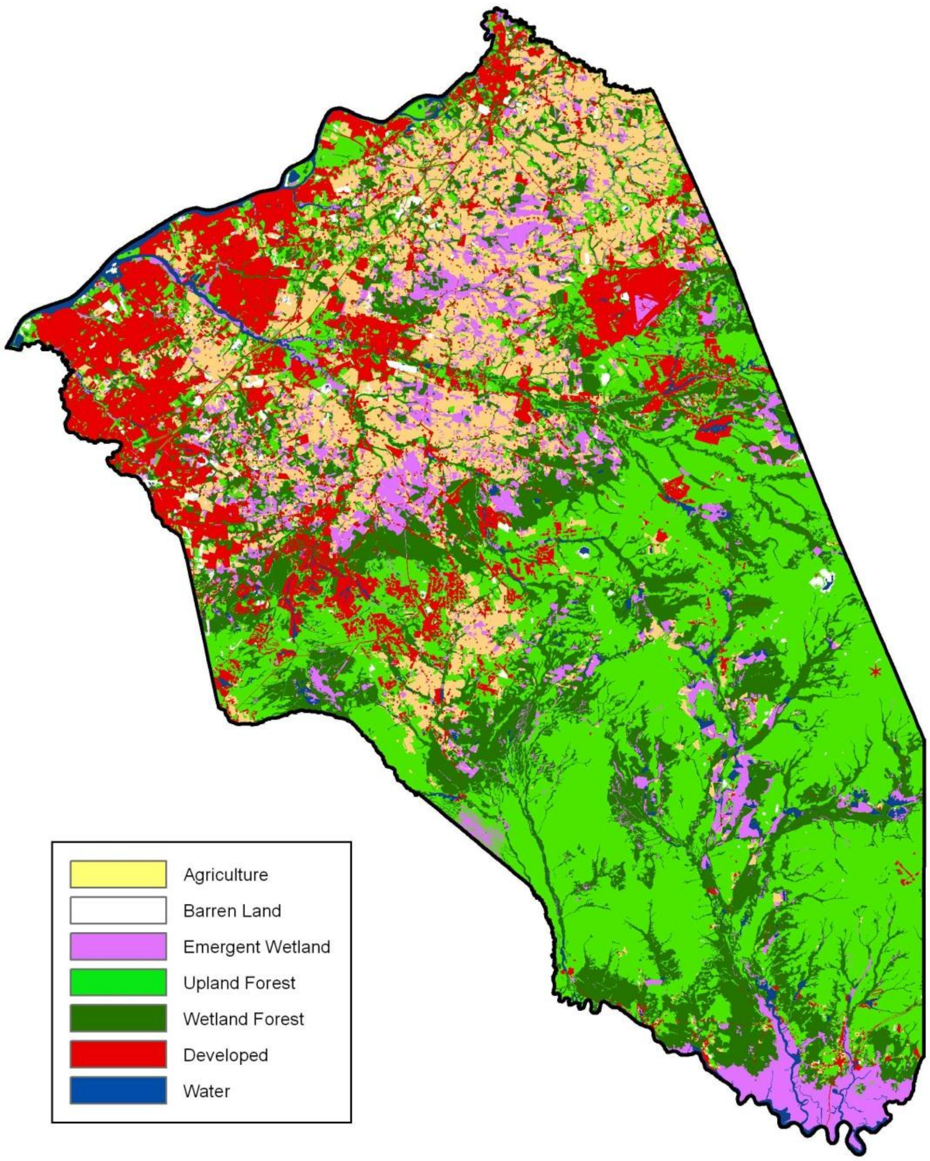

Figure 5.2a Land Use/Land Cover in Burlington County, 1986

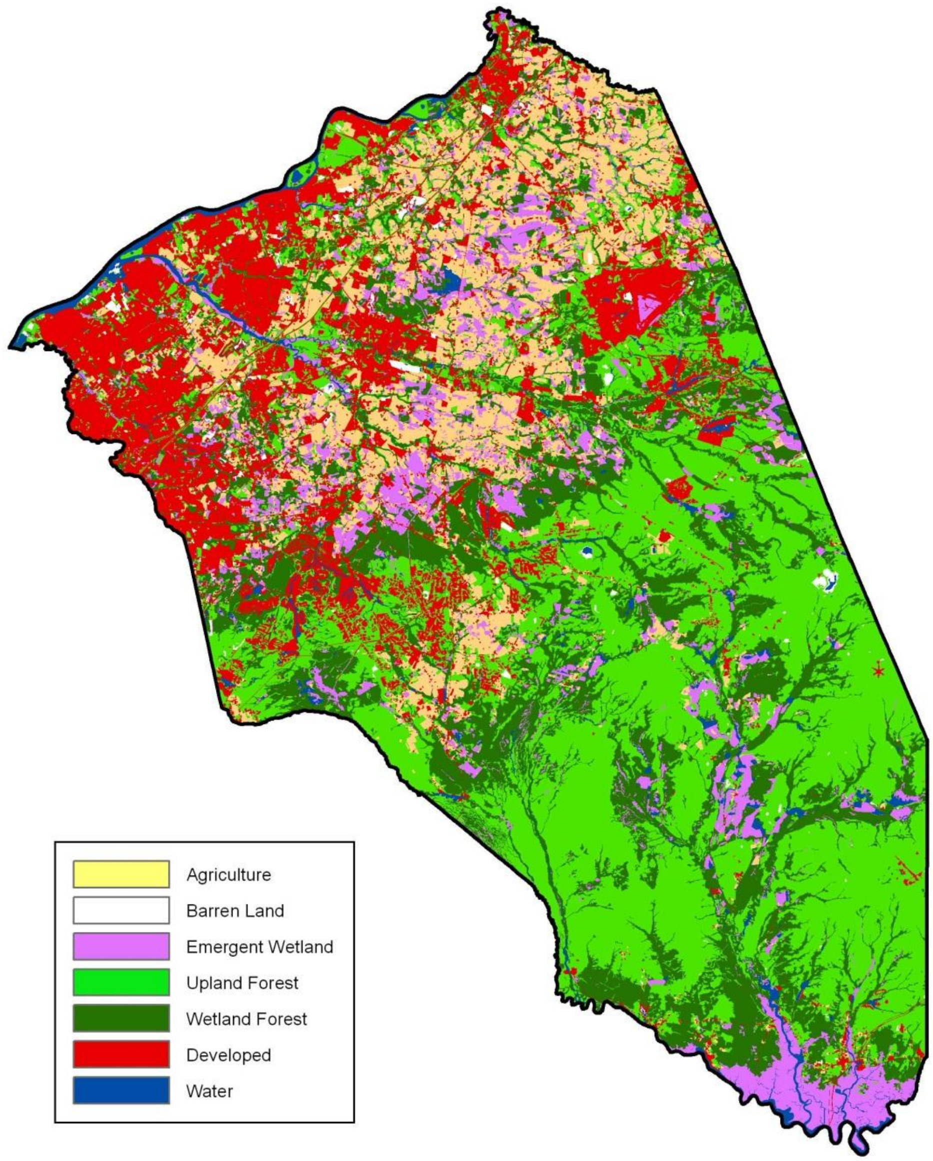

Figure 5.2b Land Use/Land Cover in Burlington County, 1995

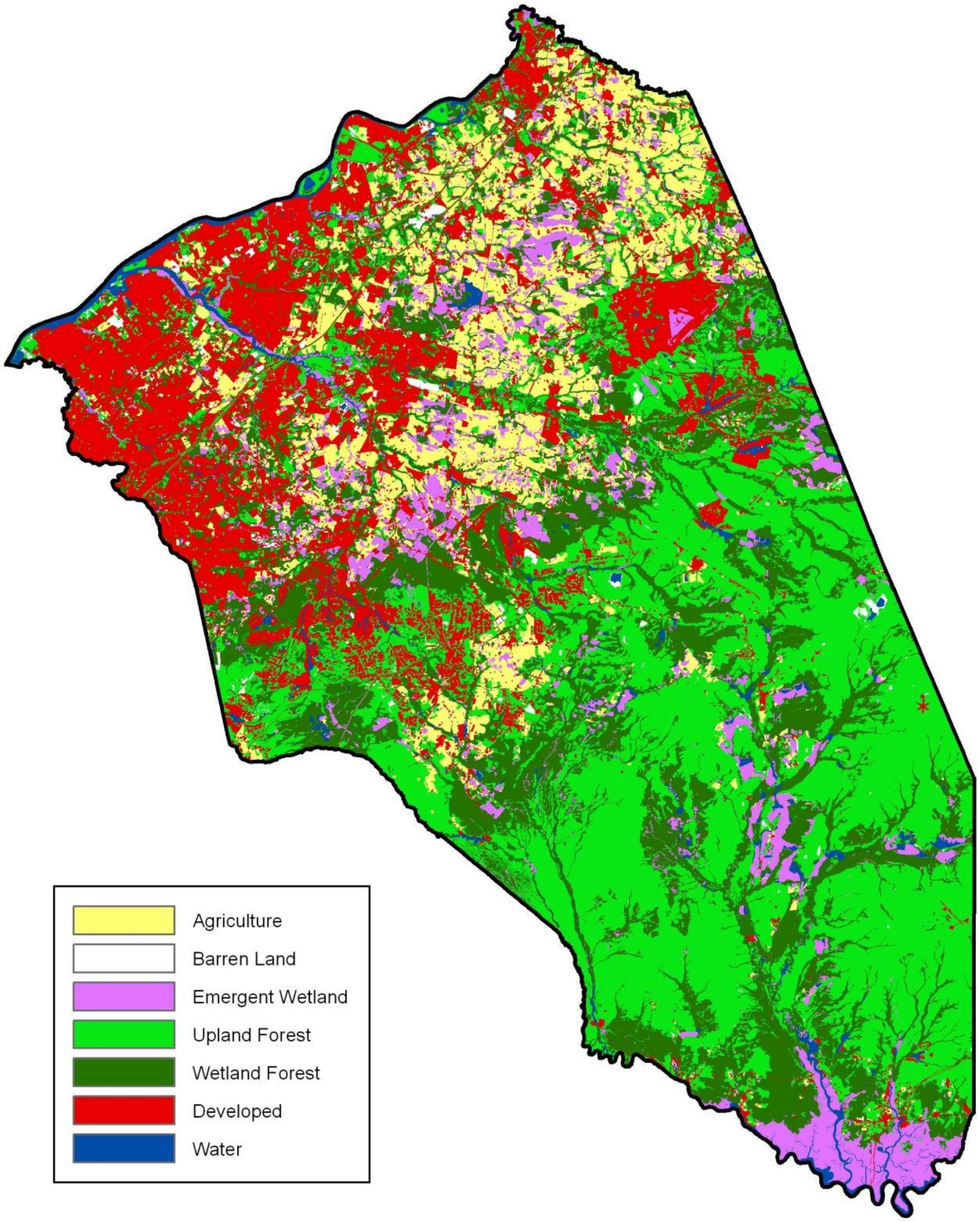

Figure 5.2c Land Use/Land Cover in Burlington County, 2002

Table 5.2 Land use/land cover, in acres, in Hunterdon (a) and Burlington (b), for 1986, 1995, 2002.

a.

LU/LC	**1986**	**1995**	**2002**
Developed	45808	55881	62961
Agricultural	101523	89376	82294
Upland Forest	99679	102368	102383
Barren	1409	1121	1525
Forested Wetland	18251	17774	18278
Emergent Wetland	7336	7078	6142
Water	6115	6523	6537

b.

LU/LC	**1986**	**1995**	**2002**
Developed	76468	89896	98702
Agricultural	72044	64126	58430
Upland Forest	194507	191128	188795
Barren	5456	4187	4623
Forested Wetland	117858	116383	120758
Emergent Wetland	44523	44208	38848
Water	13353	14280	14053

Table 5.3. Percentage change in Hunterdon (a) and Burlington (b) land cover for three time periods (annual change in parenthesis).

a.

LU/LC	**1986 - 1995**		**1995 – 2002**		**1986 – 2002**	
Developed	22.0	(2.4)	12.7	(1.8)	37.4	(2.3)
Agricultural	-12.0	(-1.3)	-7.9	(-1.1)	-18.9	(-1.2)
Upland Forest	2.7	(.3)	0.0	(0.0)	2.7	(0.2)
Barren	-20.5	(-2.3)	36.1	(5.2)	8.2	(0.5)
Forested Wetland	-2.6	(-0.3)	2.8	(0.4)	0.1	(0.0)
Emergent Wetland	-3.5	(-0.4)	-13.2	(-1.9)	-16.3	(-1.0)
Water	6.7	(0.7)	0.2	(0.0)	6.9	(0.4)

b.

LU/LC	**1986 - 1995**		**1995 – 2002**		**1986 – 2002**	
Developed	17.6	(2.0)	9.8	(1.4)	29.1	(1.8)
Agricultural	-11.0	(-1.2)	-8.9	(-1.3)	-18.9	(-1.2)
Upland Forest	-1.7	(-0.2)	-1.2	(-0.2)	-2.9	(-0.2)
Barren	-23.2	(-2.6)	10.4	(1.5)	-15.3	(-1.0)
Forested Wetland	-1.3	(-0.1)	3.8	(0.5)	2.5	(0.2)
Emergent Wetland	-0.7	(-0.1)	-12.1	(-1.7)	-12.7	(-0.8)
Water	6.9	(0.8)	-1.6	(-0.2)	5.2	(0.3)

Both counties have experienced significant development over the study period, although Hunterdon added more development as percentage of its total area (37.1% to 29.1%). Both counties also show a slight decline in the annual rate of development between 1995 – 2002 vs. 1986 – 1995. This is in contrast to the slight increase showed by the state as a whole (Hasse and Lathrop 2008). This decline is somewhat surprising given the robust general economic conditions of the latter period, and may, in fact, be evidence of effective controls being placed on development by regulation changes, increased land preservation or increased citizen involvement in the development process. Regulatory changes such as downzoning or increased use of steep slope ordinances may have curtailed the rate of development. Land preservation activities clearly increased during this time period, and could contribute to a decline in development by competing with developers for available properties. Finally, increased citizen involvement during the planning and development process may have lead to projects receiving closer scrutiny than they would otherwise have received. This scrutiny could result in contestation of the suitability or legality of the development of a particular parcel, making it more difficult and expensive to develop it.

Hunterdon and Burlington both experienced a significant decline in agricultural lands over the study period, each losing 18.9% of their farmlands during the study period. This is greater than the rate experienced by the state as whole (Hasse and Lathrop 2008). Hunterdon experienced a greater absolute loss of farmland since it had more at the beginning of the study period than Burlington. Hunterdon saw a slight decrease in the annual rate of loss (1.3% to 1.1%) while Burlington saw a slight increase (1.2% to 1.3%) in the annual rate of loss between 1986-1995 and 1995-2002. In this respect, Hunterdon mirrored the slight decline in the rate of conversion of agricultural lands to development of the state as whole (Hasse and Lathrop 2008). Given that farmland preservation programs increased their rate of preservation significantly between the two time periods, this suggests that farmland preservation programs alone may not be enough to arrest the conversion of agricultural lands into developed uses. Of course, without the increasingly active preservation programs, the amount of agricultural land converted to other uses could have been significantly higher.

In contrast, the amount of upland forest in each county changed only slightly during the study period. Hunterdon gained 2.7% in upland forest cover while Burlington lost 2.9%. While the loss of forest in Burlington may be of long term concern, it is clear that loss of agricultural land is a greater landscape planning issue in the near term. Forested wetlands similarly experienced only small changes in both counties over the entire study period. Both Hunterdon and Burlington lost forested wetland between 1986 and 1995 and gained it between 1995 and 2002. In Hunterdon this lead to a very small net increase of 0.1% in the area of forested wetland between 1986 and 2002. Burlington added 2.5% over the same time period. The losses between 1986 and 1995 were almost exclusively to development.

Emergent wetlands show an interesting trend in both counties. Between 1986 and 1995, Hunterdon experienced a moderate loss (3.5%) and Burlington a minor loss (0.7%) of emergent wetland. Between 1995 and 2002, however, both Hunterdon and Burlington experienced dramatic declines in the amount of emergent wetland present (13.2% and 12.1%, respectively). Unlike the loss of forested wetlands between 1986 and 1995, the emergent wetlands were not converted to development. Instead, the majority of emergent wetlands lost between 1995 and 2002 became forest or forested wetlands in both counties. Some of this conversion could be the result of maturing vegetation. However, it seems likely that some part of the conversion is actually attributable to differences in the resolution of the aerial photographs used to create the land use/land cover maps. The 2002 photography is sub-foot in resolution, as compared to 1 meter for the 1986 photography. The additional discernment provided by this increased resolution may have resulted in a much more refined classification of transition areas between emergent and forested wetlands. One out of six of the acres of emergent wetland lost in Burlington was lost to development, as opposed to one out of twenty in Hunterdon.

Not unexpectedly, the barren land use/land cover class shows some significant change between time periods. Because it occupies relatively little of the area of either county, small changes in area can result in large percentage changes. Also, since areas currently under development represent a substantial portion of the land occupied by the class, significant changes are likely to be observed. One or two large developments can represent a majority of the landscape in the barren class at any given time. If these developments are completed by the time of the next land use/land cover classification, then they will obviously be transferred out of the barren and into the developed category in the new land use/land cover classification.

5.3 Landscape Transitions, 1986 to 2002

The landscape change summarized in Tables 5.2 and 5.3 provides an overview of the overall land use/land cover change in Hunterdon and Burlington Counties. However, the measures of change presented do not provide information regarding transition between classes. Such information is available from transition or cross-tabulation matrices, which show the transitions between land use/land cover classes as well as over all change. These are presented for Hunterdon and Burlington below. They were calculated for the land use/land cover change observed between 1986-2002 (Tables 5.4 and 5.5), 1986-1995 (Tables 5.6 and 5.8) and 1995-2002 (Tables 5.7 and 5.9).

		2002							
		Developed	**Agriculture**	**Upland Forest**	**Barren**	**Forested Wetland**	**Emergent Wetland**	**Water**	***1986 Totals***
	Developed	41538	1393	2633	95	75	16	58	***45808***
	Agriculture	12809	78503	9086	843	171	49	62	***101523***
1986	**Upland Forest**	6771	2029	90167	276	114	35	287	***99679***
	Barren	859	28	227	287	2	0	7	***1409***
	Forested Wetland	492	171	88	14	16699	588	200	***18251***
	Emergent Wetland	463	155	81	10	1144	5417	66	***7336***
	Water	28	16	102	1	74	37	5857	***6115***
	2002 Totals	***62961***	***82294***	***102383***	***1525***	***18278***	***6142***	***6537***	***280121***

Table 5.4. Transition matrix for land use/land use land cover in Hunterdon County, 1986 to 2002, area in acres.

		2002							
	1986	**Developed**	**Agriculture**	**Upland Forest**	**Barren**	**Forested Wetland**	**Emergent Wetland**	**Water**	***1986 Totals***
	Developed	72707	613	2253	395	240	75	185	***76468***
	Agriculture	11544	56452	2075	938	228	740	67	***72044***
1986	**Upland Forest**	8350	883	183517	965	233	243	316	***194507***
	Barren	2624	123	564	2058	10	5	72	***5456***
	Forested Wetland	1567	135	167	112	112620	2640	616	***117858***
	Emergent Wetland	1822	219	91	134	7050	34197	1010	***44523***
	Water	88	6	127	22	376	946	11788	***13353***
	2002 Totals	***98702***	***58430***	***188795***	***4623***	***120758***	***38848***	***14053***	***524209***

Table 5.5. Transition matrix for land use/land use land cover in Burlington County, 1986 to 2002, area in acres.

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From 1986 to 2002, 21,422 acres were converted to development in Hunterdon County. Of these acres converted, 59.8% came from agricultural uses while 31.6% came from upland forest. A considerably smaller amount, 4.0% came from barren areas, although this represented 61.0% of the barren present in 1986. Forested and emergent wetlands contributed 2.3% and 2.2%, respectively. Using transition tables, it also becomes clear that looking at net change understates the complexity of land use/land cover processes. The net change figures presented in Table 2 do not, for instance, show an apparent transition of 1393 acres of development to agriculture and 2633 acres of development to upland forest between 1986 and 2002. The change from development to forest is likely to represent the maturation of vegetation in older developed areas. As trees mature, it can become difficult to distinguish between forested areas and older residential developments. This also suggests that the amount of development in the landscape is underestimated because of this "loss" to forest. The agricultural areas gained from developed uses may represent the conversion of yards to small horse pastures, as unpublished work by the author demonstrated such pastures are clearly visible in the higher resolution 2002 aerial photography.

Other transitions of note in Hunterdon from 1986 to 2002 include the loss of 9086 acres of agriculture to upland forest. This likely represents abandoned pastures and farmland maturing into forest vegetation. This loss represents 39.5% of the 23020 acres of agriculture lost, indicating that immediate conversion to development is not the sole source of the loss of agricultural lands that Hunterdon County has experienced.

From 1986 to 2002, 25995 acres were converted to development in Burlington County. Of these acres converted, 44.4% came from agricultural uses while 32.1% came from upland forest. While agricultural land still provides more of the land converted to developed uses, in Burlington it does not represent the majority of land converted as it does in Hunterdon. Again, considerably smaller amount, 10.1% came from barren areas, representing 48.1% of the barren present in 1986. Forested and emergent wetlands contributed 6.0% and 7.0%, respectively. It appears that development in Burlington favors natural areas more than in Hunterdon County, at a rate equal to or perhaps slightly higher than agricultural areas. Like Hunterdon, Burlington also saw some conversion of development to agricultural uses (613 acres) and upland forest (2253 acres), most likely the result of the same processes. These figures represent a lower percentage of both development and the uses they were converted to than in Hunterdon, suggesting these processes may not be as prevalent in Burlington.

Other transitions of note in Burlington from 1986 to 2002 include the loss of 2075 acres of agriculture to upland forest. This likely represents abandoned pastures and farmland maturing into forest vegetation. This loss represents 13.3% of the 15601 acres of agriculture lost, a much lower percentage than in Hunterdon, suggesting that agricultural abandonment is proceeding at a slower rate in Burlington.

					1995				
		Developed	**Agriculture**	**Upland Forest**	**Barren**	**Forested Wetland**	**Emergent Wetland**	**Water**	***1986 Totals***
	Developed	42081	1177	2362	43	68	16	60	***45808***
	Agriculture	7785	86516	6491	492	145	47	47	***101523***
1986	**Upland Forest**	4574	1352	93166	190	87	25	284	***99679***
	Barren	829	27	154	392	0	0	7	***1409***
	Forested Wetland	323	154	65	2	17038	473	196	***18251***
	Emergent Wetland	266	132	32	0	372	6483	51	***7336***
	Water	24	18	98	1	63	33	5878	***6115***
	1995 Totals	***55881***	***89376***	***102368***	***1121***	***17774***	***7078***	***6523***	***280121***

Table 5.6. Transition matrix for land use/land use land cover in Hunterdon County, 1986 to 1995, area in acres.

					2002				
		Developed	**Agriculture**	**Upland Forest**	**Barren**	**Forest Wetland**	**Emergent Wetland**	**Water**	***1995 Total***
	Developed	54627	446	706	92	7	1	0	***55881***
	Agriculture	4385	80421	3720	811	13	11	14	***89376***
1995	**Upland Forest**	2990	1341	97717	275	27	14	5	***102368***
	Barren	590	40	164	323	2	1	0	***1121***
	Forested Wetland	142	21	20	13	17376	199	4	***17774***
	Emergent Wetland	221	26	53	10	847	5900	21	***7078***
	Water	6	0	2	0	7	15	6492	***6523***
	2002 Total	***62961***	***82294***	***102383***	***1525***	***18278***	***6142***	***6537***	***280121***

Table 5.7. Transition matrix for land use/land use land cover in Hunterdon County, 1995 to 2002, area in acres

		1995							
		Developed	**Agriculture**	**Upland Forest**	**Barren**	**Forested Wetland**	**Emergent Wetland**	**Water**	***1986 Totals***
	Developed	73587	528	1795	77	222	79	180	***76468***
	Agriculture	7808	62945	468	12	199	575	37	***72044***
1986	**Upland Forest**	5103	313	188377	75	184	189	265	***194507***
	Barren	1289	22	166	3951	4	6	18	***5456***
	Forested Wetland	961	122	142	44	113578	2436	574	***117858***
	Emergent Wetland	1066	189	55	19	1970	40335	889	***44523***
	Water	82	7	125	9	227	587	12318	***13353***
	1995 Totals	***89896***	***64126***	***191128***	***4187***	***116384***	***44208***	***14280***	***524209***

Table 5.8. Transition matrix for land use/land use land cover in Burlington County, 1986 to 1995, area in acres.

		2002							
		Developed	**Agriculture**	**Upland Forest**	**Barren**	**Forest Wetland**	**Emergent Wetland**	**Water**	***1995 Total***
	Developed	88528	186	683	470	13	8	8	***89896***
	Agriculture	4017	57477	1570	832	21	180	30	***64127***
1995	**Upland Forest**	3388	618	186001	896	112	52	62	***191128***
	Barren	1411	100	421	2193	5	4	54	***4187***
	Forested Wetland	419	15	87	82	114851	874	56	***116384***
	Emergent Wetland	933	35	33	136	5624	37287	160	***44207***
	Water	6	0	1	15	133	443	13683	***14281***
	2002 Total	***98702***	***58431***	***188795***	***4623***	***120759***	***38847***	***14053***	***524210***

Table 5.9. Transition matrix for land use/land use land cover in Burlington County, 1995 to 2002, area in acres.

5.4 Landscape Trajectories and Trends

Analyzing the transition tables from the subperiods 1986-1995 and 1995-2002 allows for an examination of trends and trajectories of landscape change in Burlington and Hunterdon. In Hunterdon, between 1986 and 1995, 56.4% of the land converted to development came from agriculture while 33.1% came from upland forest. Between 1995 and 2002, 52.6% of new development still occurred on agricultural lands and 35.9% occurred in upland forest areas. Agricultural lands therefore continued to be favored as development sites, most likely because of ease of development of the already cleared agricultural fields. Taking into consideration the absolute change, the rates of change and proportional contribution to development, it is clear that agricultural areas are more threatened in Hunterdon than areas of upland forest.

In Burlington, agriculture and upland forest represented 47.8% and 31.2%, respectively, of the areas developed between 1986 and 1995, and 39.4% and 33.3% of the areas developed between 1995 and 2002. It appears the relative decline in the contribution of agricultural areas to development was made up by an increase the contribution of barren areas to development between the two time periods, from 7.9% to 13.9%. There was considerable stability in barren areas between 1986 and 1995 but not between 1995 and 2002. Much of the area barren in 1995 was barren in 1986 (94.3%) while only 47.4% of the area barren in 2002 was barren in 1995.

While a full exploration of transitions between land use/land cover classes is an important component of studying LULCC, it by no means represents the only type of change analysis possible. If data are available from more than two time periods, it is possible to undertake an analysis of the trajectories of the change over the course of the study. Trajectory analysis facilitates the discrimination of multi-state LULCC that simple analyses of transitions can miss. For example, it is possible that the abandonment of farmland and its subsequent transition to old field vegetation or young woodland might in many cases be a stage in its eventual transformation into residential or commercial development. Agricultural operations may cease while properties are transferred, designs created and approvals gathered. This process may take long enough that the abandoned farmland can transform enough to be mapped as scrub/shrub or forest LULC. Exploring trajectories of landscape change can discern whether there is an important farm-scrub-developed trajectory.

The amount of time between successive data collection periods will have a significant impact on the capacity of any particular analysis to measure trajectories. Ideally, the time between data collection periods should be shorter than the processes which result in particular trajectories. In the case of trajectories associated with development of farmland and forest, this period would most likely be on the order of 2 or 3 years. The data used in this study is separated by wider temporal gaps, but its analysis should still provide useful information into trajectories that may have implications for land preservation and management policies and practices.

Table 5.10 shows the LULCC trajectories for Hunterdon (for unique combinations of LULC over the three time periods that are greater than 400 acres). In this table and in Table 5.20, D represents developed areas, AG agricultural and grassland areas, UF upland forests, EW emergent wetlands, WF forested wetlands and B barren or transitional areas.

Table 5.10 Major LULCC trajectories in Hunterdon County, 1986-1995-2002.

Acres	1986	1995	2002
89960.0	UF	UF	UF
77772.1	AG	AG	AG
41418.6	D	D	D
16656.7	WF	WF	WF
7392.5	AG	D	D
5857.3	W	W	W
5399.6	EW	EW	EW
5153.8	AG	UF	UF
4391.8	UF	D	D
4302.0	AG	AG	D
3613.4	AG	AG	UF
2283.3	D	UF	UF
2208.4	UF	UF	D
1218.9	UF	AG	AG
1116.3	D	AG	AG
816.9	B	D	D
792.3	AG	AG	B
785.5	EW	EW	WF
731.9	UF	UF	AG
705.5	AG	UF	D
584.6	AG	UF	AG
409.1	AG	B	D

In light of the observations made by Pontius et al. (2004), it is unsurprising that most of the top 10 trajectories by area actually represent stability and not change. The trajectory that accounts for the most landscape change of any trajectory is AG-D-D, again unsurprising given the amount of conversion to development already noted as occurring in Hunterdon County. Somewhat more surprisingly is the trajectory that accounts for the secondmost amount of landscape change, AG-UF-UF. The agricultural abandonment and subsequent forest regeneration described in this trajectory does not fit most conceptions of what constitutes landscape change in this area. Yet combined with the AG-AG-UF trajectory, agricultural land changing into upland forest totals more than 50% of the area converted to developed uses.

There is some concern that the abandonment of farmland is often a precursor development, as speculators or developers buy farmland and curtail or discontinue farming while awaiting approvals or favorable economic conditions to commence development activities. Only 705.5 acres of agricultural land in 1986 was forest (or scrub/shrub) in 1995 and developed in 2002. This is only 12.0% of the land that was agriculture in 1995 and forest/shrub in 1995, suggesting the problem may not be as prevalent as presumed. The ability of the current study to draw firm conclusions about this particular issue is limited, however, because of the number of time periods and the temporal gap between the time periods for which LULC data is available, and the overall length of the study period.

The trajectory information also clearly shows the significant amount of upland forest being converted into developed uses. There is also a significant amount of 1986 development appearing as upland forest in 1995 without a similarly significant transformation apparent from 1995 to 2002. The transition seen between 1986 and 1995 may reflect the maturation of trees in developed areas, forming a canopy over areas formerly classified as developed. Why no similar transition is seen between 1995 and 2002 is open to question. Perhaps a shift in development design occurred and the vegetation planted by builders and owners was not of a type that could form a closed canopy. It may also be that the increased resolution of the 2002 aerial photography made it clear that areas with maturing vegetation were still developed.

As noted above in the transition data, a considerable amount of developed land seems to have been converted to agricultural uses between 1986 and 2002. While it is likely that some of this represents areas converted to pasture for horses, it is interesting that there isn’t a significant amount of such conversion taking place between 1995 and 2002. Perhaps development between 1995 and 2002 that were suitable for pasturage were being developed from conception as hobby farms, and little of the older development were still being converted. As always, some of the difference may be the result of the increased resolution of the 2002 photography, but it is difficult to image how increased resolution would translate into not classifying new pasturage as an agricultural use. It might suggest a change in interpretation protocol, however, where pasturage clearly associated with homes and not farms was classified as residential and therefore developed.

Table 5.11 – Major LULCC trajectories for Burlington County.

Acres	1986	1995	2002
183406.6	UF	UF	UF
112088.3	WF	WF	WF
72643.0	D	D	D
56375.9	AG	AG	AG
34152.2	EW	EW	EW
11785.9	W	W	W
7557.2	AG	D	D
5106.2	EW	EW	FW
4958.6	UF	D	D
3971.3	AG	AG	D
3346.0	UF	UF	D
2046.6	B	B	B
1939.6	EW	FW	FW
1777.7	FW	EW	EW
1752.2	D	UF	UF
1540.4	AG	AG	UF
1340.9	B	B	D
1277.3	B	D	D
1055.5	EW	D	D
956.2	FW	D	D
876.0	UF	UF	B
860.2	EW	W	W
847.4	EW	EW	FW
828.0	AG	AG	B

The LULCC trajectories in Burlington share significant similarities (Table 5.11). Because of Burlington's larger size, the threshold for inclusion in this table was 800 acres. As in Hunterdon, stabile trajectories dominate the LULCC trajectories. Also, the largest trajectory indicating change is AG-D-D. The next largest trajectory leading to development is UF-D-D, followed by AG-AG-D and UF-UF-D.

There are, however, differences. In Hunterdon, the second largest change trajectory was AG-UF-UF. In Burlington this trajectory is so small it doesn't appear in the list. AG-AG-UF does, however, although it represents a much smaller proportion of overall change than in Hunterdon. This suggests that the processes of agricultural abandonment are not occurring to same extent as they are in Hunterdon. The vast majority of the change occurring to agricultural land in Burlington is therefore conversion to development. Considering that Burlington has less farmland than Hunterdon, it seems that development is a greater threat to farmland in Burlington than in Hunterdon. This may have implications for allocation of state resources for farmland preservation.

5.5 Analyzing LULCC for Gains, Losses and Persistence

The transition matrices and trajectories above are a useful starting point for examining land use/land cover change, but as Pontius et al. (2004) point out, they are seldom utilized to the fullest extent possible and much of the information contained within them is often left unanalyzed. In addition to analyzing for net gain or loss of mapping categories, they demonstrate how the off-diagonal elements can be systematically analyzed for swap, or intercategory change that many not be reflected in the net change of categories. Their methodology goes beyond simply noting the area or proportion of a category that changes from one category to another over the study period, however. They use the observed persistence in a landscape to calculate the changes expected between each category if the changes were the result of random processes. These expected changes are then compared the actual changes to determine which transitions appear to be favored by the processes driving landscape change in the study area.

This methodology was applied to the transition tables for the Hunterdon and Burlington LULCC data to generate tables which explore systematic gains and losses between mapping categories. A separate table is produce for gains and losses. Table 5.12 presents the results of this analysis for gains in Hunterdon County between 1986 and 2002. The first row for each LULC category shows the actual percentage of that LULC category that was converted to another category in 2002 or persisted in the same category since 1986. The second row shows the percentage of conversion expected if the amount of gain in each category is held constant and the percentage converted is assumed to be equal to the proportion of the category being converted to in the study area. The third row is the actual conversion minus the expected conversion. If this number is positive, it indicates a conversion favored above random, if negative, a conversion favored less than random. The fourth row is calculated by dividing the difference between the observed and expected conversion value by the expected value and indicates the magnitude of that difference relative to the magnitude of the expected value.

		2002								
		Developed	**Agriculture**	**Upland Forest**	**Barren**	**Wetland Forest**	**Emergent Wetland**	**Water**	**1986 Total**	**Loss**
	Developed	14.83%	0.50%	0.94%	0.03%	0.03%	0.01%	0.02%	16.35%	1.52%
		14.83%	0.10%	0.26%	0.08%	0.27%	0.15%	0.07%	15.75%	0.93%
		0.00%	0.40%	0.68%	-0.05%	-0.25%	-0.14%	-0.05%	0.60%	0.60%
		0	4.137	2.678	-0.578	-0.902	-0.962	-0.711	0.038	0.647
	Agriculture	4.57%	28.03%	3.24%	0.30%	0.06%	0.02%	0.02%	36.24%	8.22%
		3.31%	28.03%	0.57%	0.18%	0.60%	0.33%	0.16%	33.18%	5.15%
		1.25%	0.00%	2.68%	0.12%	-0.54%	-0.31%	-0.14%	3.07%	3.07%
		0.38	0	4.73	0.69	-0.9	-0.95	-0.86	0.09	0.6
	Upland Forest	2.41%	0.72%	32.19%	0.10%	0.04%	0.01%	0.10%	35.58%	3.40%
		3.25%	0.21%	32.19%	0.18%	0.59%	0.32%	0.16%	36.90%	4.71%
		-0.83%	0.51%	0.00%	-0.08%	-0.55%	-0.31%	-0.06%	-1.32%	-1.32%
		-0.257	2.438	0	-0.436	-0.931	-0.962	-0.349	-0.036	-0.279
1986	**Barren**	0.30%	0.01%	0.08%	0.10%	0.00%	0.00%	0.00%	0.50%	0.40%
		0.04%	0.00%	0.01%	0.10%	0.01%	0.01%	0.00%	0.17%	0.07%
		0.26%	0.01%	0.07%	0.00%	-0.01%	0.00%	0.00%	0.33%	0.33%
		5.669	2.343	9.29	0	-0.928	-0.971	0.105	1.887	4.567
	Wetland Forest	0.18%	0.06%	0.03%	0.01%	5.96%	0.21%	0.07%	6.52%	0.55%
		0.60%	0.04%	0.10%	0.03%	5.96%	0.06%	0.03%	6.82%	0.86%
		-0.42%	0.02%	-0.07%	-0.03%	0.00%	0.15%	0.04%	-0.30%	-0.30%
		-0.705	0.583	-0.692	-0.849	0	2.535	1.474	-0.044	-0.353
	Emergent Wetland	0.17%	0.06%	0.03%	0.00%	0.41%	1.93%	0.02%	2.62%	0.69%
		0.24%	0.02%	0.04%	0.01%	0.04%	1.93%	0.01%	2.30%	0.36%
		-0.07%	0.04%	-0.01%	-0.01%	0.37%	0.00%	0.01%	0.32%	0.32%
		-0.31	2.562	-0.291	-0.711	8.387	0	1.031	0.14	0.883
	Water	0.01%	0.01%	0.04%	0.00%	0.03%	0.01%	2.09%	2.18%	0.09%
		0.20%	0.01%	0.03%	0.01%	0.04%	0.02%	2.09%	2.40%	0.31%
		-0.19%	-0.01%	0.00%	-0.01%	-0.01%	-0.01%	0.00%	-0.22%	-0.22%
		-0.951	-0.563	0.07	-0.969	-0.273	-0.336	0	-0.092	-0.707
	2002 Total	22.48%	29.38%	36.55%	0.55%	6.53%	2.19%	2.33%	100.00%	14.87%
		22.48%	29.38%	36.55%	0.55%	6.53%	2.19%	2.33%	100.00%	14.87%
		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Gain	7.65%	1.35%	4.38%	0.44%	0.56%	0.26%	0.24%	14.87%	
		7.65%	1.35%	4.38%	0.44%	0.56%	0.26%	0.24%	14.87%	
		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	

Table 5.12 Hunterdon LULCC, 1986 – 2002, analyzed for gains.

Looking down the column for the category, it is clear that the development process in Hunterdon County favors the conversion of agricultural and barren land to developed uses beyond what is expected at random. Since agricultural areas are usually easier and less costly to develop than other land uses, and barren areas are often in transition to developed uses, these results are expected. Likewise, the result that wetland and water categories are converted at rates lower than expected is not surprising, since those areas are difficult to develop for regulatory and/or physical reasons. Interestingly, upland forests are converted to development at a rate lower than expected if the process was random. This again suggests that agricultural areas in Hunterdon are at greater risk to development than upland forest areas.

Other categories experienced significantly less gain than the developed category between 1986 and 2002. Upland forest and wetland forest had the greatest gross gain (expressed as a percentage of the landscape as whole) at 1.007% and 1.522%, respectively. Upland forest expanded at the expense of agricultural and developed areas, again reflecting the findings of the previous sections which indicated some agricultural abandonment and the maturation of vegetation in developed areas to the point at which it might be classified as forest. Wetland forest expanded at the expense of emergent forest, which is most likely the result of ecological succession. All of these changes may to be impacted to some extent by the capacity of the higher resolution base imagery of the 2002 LULC to distinguish boundaries between developed areas and forests and emergent wetland and forested wetland more accurately.

LULCC data can also be analyzed for losses, by holding the amount of loss in each LULC category steady and calculating the amount of loss to other categories

					2002					
		Developed	**Agriculture**	**Upland Forest**	**Barren**	**Wetland Forest**	**Emergent**	**Water**	**1986 Total**	**Loss**
	Developed	14.83%	0.50%	0.94%	0.03%	0.03%	0.01%	0.02%	16.35%	1.53%
		14.83%	0.58%	0.72%	0.01%	0.13%	0.04%	0.05%	16.35%	1.53%
		0.00%	-0.08%	0.22%	0.02%	-0.10%	-0.04%	-0.03%	0.00%	0.00%
		0	-0.14	0.307	2.091	-0.789	-0.86	-0.543	0	0.00
	Agriculture	4.57%	28.03%	3.24%	0.30%	0.06%	0.02%	0.02%	36.24%	8.22%
		2.62%	28.03%	4.25%	0.06%	0.76%	0.26%	0.27%	36.24%	8.22%
		1.96%	0.00%	-1.01%	0.24%	-0.70%	-0.24%	-0.25%	0.00%	0.00%
		0.75	0	-0.24	3.78	-0.92	-0.93	-0.92	0.00	0.00
	Upland Forest	2.42%	0.72%	32.19%	0.10%	0.04%	0.01%	0.10%	35.58%	3.40%
		1.20%	1.57%	32.19%	0.03%	0.35%	0.12%	0.13%	35.58%	3.40%
		1.21%	-0.85%	0.00%	0.07%	-0.31%	-0.11%	-0.02%	0.00%	0.00%
		1.009	-0.539	0	2.414	-0.883	-0.897	-0.184	0.00	0.00
1986	**Barren**	0.31%	0.01%	0.08%	0.10%	0.00%	0.00%	0.00%	0.50%	0.40%
		0.09%	0.12%	0.15%	0.10%	0.03%	0.01%	0.01%	0.50%	0.40%
		0.22%	-0.11%	-0.07%	0.00%	-0.03%	-0.01%	-0.01%	0.00%	0.00%
		2.374	-0.915	-0.449	0	-0.962	-1	-0.778	0.00	0.00
	Wetland Forest	0.18%	0.06%	0.03%	0.01%	5.93%	0.21%	0.07%	6.48%	0.55%
		0.13%	0.17%	0.22%	0.00%	5.93%	0.01%	0.01%	6.48%	0.55%
		0.04%	-0.11%	-0.19%	0.00%	0.00%	0.20%	0.06%	0.00%	0.00%
		0.323	-0.649	-0.857	0.667	0	15.154	4.071	0.00	0.00
	Emergent	0.17%	0.06%	0.03%	0.00%	0.41%	1.93%	0.02%	2.62%	0.68%
		0.16%	0.21%	0.26%	0.00%	0.05%	1.93%	0.02%	2.62%	0.69%
		0.01%	-0.15%	-0.23%	0.00%	0.36%	0.00%	0.01%	0.00%	0.00%
		0.051	-0.733	-0.887	0	7.87	0	0.438	0.00	0.00
	Water	0.01%	0.01%	0.04%	0.00%	0.03%	0.01%	2.09%	2.18%	0.09%
		0.02%	0.03%	0.03%	0.00%	0.01%	0.00%	2.09%	2.18%	0.09%
		-0.01%	-0.02%	0.00%	0.00%	0.02%	0.01%	0.00%	0.00%	0.00%
		-0.524	-0.786	0.088	-1	3.333	5.5	0	0.00	0.00
	2002 Total	22.48%	29.38%	36.55%	0.55%	6.53%	2.19%	2.33%	100.00%	14.87%
		19.05%	30.70%	37.82%	0.21%	7.28%	2.37%	2.57%	100.00%	14.87%
		3.43%	-1.32%	-1.27%	0.33%	0.75%	-0.18%	-0.05%	0.00%	0.00%
		0.18	-0.04	-0.03	1.56	-0.1	-0.08	-0.09	0.00	0.00
	Gain	7.65%	1.35%	4.38%	0.44%	0.56%	0.26%	0.24%	14.87%	
		4.22%	2.68%	5.63%	0.11%	1.31%	0.44%	0.48%	14.87%	
		3.43%	-1.32%	-1.27%	0.33%	-0.75%	-0.75%	-0.18	0.00%	
		1.23	-2.02	-4.45	0.33	-1.75	-2.44	-2	0	

Table 5.13 Hunterdon LULCC, 1986 – 2002, analyzed for losses

expected if the losses occurred proportional to the other categories' representation in the landscape. This analysis is presented in Table 5.13. When analyzing for loss, the results are read across the row, not down column as for gains.

Most of the loss in Hunterdon between 1986 and 2002 is accounted for by agriculture and upland forest. Agriculture lost substantial area to development and to upland forest. The amount lost to development was greater than the amount expected by the proportion of development in the landscape while the amount lost to upland forest was than expected given the proportion of upland forest in the landscape. Most of the loss of upland forest is attributable to development and was at a rate higher than expected given the proportion of development in the landscape. A small but notable amount of upland forest was lost to agriculture, but at rate lower than expected given the amount of agriculture in the landscape. Emergent wetland lost a substantial proportion of its area to wetland forest.

The gains and losses analyses can be summarized in a single table that contains the gain, loss, swap and net change of each category. These results are presented in Table 5.14.

Table 5.14 Summary of gains, losses, swap and net change in Hunterdon County LULC, 1986-2002, expressed as percentage of landscape.

	Gain	**Loss**	**Total Change**	**Swap**	**Absolute Value of Net Change**
Developed	7.648	1.524	9.172	3.050	6.122
Agriculture	1.353	8.218	9.571	2.731	6.840
Upland Forest	4.381	3.396	7.777	6.811	0.966
Barren	0.443	0.401	0.844	0.801	0.043
Wetland Forest	0.564	0.554	1.118	1.073	0.045
Emergent Wetland	0.259	0.684	0.944	0.518	0.426
Water	0.241	0.092	0.333	0.182	0.151
Total	14.869	14.869	14.869	7.588	7.311

It is clear that developed areas and upland forest have gained the most of any categories, and that agriculture and upland forest have lost the most. The summary table makes clear that both wetland and upland forests in Hunterdon are actually experiencing a fair amount of change, but because that change is in the form of swapping, much of it is hidden in net statistics of LULCC. The large of amount of swap in the barren category is again indicative of the fact that it is category encompassing transitional land uses that are likely to change during the time period between the creation of the LULC data sets.

Figure 5.3 presents a map of upland forest gains and loss from 1986 to 2002. Both gains and losses are spread relatively evenly throughout the county. It appears that in the southern portion of the county, both gains and losses are occurring more on the margins of forested patches rather than in the interior. In the northern portion, where there are larger, continuous patches, there appears to be more change in the interior of the patches than in the south.

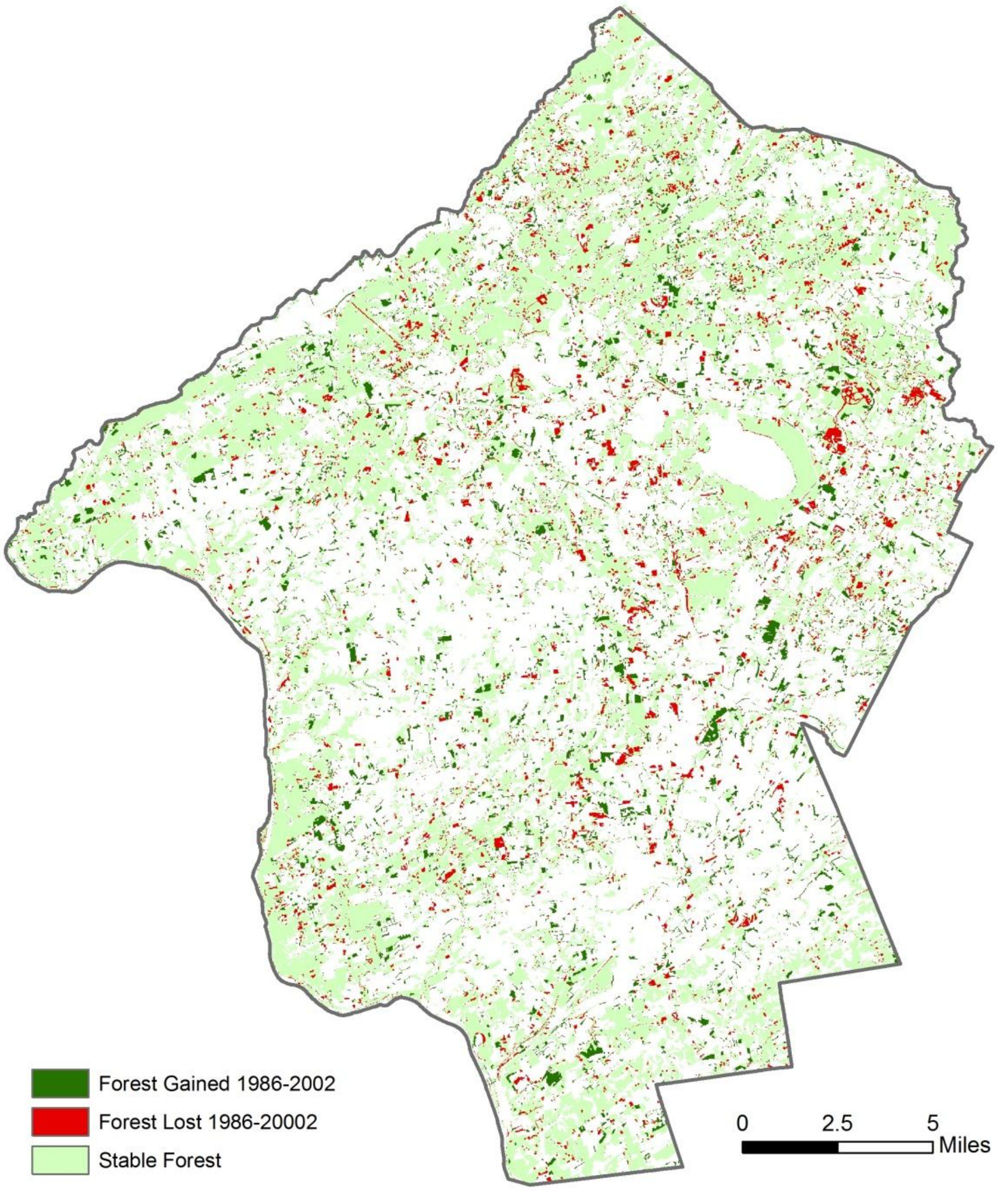


Figure 5.3 Upland forest change in Hunterdon County

Table 5.15 presents the results of the analysis of LULCC for gains in Burlington County between 1986 and 2002. The results generally parallel those seen in Hunterdon County. Like Hunterdon, agriculture and barren land were favored for conversion for development beyond what would be expected given their proportions in the landscape. Upland forest was not favored for conversion to development, nor were the wetland types or open water. Agriculture is gaining area from developed uses in Burlington as in Hunterdon. Also similar to Hunterdon is the fact that upland forest is gaining from agricultural lands at a higher than expected rate, suggesting similar processes of land abandonment are operating.

					2002					
		Developed	**Agriculture**	**Upland Forest**	**Barren**	**Wetland Forest**	**Emergent Wetland**	**Water**	**1986 Total**	**Loss**
	Developed	13.87%	0.12%	0.43%	0.08%	0.05%	0.01%	0.04%	14.59%	0.72%
		13.87%	0.06%	0.23%	0.07%	0.29%	0.14%	0.07%	14.74%	0.87%
		0.00%	0.05%	0.20%	0.00%	-0.25%	-0.13%	-0.03%	-0.15%	-0.15%
		0	0.832	0.84	0.045	-0.843	-0.898	-0.455	-0.01	-0.173
	Agriculture	2.20%	10.77%	0.40%	0.18%	0.04%	0.14%	0.01%	13.74%	2.97%
		0.80%	10.77%	0.22%	0.07%	0.28%	0.13%	0.06%	12.32%	1.56%
		1.40%	0.00%	0.18%	0.11%	-0.23%	0.01%	-0.05%	1.42%	1.42%
		1.76	0	0.8	1.63	-0.84	0.06	-0.79	0.12	0.91
	Upland Forest	1.59%	0.17%	35.01%	0.18%	0.04%	0.05%	0.06%	37.11%	2.10%
		2.15%	0.16%	35.01%	0.18%	0.74%	0.36%	0.17%	38.78%	3.77%
		-0.56%	0.01%	0.00%	0.00%	-0.70%	-0.31%	-0.10%	-1.67%	-1.67%
		-0.261	0.037	0	0.003	-0.94	-0.871	-0.634	-0.043	-0.444
1986	**Barren**	0.50%	0.02%	0.11%	0.39%	0.00%	0.00%	0.01%	1.04%	0.65%
		0.06%	0.01%	0.02%	0.39%	0.02%	0.01%	0.01%	0.51%	0.12%
		0.44%	0.02%	0.09%	0.00%	-0.02%	-0.01%	0.01%	0.53%	0.53%
		7.283	4.141	5.462	0	-0.905	-0.912	1.982	1.042	4.531
	Wetland Forest	0.30%	0.03%	0.03%	0.02%	21.48%	0.50%	0.12%	22.48%	1.00%
		1.31%	0.10%	0.36%	0.11%	21.48%	0.22%	0.10%	23.68%	2.19%
		-1.01%	-0.07%	-0.33%	-0.09%	0.00%	0.29%	0.02%	-1.19%	-1.19%
		-0.771	-0.738	-0.911	-0.808	0	1.311	0.178	-0.05	-0.544
	Emergent Wetland	0.35%	0.04%	0.02%	0.03%	1.35%	6.52%	0.19%	8.49%	1.97%
		0.49%	0.04%	0.14%	0.04%	0.17%	6.52%	0.04%	7.44%	0.92%
		-0.15%	0.01%	-0.12%	-0.02%	1.18%	0.00%	0.16%	1.05%	1.05%
		-0.295	0.122	-0.872	-0.393	6.906	0	4.117	0.142	1.15
	Water	0.02%	0.00%	0.02%	0.00%	0.07%	0.18%	2.25%	2.55%	0.30%
		0.15%	0.01%	0.04%	0.01%	0.05%	0.03%	2.25%	2.54%	0.29%
		-0.13%	-0.01%	-0.02%	-0.01%	0.02%	0.16%	0.00%	0.01%	0.01%
		-0.886	-0.892	-0.407	-0.665	0.407	6.31	0	0.004	0.037
	2002 Total	18.83%	11.15%	36.02%	0.88%	23.04%	7.41%	2.68%	100.00%	9.70%
		18.83%	11.15%	36.02%	0.88%	23.04%	7.41%	2.68%	100.00%	9.70%
		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
		0	0	0	0	0	0	0	0	0
	Gain	4.96%	0.38%	1.01%	0.49%	1.55%	0.89%	0.43%	9.70%	
		4.96%	0.38%	1.01%	0.49%	1.55%	0.89%	0.43%	9.70%	
		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
		0	0	0	0	0	0	0	0	

Table 5.15 Burlington LULCC, 1986 – 2002, analyzed for gain

The results for the analysis of LULCC in Burlington for losses between 1986 and 2002 are presented in Table 5.16. Again, the loss table reinforces the trends seen in the gains table and are for the most part similar to what was seen in Hunterdon County. The main difference is that in Burlington there was slightly more loss of development to agricultural uses than expected. Among the similarities between the two counties are larger than expected losses of agriculture, barren areas and upland forest to development and smaller than expected losses of agriculture to upland forest and upland forest to agriculture. Table 5.17 presents a summary of the gains, losses, swap and net change for land use/land cover change in Burlington County between 1986 and 2002.

Figure 5.4 presents a map of upland forest change in Burlington County for the same time period. Forest gains appear to be happening in heavily forested areas. Forest loss, on the other hand, is occurring in two general areas. There is a widespread loss of forest in the western corner of the county where development is widespread. Perhaps more consequentially, there is a band of forest loss midway along the southern border, extending along the western edge of the forested southern half of the county. This appears to be a development, resulting from development occurring over the period of the study (compare with Figure 5.2).

					2002					
		Developed	**Agriculture**	**Upland Forest**	**Barren**	**Wetland Forest**	**Emergent Wetland**	**Water**	**1986 Total**	**Loss**
	Developed	13.87%	0.12%	0.43%	0.08%	0.05%	0.01%	0.04%	14.59%	0.72%
		13.87%	0.10%	0.32%	0.01%	0.20%	0.07%	0.02%	14.59%	0.72%
		0.00%	0.02%	0.11%	0.07%	-0.16%	-0.05%	0.01%	0.00%	0.00%
		0	0.182	0.352	8.375	-0.775	-0.788	0.458	0	0
	Agriculture	2.20%	10.77%	0.40%	0.18%	0.04%	0.14%	0.01%	13.74%	2.97%
		0.63%	10.77%	1.21%	0.03%	0.77%	0.25%	0.09%	13.74%	2.97%
		1.57%	0.00%	-0.81%	0.15%	-0.73%	-0.11%	-0.08%	0.00%	0.00%
		2.5	0	-0.67	4.97	-0.94	-0.43	-0.86	0	0
	Upland Forest	1.59%	0.17%	35.01%	0.18%	0.04%	0.05%	0.06%	37.11%	2.10%
		0.62%	0.37%	35.01%	0.03%	0.76%	0.24%	0.09%	37.11%	2.10%
		0.98%	-0.20%	0.00%	0.16%	-0.71%	-0.20%	-0.03%	0.00%	0.00%
		1.582	-0.54	0	5.345	-0.942	-0.811	-0.318	0	0
1986	**Barren**	0.50%	0.02%	0.11%	0.39%	0.00%	0.00%	0.01%	1.04%	0.65%
		0.12%	0.07%	0.24%	0.39%	0.15%	0.05%	0.02%	1.04%	0.65%
		0.38%	-0.05%	-0.13%	0.00%	-0.15%	-0.05%	0.00%	0.00%	0.00%
		3.065	-0.685	-0.542	0	-0.987	-0.979	-0.222	0	0
	Wetland Forest	0.30%	0.03%	0.03%	0.02%	21.48%	0.50%	0.12%	22.48%	1.00%
		0.24%	0.15%	0.47%	0.01%	21.48%	0.10%	0.04%	22.48%	1.00%
		0.06%	-0.12%	-0.44%	0.01%	0.00%	0.41%	0.08%	0.00%	0.00%
		0.225	-0.821	-0.932	0.909	0	4.25	2.343	0	0
	Emergent Wetland	0.35%	0.04%	0.02%	0.03%	1.35%	6.52%	0.19%	8.49%	1.97%
		0.40%	0.24%	0.77%	0.02%	0.49%	6.52%	0.06%	8.49%	1.97%
		-0.05%	-0.20%	-0.75%	0.01%	0.86%	0.00%	0.14%	0.00%	0.00%
		-0.132	-0.823	-0.978	0.368	1.745	0	2.386	0	0
	Water	0.02%	0.00%	0.02%	0.00%	0.07%	0.18%	2.25%	2.55%	0.30%
		0.58%	0.03%	0.11%	0.00%	0.07%	0.02%	2.25%	2.55%	0.30%
		-0.56%	-0.03%	-0.09%	0.00%	0.00%	0.16%	0.00%	0.00%	0.00%
		-0.971	-0.971	-0.784	0.333	0.014	6.87	0	0	0
	2002 Total	18.83%	11.15%	36.02%	0.88%	23.04%	7.41%	2.68%	100.00%	9.70%
		15.94%	11.72%	38.11%	0.49%	23.93%	7.25%	2.56%	100.00%	9.70%
		2.89%	-0.58%	-2.10%	0.39%	-0.89%	0.16%	0.12%	0.00%	0.00%
		0.18	-0.05	-0.06	0.79	-0.04	0.02	0.05	0	0
	Gain	4.96%	0.38%	1.01%	0.49%	1.55%	0.89%	0.43%	9.70%	
		2.07%	0.95%	3.10%	0.10%	2.44%	0.72%	0.31%	9.70%	
		2.89%	-0.58%	-2.10%	0.39%	-0.89%	0.16%	0.12%	0.00%	
		1.392	-0.604	-0.676	3.944	-0.364	0.225	0.39	0	

Table 5.16 Burlington LULCC, 1986 – 2002, analyzed for losses

Table 5.17 Summary of gains, losses, swap and net change in Burlington County LULC, 1986-2002, expressed as percentage of landscape.

	Gain	**Loss**	**Total Change**	**Swap**	**Absolute Value of Net Change**
Developed	4.959	0.718	5.677	1.715	3.962
Agriculture	0.377	2.974	3.351	0.754	2.597
Upland Forest	1.007	2.096	3.103	2.013	1.09
Barren	0.489	0.648	1.137	0.978	0.159
Wetland Forest	1.552	0.999	2.551	1.998	0.553
Emergent Wetland	0.887	1.97	2.857	1.775	1.082
Water	0.432	0.299	0.731	0.597	0.134
Total	9.703	9.704	9.704	4.915	4.789

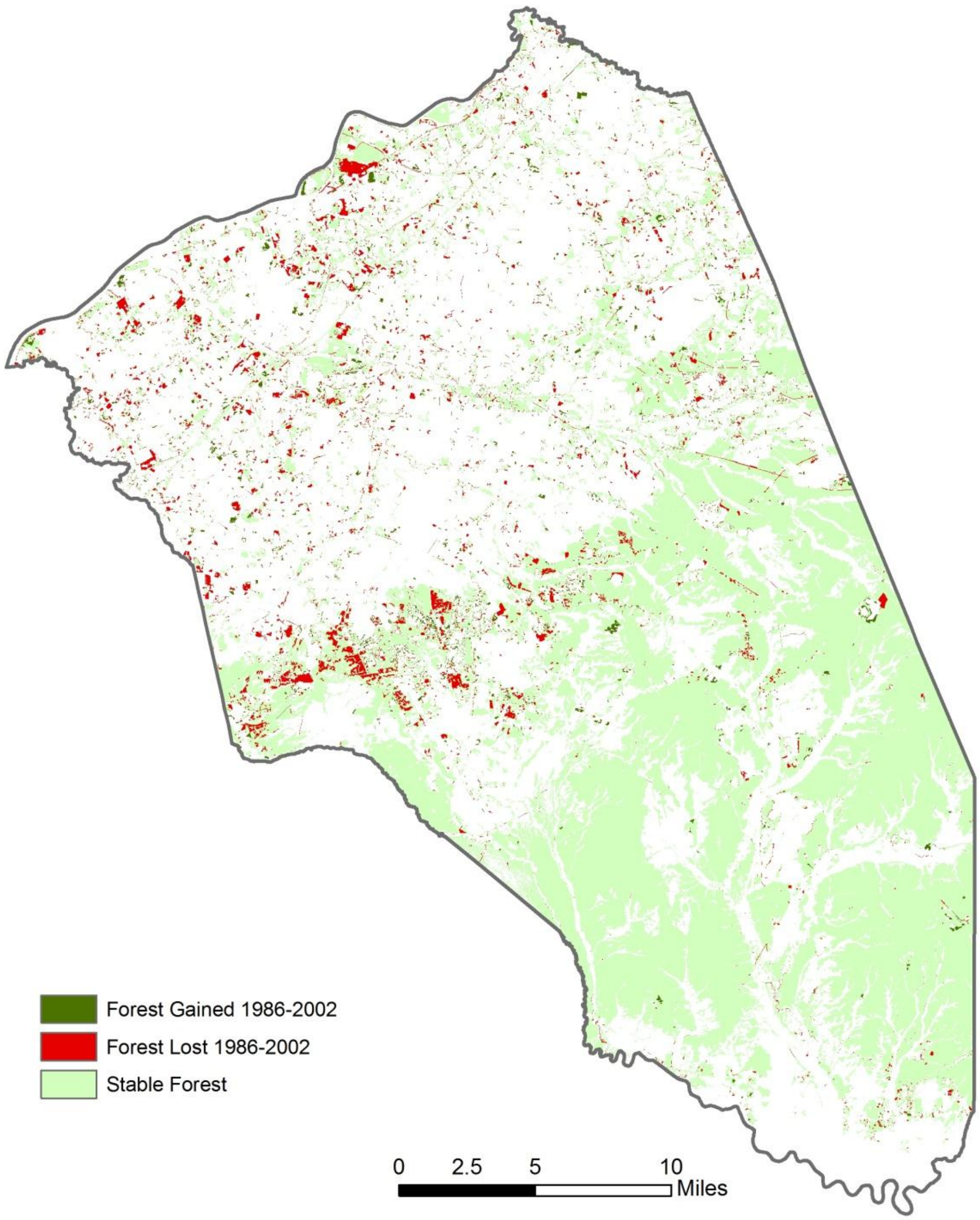


Figure 5.4 Upland forest change in Burlington County

5.6 Landscape Metric Change Assessment

As discussed previously, landscape metrics are important for measuring relevant characteristics of landscapes. Although many metrics are difficult to compare across landscapes, they can be compared over multiple time periods within landscapes. They can therefore be an integral component to landscape change assessments.

Choosing metrics that measure landscape characteristics relevant to the questions under study is important if the full utility of landscape metrics is to be realized. However, at times it may be desirable or necessary to analyze landscape metrics to develop a general description of a landscape and the changes occurring there without reference to a specific research question. A number of landscape metric suites have been proposed in an attempt to generate maximum information from as few metrics as possible (e.g. Riiters, et al.1995, Gustafson 1998). For the landscape change assessment portion of this study, the suite of landscape ecological metrics proposed by Leitao and Ahern (2002) for use in sustainable landscape planning are used (Table 5.18). These metrics were developed to provide planners a set of metrics that can form a common framework for ecological landscape planning. Their use in this study serves several purposes. They provide a relatively comprehensive description of landscape character useful for landscape ecological planning and can therefore be used to examine the ecological consequences of landscape change in the study area. Their use also represents a test of their utility in a new geographic area, which allows an assessment of how broad their utility. Finally, their effectiveness at generating information relevant to land preservation activities can be contrasted with the policy specific indicators that will be developed later in this study.

Table 5.18. Landscape metrics used to assess change relevant to ecological planning (adapted from Leitao and Ahern 2002).

Metric	**Measures**
Patch Richness (PR)	Number of land use/land cover classes
Class Area Proportion (CAP)	Proportion of each class in landscape
Patch Number (PN)	Number of patches in each class
Patch Density (PD)	Number of patches in each class per sq. km
Mean Patch Size (MPS)	Mean size of patches in each class
Patch Shape (SHAPE)	Actual perimeter to minimum possible perimeter ratio
Edge Contrast (TECI)	Similarity/difference in ecological value of adjacent patches
Radius of Gyration (RGYR)	Mean of distance between center of each cell of a patch and the center of the patch's centroid
Mean Nearest Neighbor Distance	Mean distance between two patches of the same class
Contagion	The actual contagion divided by the maximum possible contagion of the landscape
Mean Proximity Index	Measures nearness of patches of same type within a specificed neighborhood by dividing the area of neighboring patches by the square of the edge-to-edge distance between them and the focal patch

Patch richness (PR) and class area proportion (CAP) are simple metrics that provide basic information regarding number and proportion of land use/land cover classes in the study landscape. Patch richness provides the most basic measurement of diversity in the landscape while class area proportion aspatially measures the evenness of representation of the land use/land cover classes in the study area. A landscape with low patch richness or dominated by one class represent simple landscapes and may not be ideal for species requiring more than one habitat type. A landscape change trajectory resulting in lower patch richness or dominance by one particular class indicates a simplification of the landscape.

Patch number (PN), patch density (PD) and mean patch size (MPS) measure the fragmentation of a landscape. Fragmented landscapes have reduced connectivity and greater isolation between patches and a greater area susceptible to potential edge effects. A large number of patches, high patch density and low mean patch size indicate a fragmented landscape for any particular land use/land cover or habitat type. A landscape change trajectory resulting in a larger number of patches, higher patch density and/or smaller mean patch size indicates the landscape is fragmenting.

Patch shape (SHAPE) and patch compaction (RGYR) provide a measure of how compact or spread-out patches of a particular land use/land cover type are. Like fragmentation measures, this provides an indication of the importance of potential edge effects on particular land use/land cover types. Patch types with high SHAPE or mean RGYR values are typified by patches of complex shapes. The more complex the shape, the greater the amount of edge and potential area that could be affected by edge effects. If these metrics increase over time, it suggests a landscape susceptible to an increase in edge effects.

Total edge contrast (TECI) measures the similarity between patches of one type and the patches adjacent to them. This requires establishing the amount of contrast between edges of various land use/land cover types, which will vary depending on the particular focus of a study. The contrasts can range from 0 to 1, with 0 being without contrast and 1 being maximally contrasting. Table 5.19 shows the edge contrasts used in this study. They were selected to favor edges between natural and semi-natural land use/land cover types. A high amount of total edge contrast suggests a landscape with isolated natural patches interspersed with more human dominated patches, while a low total edge contrast suggests a landscape of contiguous natural/semi-natural patches. Increasing edge contrast over time indicates a reduction in connectivity in the landscape.

Table 5.19 Edge contrast values used in the TECI metric.

	Developed	Ag	Upland Forest	Barren	Wetland Forest	Emergent Wetland	Water
Developed	0	0.8	0	0	0	0	0
Ag	0.8	0	0.6	0	0.8	0.8	0
Upland Forest	0	0.6	0	0	0.1	0.5	0
Barren	0	0	0	0	0	0	0
Wetland Forest	0	0.8	0.1	0	0	0.4	0.8
Emergent Wetland	0	0.8	0.5	0	0.4	0	0.8
Water	0	0	0	0	0.8	0.8	0

Mean nearest neighbor (MNND) and proximity (PROXIM) measure how far apart patches of the same patch type are, and provide an indication of the connectivity between patches of the same type.   High connectivity can have both positive and negative effects. By facilitating the travel of individuals across a landscape, it can increase the amount of habitat available to a species, which can be positive if this species is a preferred species but can be negative if this species is invasive or a predator to a preferred species. High connectivity can also facilitate the spread of disturbance, which, again, may be positive or negative depending the management goals for the landscape in question. Contagion (CONTAG) measures the mean aggregation of patches, and also provides an indication of connectivity and potential for disturbance spread. Decreases in MNND or increase in PROXIM or CONTAG over time indicates an increase in connectivity in the landscape.

The results of the landscape metric assessment for Hunterdon County are displayed in Table 5.20. Two metrics, contagion and total edge contrast index (TECI), were measured for the entire landscape. In Hunterdon, the contagion values decreased for each time period, with values of 47.69, 46.28 and 45.72 for 1986, 1995 and 2002, respectively. A decreasing contagion suggests that pixels of the same LULC class are becoming less likely to be adjacent to one another. TECI values also decreased over time, at 38.69, 34.91 and 33.01.

The rest of the metrics were calculated on a class-specific basis. Developed areas saw an increase in the number of patches (NP), patch density (PD) and mean patch size (MPS), while the nearest neighbor distance (ENN_MN) decreased. The radius of gyration measures (GYRATE_MN and GYRATE_AM) both decreased then increased, while the perimeter area ratio (PARA_MN) and the proximity metric (PROX_MN) increased. These results, particularly the slight decrease and then increase in the radius of gyration measures, suggest that development spread throughout the county between 1986 and 1995 and then began a process of infill between 1995 and 2002. The increase in MPS is likely an indication of this and perhaps also of an increase in the size of new developments.

Table 5.20 Landscape metric assessment results for Hunterdon County (GM = GYTRATE_MN and GAM = GYRATE_AM

Type	Year	NP	PD	GMN	GAM	PARA MN	PROX MN	ENN MN	CAP	MPS
Developed	1986	4990	0.409	212.9	3863.5	176.7	70.6	349.5	0.164	9.2
	1995	5594	0.458	208.6	3575.6	188.6	81.1	313.1	0.199	10
	2002	5616	0.460	210.6	4719.8	190.3	179.3	302.3	0.225	11.2
Agriculture	1986	1757	0.144	421.6	6165.3	144.2	1027.1	325.9	0.362	57.8
	1995	1989	0.163	382.4	4464.2	153.0	530.7	334.5	0.319	44.9
	2002	2181	0.179	358.2	3739.1	158.5	309.0	342.9	0.294	37.7
Forest	1986	3420	0.280	276.5	6716.2	223.3	665.0	270.4	0.356	29.1
	1995	4688	0.384	228.8	7023.5	260.4	603.5	242.3	0.365	21.8
	2002	5015	0.411	219.7	7421.9	266.2	677.4	236.6	0.366	20.4
Barren	1986	102	0.008	289.6	583.5	138.2	1.8	3428.0	0.005	13.8
	1995	209	0.017	184.6	423.6	189.9	0.6	2525.0	0.004	5.4
	2002	266	0.022	192.8	552.4	197.4	0.5	1937.1	0.005	5.7
Emergent Wetland	1986	2504	0.205	150.7	527.4	274.5	1.5	511.3	0.026	2.9
	1995	2752	0.226	139.5	482.9	283.7	1.7	493.5	0.025	2.6
	2002	2597	0.213	134.4	408.9	287.2	1.4	509.5	0.022	2.4
Wetland Forest	1986	3734	0.306	195.1	1006.6	282.0	5.7	361.2	0.065	4.9
	1995	3995	0.327	182.7	894.8	286.5	5.2	354.1	0.063	4.4
	2002	4298	0.352	177.4	883.1	288.4	5.4	339.9	0.065	4.3
Water	1986	1311	0.107	122.5	8162.6	351.8	17.5	757.2	0.022	4.7
	1995	1993	0.163	103.5	7962.3	369.2	13.2	563.7	0.023	3.3
	2002	2007	0.165	103.5	7926.0	368.5	13.0	563.0	0.023	3.3

Agriculture and upland forest saw an increase in the NP, PD and PARA_MN and a decrease in MPS. This is a clear signal of fragmentation. In the case of agriculture this was accompanied by an increase in ENN_MN and a decrease in the radius of gyration measurements. This suggests a separation of remaining agricultural areas. Upland forests, on the other hand, had a decrease in ENN_MN and an increase in the radius of gyration measures. These trends are consistent with the increase in upland forest in the landscape, which is apparently occurring at the same time as fragmentation. This is another argument for the need to comprehensively describe and measure landscape and not rely on simple measures of proportional changes in land use classes.

Wetland areas differed in their metrics depending on whether they were emergent or forested. Emergent wetlands were relatively stable, with a small decrease in MPS and in class area proportion (CAP). The decreases in the radius of gyration measures are indicative of the slight decrease in CAP. Forested wetland saw an increase in NP and PD and a decrease in ENN_MN and MPS, suggesting a similar fragmentation as experienced by upland forest, but with less overall change.

In Burlington, unlike Hunterdon, contagion values did not drop significantly over time, remaining almost stable for the three time periods (values of 44.98, 44.64 and 44.93 for 1986, 1995 and 2002, respectively). This implies that there is not a large amount of interspersion occurring among the LULC classes. The TECI for Burlington did decrease, as in Hunterdon, with values of 30.36, 29.08 and 27.39.

The class-based landscape metric assessment for Burlington County contained several notable differences with that for Hunterdon County (Table 5.21). In developed areas, NP and PD increased and then decreased, ENN decreased and MPS increased. This suggests that between 1986 and 1995, development was occurring in areas not adjacent to existing development, while between 1995 and 2002 development was primarily occurring adjacent to existing development. This interpretation is supported by the decrease PARA_MN between 1986 and 1995 and subsequent increase between 1995 and 2002.

Table 5.21 Landscape metric assessment results for Burlington County

Type	Year	NP	PD	GMN	GAM	PARA MN	PROX MN	ENN MN	CAP	MPS
Developed	1986	3799	0.166	203.8	14465.2	224.6	739.2	387.6	0.146	20.1
	1995	4055	0.178	210.1	11640.5	227.3	675.7	351.7	0.172	22.2
	2002	3935	0.172	210.7	12489.2	230	903.8	343.8	0.183	24.4
Agriculture	1986	2234	0.098	301.7	3486.1	215	128.3	405.2	0.137	32.2
	1995	2103	0.092	306.1	2750.4	206.8	100.6	436.3	0.122	30.5
	2002	2110	0.092	294.1	2464.8	206.7	89.4	429.1	0.115	28.5
Forest	1986	5773	0.253	234.6	14337.9	250.4	1190.3	289.2	0.371	33.7
	1995	6563	0.287	217.4	14115	262.6	1019.1	278.8	0.365	29.1
	2002	7014	0.307	209.8	14184.2	265.9	1004.6	276.3	0.36	26.9
Barren	1986	560	0.025	236.7	619.7	189.9	2.5	1503.4	0.01	9.7
	1995	485	0.021	225	598.1	188.8	2.6	1664.7	0.008	8.6
	2002	602	0.026	211.1	646.8	199.9	2	1469.4	0.009	7.7
Emergent Wetland	1986	3557	0.156	235.4	2066.6	229.3	21.6	440.4	0.085	12.5
	1995	4252	0.186	211.3	1958.5	246.7	18.7	416	0.084	10.4
	2002	4106	0.18	195.4	2000.5	252.8	16.9	439.2	0.074	9.5
Wetland Forest	1986	4767	0.209	257	9060.6	264.3	581.6	278.9	0.225	24.7
	1995	5161	0.226	246.9	7257.7	271.7	456.1	272.3	0.222	22.5
	2002	5139	0.225	244.3	8452.2	272.9	643.8	267.8	0.23	23.5
Water	1986	2043	0.09	167.8	9839.6	311.5	19.2	623.6	0.026	6.5
	1995	3380	0.148	123.3	10487.4	347.4	31.6	487.2	0.027	4.2
	2002	3452	0.151	120.4	10561.3	347.9	31.7	487.7	0.027	4.1

For agricultural areas in Burlington, NP and PD decreased and then stabilized, while MPS declined and ENN increased. PARA_MN, GYRATE_MN and PROX_MN all decreased. These results are suggestive of the loss of entire areas of contiguous farmland rather than the fragmentation of agricultural areas apparent in Hunterdon. Upland forest in Burlington gave the same indicators of fragmentation evident in Hunterdon County, with increasing NP and PD and decreasing ENN and MPS. Unlike Hunterdon, this was accompanied by decreases in PROX_MN and the radius of gyration measures, most likely the results of the decrease of upland forest in the landscape.

As in Hunterdon, trends in the metrics of wetland forests in Burlington County paralleled those of upland forests. The increases in NP and PD and decreases in ENN and MPS are consistent with fragmentation, with less overall change than the upland forest. Unlike Hunterdon County, there were some signs of stability in wetlands forests, with changes in NP, PD and MPS leveling off between 1995 and 2002. Trends in emergent wetlands in Burlington are broadly similar to those in the wetland forests, except that MPS did not stabilize but continued decrease between 1995 and 2002.

Chapter 6 – Interactions between Landscape Change and Open Space Preservation

6.1 Introduction

This chapter presents the results of the analyses of preserved open space and how open space preservation programs and purchases interact with the landscape change. First, an analysis of preserved open space in Hunterdon and Burlington counties is presented, describing their land cover, how it varies by ownership and how it has changed over time. Then the impact of landscape change in areas targeted by preservation programs is examined in order to understand how recent change may be impacting land preservation programs. The analyses dealing with change in areas targeted by open space preservation programs represent policy specific indicators as described in Chapter 3. Hunterdon's current open space preservation plan was adopted in 2000 (Hunterdon County Planning Board 2000). The changed observed between 1986 and 1995 therefore occurred prior to the implementation of the plan. Some of the change seen between 1995 and 2002 would have occurred after the implementation of the plan. Burlington's open space preservation plan was adopted in 2002 (Burlington County Department of Resource Conservation 2002). Therefore all of the changes are pre-implementation changes. It should be noted, however, that both counties had been preserving open space prior the implementation of these plans. The development of these current plans was necessary to secure funding for open space preservation under the Garden State Preservation Trust Act of 1998.

6.2 Land Use/Land Cover Characteristics of Preserved Open Space

This section describes the results of a series of analyses that sought to determine the current (2002) land use/land cover of preserved open space by owner ((state, county, local government, non-profit organization) and the land use/land cover of preserved open space near the date of their preservation and how these areas have changed over time

6.2.1 2002 Land Use/Land Cover of Preserved Open Space

The first part of the assessment of preserved lands determined the 2002 LULC of preserved open space by ownership using the 2002 LULC product described in previous chapters. Different organizations preserve lands for different reasons, and this should be reflected in the land use/land cover of preserved lands. The results of this analysis for Hunterdon County are presented in Table 6.1.

Table 6.1 2002 Land use/land cover of preserved open space in Hunterdon County, by owner/purpose (number in parentheses are proportion of each LULC class to lands owned by a particular owner as a whole)

	State	County	Municipal	Non-profit	Total
Developed	760.7	403	335.6	115.8	1615.1
	(0.055)	(0.074)	(0.105)	(0.059)	(0.066)
Agriculture	1451	869.7	895.9	654	3870.6
	(0.104)	(0.159)	(0.281)	(0.336)	(0.158)
Upland Forest	6691.8	3104.4	1549.9	953	12299.1
	(0.480)	(0.569)	(0.486)	(0.490)	(0.501)
Barren	21.8	8.2	4.8	1.3	36.1
	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)
Forested	1011.6	811.9	251.2	167.2	2241.9
	(0.073)	(0.149)	(0.079)	(0.086)	(0.091)
Emergent	121.1	151.7	113.8	43.9	430.5
	(0.009)	(0.028)	(0.036)	(0.023)	(0.018)
Water	3880	103.9	37	11.2	4032.1
	(0.278)	(0.019)	(0.012)	(0.006)	(0.164)
Total	13938	5452.8	3188.2	1946.4	24525.4

When compared to the county as whole (see Table 5.12), the proportions of LULC classes on preserved lands in Hunterdon show expected but significant differences. Upland and wetlands forests and developed areas are overrepresented versus the county as a whole on all lands preserved for open space regardless of ownership. Agricultural areas are underrepresented on all open space lands except for those owned by non-profits.

Properties preserved as open space do have different characteristics depending on ownership. County and municipal lands are more likely than others to contain developed areas, which either existed prior to preservation or indicate the presence of facilities built after preservation. Since the county and municipalities are more inclined to promote active recreation than the state or non-profits, it is likely this is the result of post-preservation facility construction. County lands are more forested than other lands as well. In contrast, state lands contain a significant amount of open water, primarily the result of the inclusion of Spruce Run and Round Valley reservoirs, both part of state facilities, in the acreage total. Non-profit lands, in contrast, have a higher proportion of agricultural areas than the others, which may indicate that non-profits are more likely to rent out cultivatable portions of their properties to farmers in order to produce income than the government land owners. Municipal lands also have a relatively high proportion of areas classified as agriculture, which may in part be a result of athletic fields being classified as grasslands.

A number of differences between Hunterdon and Burlington become evident by examining the LULC data for preserved lands in Burlington County (Table 6.2). For instance, county and municipal owned lands in Burlington do not have a higher proportion forests than the county as a whole (compare with county-wide data in Table 5.15), and while state lands do have a higher percentage of upland forests than the county as a whole, this overrepresentation is not seen with regards to wetland forests. In contrast, only wetland forests are overrepresented on nonprofit lands in Burlington as in Hunterdon.

Table 6.2 2002 Land use/land cover of preserved lands in Burlington County, by owner/purpose (number in parentheses are proportion of each LULC class to lands owned by a particular owner as a whole)

	State	County	Municipality	Non-profit	*Total*
Developed	707.5	63	71.6	313.1	1155.2
	(0.005)	(0.025)	(0.121)	(0.130)	(0.008)
Agriculture	440	323.4	95.8	158.6	1017.8
	(0.003)	(0.128)	(0.161)	(0.066)	(0.007)
Upland Forest	89897.5	518.4	87.8	797.4	91301.1
	(0.639)	(0.204)	(0.148)	(0.330)	(0.624)
Barren	62.5	1.7	3.5	32.9	100.6
	(0.000)	(0.001)	(0.006)	(0.014)	(0.001)
Forested	43148.3	163.6	264.6	911.9	44488.4
	(0.307)	(0.065)	(0.446)	(0.377)	(0.304)
Emergent	4988.1	42.2	57.6	191.3	5279.2
	(0.035)	(0.017)	(0.097)	(0.079)	(0.036)
Water	1460.6	103.9	37	11.2	1612.7
	(0.010)	(0.001)	(0.000)	(0.000)	(0.011)
Total	140704.6	2536	593.2	2416.4	146250.2

The sheer magnitude of forests preserved by state lands in Burlington (primarily in Pinelands) perhaps explains why county lands in Burlington do not favor forests as they do in Hunterdon. With so much forest preserved by the state, it seems likely that the county has decided to concentrate its preservation efforts elsewhere. Nonprofits, which do favor forests lands above their representation in the landscape, do so for several reasons. They preserve small, ecologically valuable forested areas and/or areas that form connections between larger preserves that are perhaps not large enough themselves to attract direct state attention. They may also be preserving land that government agencies have little interest in but is offered to them at a reduced price or even donated.

6.2.2 Land Use-Land Cover Change in Preserved Open Space, 1986 – 2002

Simply because land is preserved does not mean that land use-land cover change does not occur within the boundaries of preserved areas. The following results show how preserved lands have or have not been impacted by LULCC over the study period. Within each county, the lands preserved for open space purposes (i.e. excluding preserved farmland) are grouped by acquisition period, before 1986, 1986 to 1995 and 1995 to 2002. The preserved open space data used was that provided by the state, and some of the preserved land parcels came tagged with their acquisition date. For those parcels that were not tagged with their acquisition date, a multi-step process was used to determine or estimate their acquisition date using a variety of data sources. These sources include the MOD4 digital property record and transaction database, digital and hardcopy literature provided by the preserving agencies, and, in some cases, non-official websites that were judged to be trustworthy. If an actual preservation date could not be ascertained but the general acquisition time period could be, parcels were tagged with an acquisition period corresponding to the date of land use/land cover data layer created most immediately after its preservation. The process resulted in a success rate of approximately 55%, so the data presented in this part of analysis does not include the entire data set (see Figures 6.1 and 6.2 for maps of preserved lands by acquisition period for Hunterdon and Burlington Counties).

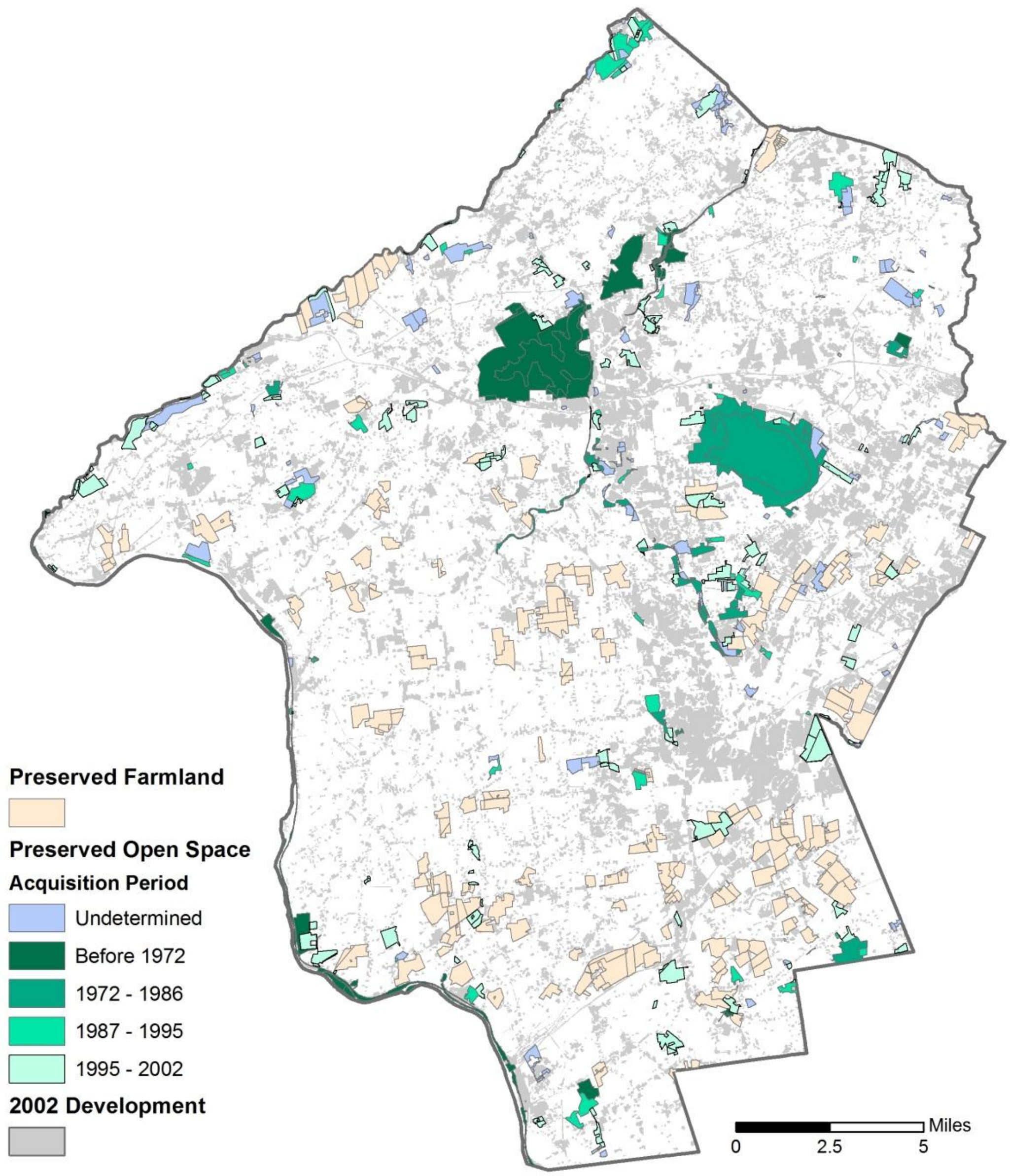


Figure 6.1 Preserved open space by acquisition period, Hunterdon County

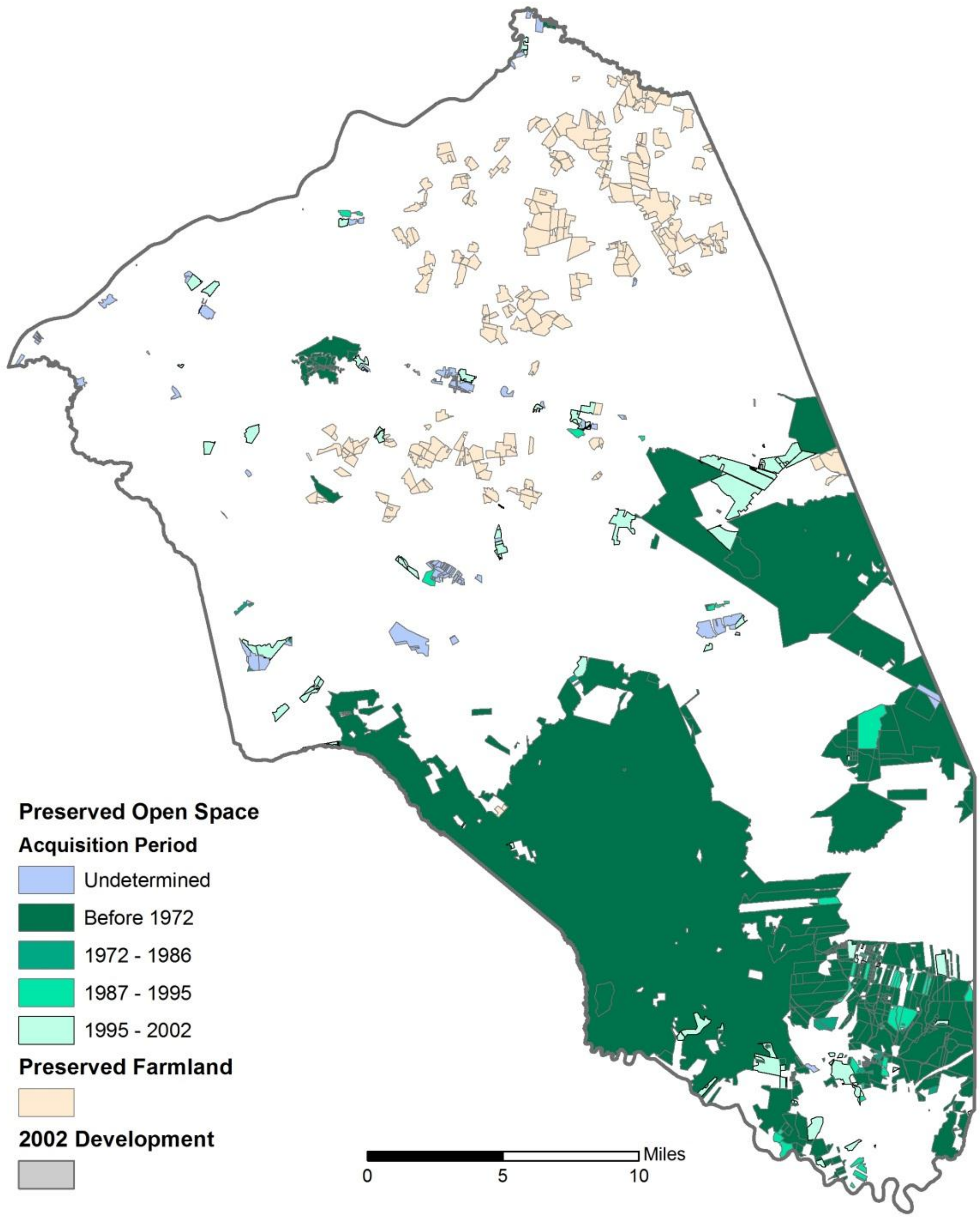


Figure 6.2 Preserved open space by acquisition period, Burlington County

For each county, land use/land cover acreages were generated for land preserved in each of the three acquisition periods – pre-1986, 1986-1995, 1995-2002. The LULC for these groups were then determined for 1986, 1995 and 2002. The results for Hunterdon County are found in Table 6.3. For Hunterdon County, these results exclude 3511.7 acres of land whose acquisition period could not be dated.

Table 6.3 Land use/land cover of preserved lands over time by acquisition period in Hunterdon County (acres).

a. Lands preserved before 1986

	1986	**1995**	**2002**
Developed	694.2	756.1	757.6
Agriculture	687.5	612.9	713.1
Upland Forest	4670.7	4693.4	4589.4
Barren	63.0	21.6	23.2
Forested Wetland	810.7	787.7	799.0
Emergent Wetland	109.9	117.9	108.2
Water	3837.3	3883.8	3882.6
Total	**10873.3**	**10873.3**	**10873.3**

b. Lands preserved between 1986 and 1995

	1986	**1995**	**2002**
Developed	69.2	116.6	116.0
Agriculture	432.9	358.1	331.2
Upland Forest	1338.1	1365.4	1390.9
Barren	0.0	0.2	1.3
Forested Wetland	197.9	200.1	202.7
Emergent Wetland	54.7	51.0	49.3
Water	12.5	13.8	13.8
Total	**2105.1**	**2105.1**	**2105.1**

c. Lands preserved between 1995 and 2002

	1986	**1995**	**2002**
Developed	162.5	176.7	405.6
Agriculture	1625.0	1508.6	1259.6
Upland Forest	2558.9	2650.4	2675.6
Barren	0.0	9.7	5.4
Forested Wetland	435.5	447.6	463.8
Emergent Wetland	155.8	140.8	121.4
Water	54.7	58.8	61.0
Total	**4992.4**	**4992.4**	**4992.4**

There is an increase in developed areas in all three groups. This increase can be significant in the time period immediately following acquisition, presumably as facilities such as athletic fields, playgrounds, parking lots and restrooms are constructed. This increase came at the expense of agriculture and upland forest areas. Beyond this single similarity, there seems to be a few significant differences between the lands preserved prior to 1986 and those preserved later. The pre-1986 lands show a decrease then an increase in agriculture while those preserved after 1986 have a decrease in agricultural areas. Lands preserved after 1986 may show the same increase in agricultural areas in the future if the management imperatives remain similar to those evidenced between 1995 and 2002. Upland forests decreased in pre-1986 lands while increasing in those preserved later. Wetland forests also followed these trends, although with only a small decrease in pre-1986 preserved lands. Emergent wetlands remained stable in pre-1986 preserved lands while decreasing in those lands preserved later, particularly in those lands preserved between 1995 and 2002.

The data in Table 6.3 also show a significant increase in the amount of land preserved between 1986-1995 and 1995-2002. While some of this difference may be attributable to the absence of data from the lands which had an indeterminate preservation date, it is likely that this difference is in some part attributable to passage of the Garden State Preservation Trust Act in 1998. This open space and farmland preservation funding act significantly increased the amount of funding available for preservation, increasing the rate of preservation acquisitions across the state.

Comparing the LULCC trends in preserved lands to those in the county as a whole that were discussed in the previous chapter, there is again a difference between lands preserved prior to 1986 and those preserved later. The decrease followed by an increase in agricultural areas and the decrease in upland forest found in those lands preserved before 1986 is opposite the trend seen in the county as whole. Conversely, the trends seen in those lands preserved after 1986 do mirror the trends seen in the county as a whole.

The proportion of agricultural areas in lands preserved for open space appears to differ by preservation date as well. Although all of the preserved open space groups underrepresent agricultural areas with reference to the county as a whole, those preserved prior to 1995 have a much lower proportion of agriculture lands than those preserved later. This is true even if the water that is one-third of the area preserved prior to 1986 is excluded. This suggests a greater willingness to preserve agricultural lands as open space and/or a greater availability of those lands for preservation, perhaps related to the greater availability of funding for preservation after the passage of the Garden State Preservation Trust Act.

The corresponding data for Burlington County are presented in Table 6.4. In the case of Burlington, lands preserved prior to 1995 share more trends than with each other than with the lands preserved later. Both of the groups preserved prior to 1995 show an increase in developed areas along with decrease in agriculture and upland forest. Those preserved later also show a decrease in agriculture, but they show a slight decrease then increase (though not to the 1986 amount) in developed areas and increase in upland forests. Also notable is the almost complete absence of agricultural lands preserved as open space between 1986 and 1995. As in Hunterdon, the amount of agricultural land preserved as open space increased in the post-1995 group, although it is proportionally lower than in Hunterdon and still underrepresents agriculture as compared to the county as whole.

Table 6.4 Land use/land cover of preserved lands over time by acquisition period in Burlington County

a. Lands preserved before 1986

	1986	1995	2002
Developed	546.1	633.9	651.2
Agriculture	578.3	447.0	430.8
Upland Forest	84015.7	83864.6	83858.4
Barren	56.7	52.8	52.4
Forested Wetland	37515.9	37988.2	39080.5
Emergent Wetland	5481.6	5065.1	4062.5
Water	1194.9	1337.7	1253.5
Total	**129389.3**	**129389.3**	**129389.3**

c. Lands preserved between 1986 and 1995

	1986	1995	2002
Developed	8.2	9.5	26.6
Agriculture	2.8	0.7	0.2
Upland Forest	1689.2	1688.6	1657.9
Barren	2.6	2.0	15.2
Forested Wetland	640.4	641.0	643.4
Emergent Wetland	374.1	371.9	372.6
Water	60.6	64.2	61.9
Total	**2777.9**	**2777.9**	**2777.9**

c. Lands preserved between 1995 and 2002

	1986	1995	2002
Developed	101.9	96.7	98.7
Agriculture	286.0	279.3	261.4
Upland Forest	3635.1	3647.2	3667.7
Barren	13.6	14.3	10.0
Forested Wetland	2734.6	2694.0	2750.6
Emergent Wetland	512.9	548.9	495.7
Water	190.6	194.1	190.4
Total	**7474.6**	**7474.6**	**7474.6**

6.3 Characterizing Landscape Change in Open Space Preservation Target Areas

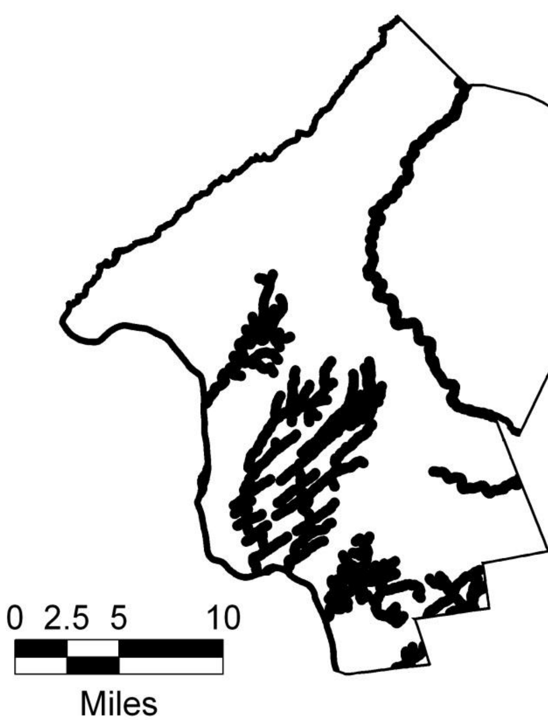
Because open space preservation programs explicitly define areas that will be targeted for acquisition, it is possible to determine the rate and nature of landscape change in these target areas. This section presents the results of several analyses that examine the landscape change occurring in these target areas in a variety of ways. These analyses allow for a detailed examination between one aspect of open space preservation program implementation, the establishment of target areas, and landscape change. The results can show whether some target areas are more threatened with development than others, and can be used to assess whether target areas goals should be reprioritized. These analyses also represent policy specific indicators of change, since they focus on change directly related to the implementation of the policy.

In order to explore this interaction, it was necessary to first create spatial representations of the target areas of the county land preservation programs in Hunterdon and Burlington Counties. Previous work (Myers 2004) has produced GIS data layers representing the spatial location and extent of these goals. Table 6.5 presents a list of the goals and their GIS representation. The conservation zones layer (Figure 6.3a) combines the Highlands, Sourland Mountain and Delaware Bluffs areas that were digitized from paper maps in Hunterdon's Open Space, Farmland and Historic Preservation Trust Fund Plan (2000). The river corridors layer (Figure 6.3b) was created by buffering the river mentioned in the plan by ½ mile. The habitat layers were defined by the New Jersey Endangered and Non-game Species Program's Landscape Project (ENSP 2001) (Figure 6.3 c –f). The Greenways links layer (Figure 6.3g) was created by digitizing the proposed linkage trails and buffering them by ¼ mile. The adjacency layer (Figure 6.3h) was created by buffering the existing county parks by 75 feet. The Viewshed layer (Figure 6.1i) was created by digitizing the highest point in each county park (or points, if there were local maxima) and then calculating the viewshed within the county from these points. See Myers (2004) for a complete description of the methodology used to create these layers.

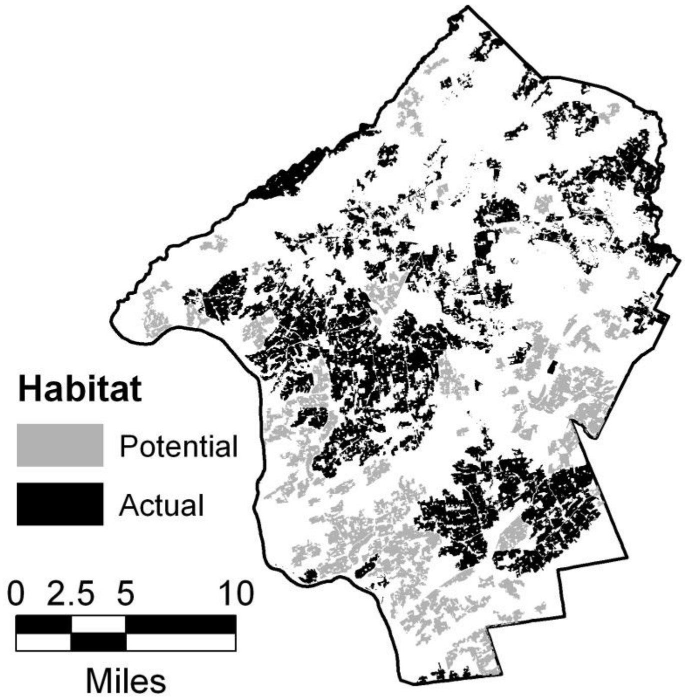
Table 6.5 Hunterdon County's open space preservation target areas and their GIS representation.

Hunterdon County Open Space Goal	**Digitized Representation**
Conservation Zones – Highlands, Sourland Mountain, Delaware Bluffs	Conservation Zones layer
River corridors	River Corridors layer
Linkages between parks and corridors	Greenway Links layer
Endangered species habitat	Landscape Project Grassland habitat layer Landscape Project Forest habitat layer Landscape Project Emergent Wetland habitat layer Landscape Project Forested Wetland habitat layer
Fragile flora habitat	Natural Heritage Program Priority Sites layer
Adjacency to existing parks	Adjacency layer
County park viewshed protection	Viewshed layer

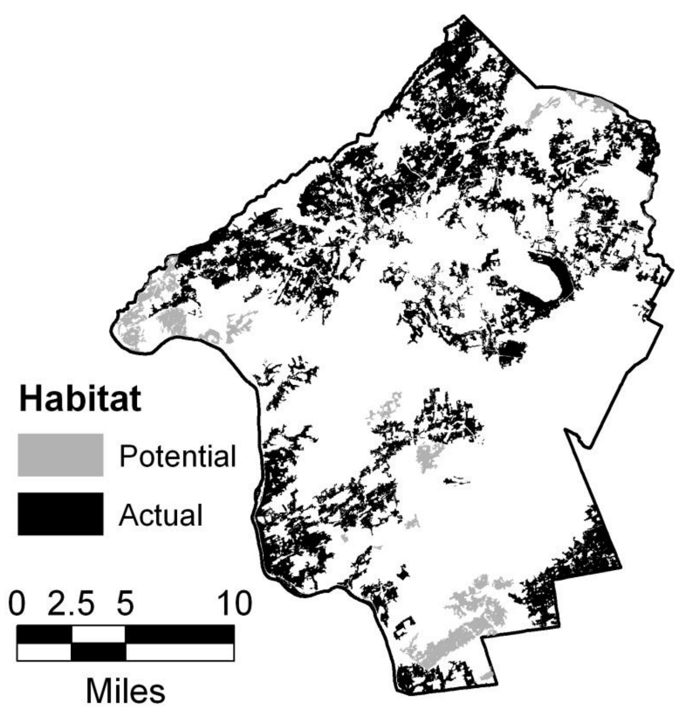
a. Conservation zones



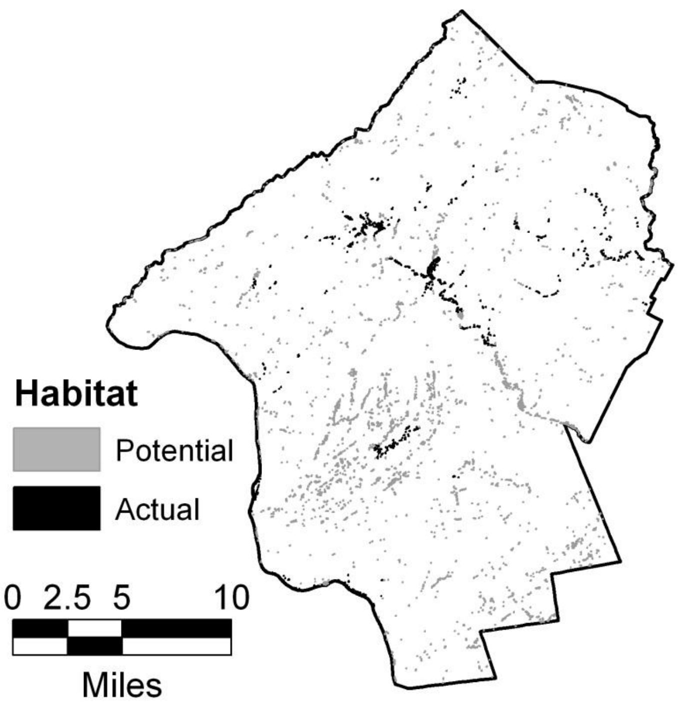
b. River Corridors



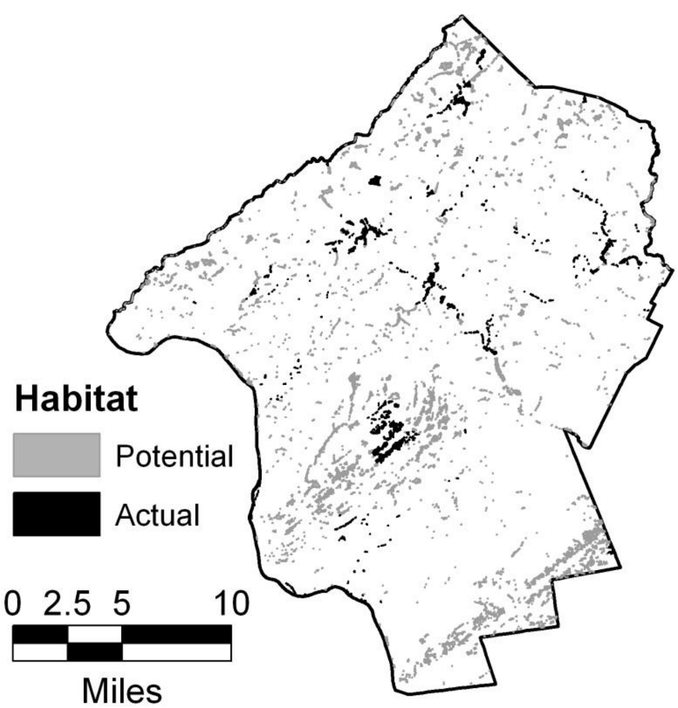
c. Grassland



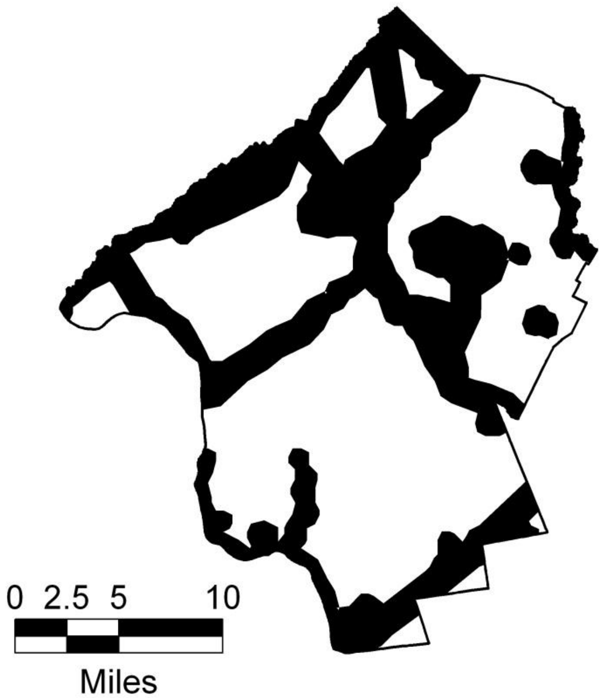
d. Forest



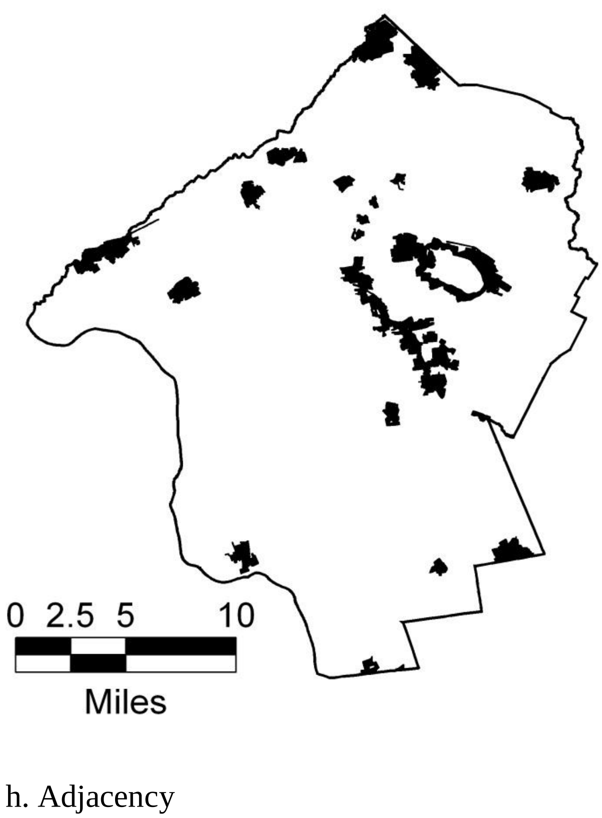
e. Emergent Wetland



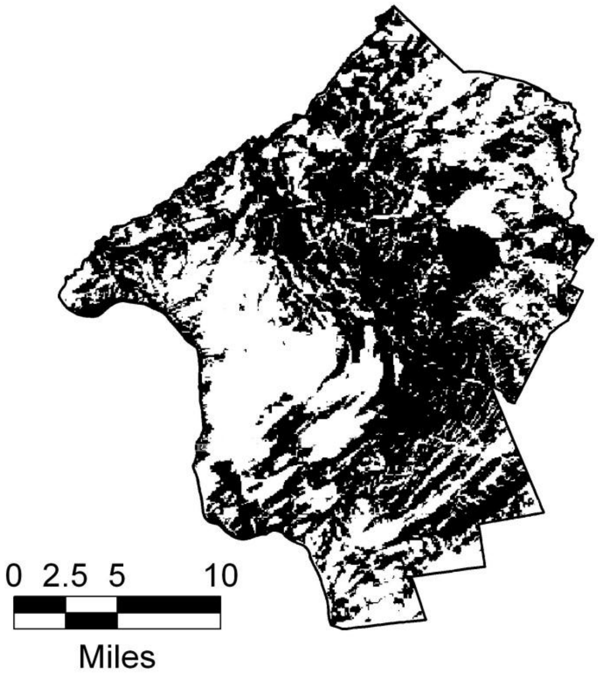
F. Forested Wetland



g. Greenway links



h. Adjacency



i. Viewshed

Figure 6.3 (a-i). Target areas for open space preservation in Hunterdon County.

The target areas for Burlington County's open space preservation program are geographically defined project areas rather than targeted characteristics as in Hunterdon. These are detailed and mapped in Burlington's Parks and Open Space Master Plan (Burlington County Department of Resource Conservation, 2002). These areas were digitized on-screen using municipal boundaries and roads as base layers (Figure 6.4).

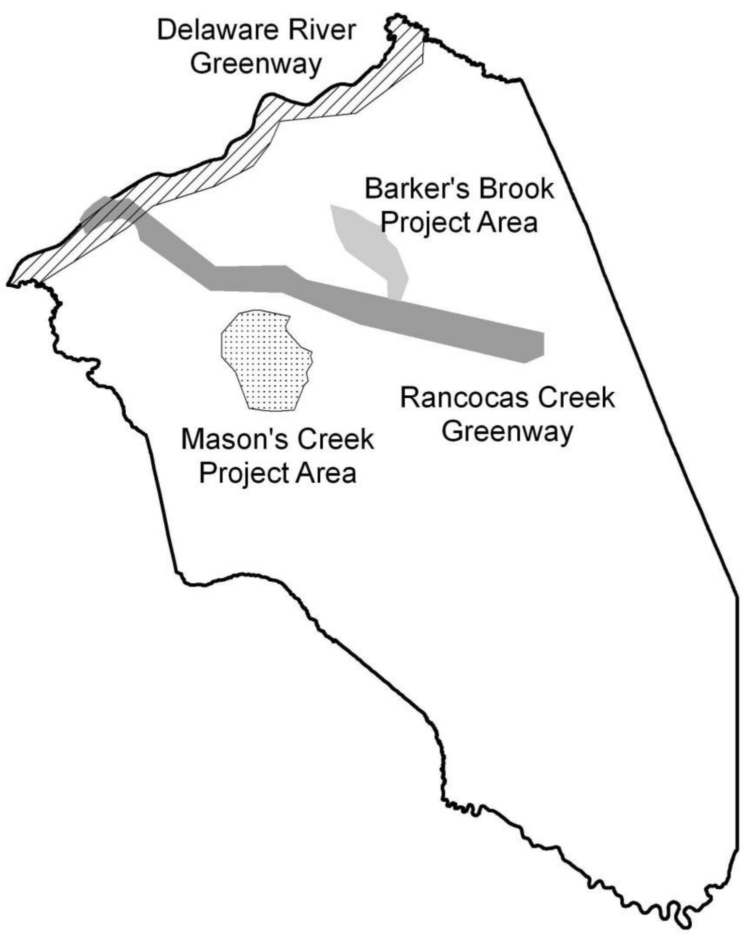


Figure 6.4 Project areas for open space preservation in Burlington County

6.3.1 Visual Assessment of Landscape Change in Open Space Preservation Target Areas

The first analysis of development in land preservation target areas involves the visual examination of a series of maps depicting development in 1986, 1995 and 2002 in and/or around the target areas in Hunterdon (Figures 6.5 a-f) and Burlington (Figures 6.6 a-d) (see end of chapter for figures). Two of the Hunterdon target areas were not included in this analysis, those areas adjacent to county owned preserved open space and the viewshed of county owned preserved open space. The former occupies a very small buffer around preserved open space and is difficult to visualize at a county scale, while the latter is difficult to analyze because it occupies a significant percentage of the county.

6.3.1.1 Conservation Zones Target Area in Hunterdon County

This target area is comprised of three distinct areas, the Delaware Bluffs in the western section of the county, the Sourland Mountains in the southern portion of the county and the Highlands in the northern portion of the county (Figure 6.5a). These vary significant in size, terrain and suitability for development. The Delaware Bluffs are the smallest and least developable of the three, and show little development over the study period. The Sourland Mountains has seen some development along larger roads, and some development in the center and west of State Route 31. The Highlands is the largest area and has seen the most significant development since 1986 except for the extreme northern portion of the area.

6.3.1.2 Emergent Wetland Habitat Target Area in Hunterdon County

This and the other habitat target areas are mapped to show development around them. Development within in the habitat target areas will be considered in the next section. The emergent wetland habitat type is concentrated in several areas within the county. The centrally located South Branch of the Raritan River corridor contains a number of emergent wetlands that are being encroached upon by development (Figure 6.5b). The Sourland Mountains in the southern portion of the county contains a number of widely scattered, relatively unthreatened emergent wetlands. The southwest quadrant of the county appears to contain the largest number of emergent wetland patches that are threatened by continuing development.

6.3.1.3 Forest Habitat Target Area in Hunterdon County

Several forest areas of the Highlands in the northern portion of the county are vulnerable to fragmentation and isolation from larger patches of forest habitat (Figure 6.5c). Forest in the Sourland Mountains is still reasonably well connected, although the sectioning of this area by State Route 31 has led to a separation of the forest habitats into two distinct parts. As with the emergent wetlands, the forests in the southwestern quadrant seem to be vulnerable to fragmentation, as there are several areas that are tenuously connected to larger patches.

6.3.1.4 Grassland Habitat Target Area in Hunterdon County

Grassland in the east central area of the county has been fragmented and separated by development (Figure 6.5d). Areas in the west central portion of county have experienced moderate fragmentation. Those in the southwest corner of the county have experienced less fragmentation, although development there does seem to be increasing, leading to the potential for future fragmentation.

6.3.1.5 Forested Wetland Habitat Target Area in Hunterdon County

Forested wetland habitat is suffering from isolation and encroachment by development, particularly in the northern section of the county (Figure 6.5e).

6.3.1.6 River Corridor Target Area in Hunterdon County

There is widespread but relatively dispersed development in most river corridors (Figure 6.5f). The south branch of the Raritan River is an exception, particularly in its northern section, where there has been considerable development, much but not all of it pre-1986. The area suffering from the most recent development is the headwaters of the Neshanic River in the southeastern corner of the county, which is particular troubling given the sensitive nature of head water areas.

6.3.1.7 Greenway Links Target Area in Hunterdon County

The Highlands area of the county has considerable post-1986 development in the main linkage areas (Figure 6.5g). The connector between the Musconetcong River and the Delaware River has also experienced considerable development. The connector between the Delaware River and the Raritan River has experienced some development in its central portion, which could compromise the ability to develop contiguous tracts of natural land.

6.3.1.8 Barker's Brook Target Area in Burlington County

The Barker's Brook target area in Burlington has not experienced considerable development (Figure 6.6a). However, the development that has occurred has been in central portion, where it may have the most impact. The presence of a significant crossroads in the central portion of the target area suggests a potential for future development that may further separate the northern portion of the target area from the southern.

6.1.3.9 Mason's Creek Target Area in Burlington County

Unlike the Barker's Brook target area, the Mason's Creek target area has seen considerable development (Figure 6.6b), both around the periphery and in the north central section. There is also considerable existing fragmentation in the target area because of dispersed development.

6.1.3.10 Rancocas River Greenway Target Area in Burlington County

The center of the Rancocas Greenway target area is very developed (Figure 6.6c), while the eastern section has experienced recent development along its central axis.

6.1.2.11 Delaware River Greenway Target Area in Burlington County

The Delaware River Greenway Target Area is very developed along its entire length (Figure 6.6d), which is unsurprising given the importance of the riverfront to Burlington's economy throughout its history.

6.3.2 Quantifying Development in Open Space Preservation Target Areas

The next analysis of landscape change in open space preservation target areas identified the amount and rate of development occurring in the target areas. Note that the habitat target areas are based on 1995 land use/land cover data. The conversion to raster of the land use/land cover products used in this analysis has resulted in some overlap between developed areas and the 1986 and 1995 land covers where none should exist since the habitats exclude development. The development between 1995 and 2002 in the habitat target areas does represent change. The results are presented to be consistent the other target areas. The results for the land preservation target areas in Hunterdon County are presented in Table 6.6.

In 1986, only the viewshed target area had more development than the county as a whole, although the greenway links and conservation zones target areas had only slightly less. In 1995, the viewshed target areas still had more development that the county as a whole while the conservation zones and greenway links target areas were not as close to being as developed as the county as whole as they were in 1986. These trends continue in 2002.

Table 6.6 Development in Open Space Preservation Target Areas in Hunterdon County

	Percent Developed before 1986	**Percent Developed in 1995**	**Percent Developed in 2002**	**Increase in Development, 1986 to 1995**	**Increase in Development, 1995 to 2002**
Adjacency	9.9%	12.9%	14.3%	30.4%	10.7%
Conservation Zones	16.1%	20.0%	22.8%	24.4%	14.1%
Emergent Wetlands	1.8%	3.0%	3.5%	70.8%	17.9%
Upland Forest	3.9%	5.5%	6.8%	40.5%	24.5%
Grasslands	3.6%	5.6%	9.5%	55.5%	69.6%
Wetland Forests	1.0%	1.4%	1.8%	41.9%	27.2%
Priority Sites	11.6%	14.3%	16.0%	23.5%	11.6%
River Corridors	12.4%	15.4%	17.2%	23.9%	11.9%
Greenway Links	15.6%	19.8%	21.9%	27.1%	11.0%
Viewshed	18.0%	23.7%	27.1%	31.9%	14.6%
County as a whole	***16.4%***	***21.3%***	***24.2%***	***30.1%***	***13.8%***

An examination of the proportional rates of development from 1986 to 1995 and 1995 to 2002 show a more complex pattern. Between 1986 and 1995, the open space buffer and viewshed developed at a rate faster than the county as whole. The habitat and viewshed target areas continued to develop faster than the county as a whole between 1995 and 2002, as did the conservation zones target area. For both time periods, the agricultural development areas and areas containing soils of statewide agricultural importance developed faster than the county as a whole and areas with prime soils developed at a rate close to the county as a whole.

The results of the analysis of development in target areas for land preservation in Burlington County are presented in Table 6.7. In 1986, the Barker's Brook Project Area and the Mason's Creek Project Area were less developed than the county as a whole. By 1995, only the Barker's Brook Project Area was less developed than the county as a whole, a conditioned that continued in 2002. The Delaware Greenway area is particularly developed, occurring as it does in the most developed and longest developed part of the county, the area along the Delaware River. By 2002 this area was 50% developed. This suggests that land preservationists should move quickly to preserve any remaining parcels in this area that serve the needs identified by the county in the open space plan (Burlington County 2006).

Table 6.7 Development in Open Space Preservation Target Areas in Burlington County

	Percent Developed before 1986	**Percent Developed in 1995**	**Percent Developed in 2002**	**Increase in Development, 1986 to 1995**	**Increase in Development, 1995 to 2002**
Barker's Brook Project Area	5.3%	8.2%	9.6%	55.0%	16.3%
Mason's Creek Project Area	13.2%	21.5%	27.7%	63.1%	28.8%
Rancocas Creek Greenway	25.9%	28.4%	29.6%	9.5%	4.3%
Delaware River Greenway	44.4%	47.6%	50.0%	7.1%	5.1%
County as a Whole	***14.4%***	***17.5%***	***19.4%***	***21.3%***	***10.9%***

The results concerning the proportional changes in development in Burlington's target area show the Barker's Brook Project Area and Mason Creek's Project Area to be developing at a rate faster than the county as a whole. Both of those project areas showed a dramatic increase in the proportion of their area developed between 1986 and 1995, both well over 2 times rate of development in the county as a whole. Between 1995 and 2002, the Mason Creek's Project Area still experienced growth at over twice the county's development rate, but development in the Barker's Brook Project Area slowed to only 1.5 times the countywide rate. If these differences in development rates have continued, then key properties in the Mason's Brook Project Area should be a priority for the county to preserve. The proportional rates of development are slower than the county as a whole in the Delaware River Greenway and the Rancocas Creek Greenway, which may be related to the fact that they are already more developed than the other areas.

6.3.3 Development Near Habitat Target Areas

The presence of development near the edges of critical wildlife habitat can have decidedly negative impacts on the habitat quality and the species living in it (Theobald et al. 1997). Table 6.8 shows the results of an analysis that determined the amount of development in 1986, 1995 and 2002 within 100m of the critical wildlife habitat that represent one of the goals of the Hunterdon County open space preservation program.

Areas within 100m of the upland forest and grassland target areas are developed at a higher proportion than the rest of the county for all three LULC dates, while areas within 100m of the wetland target areas are proportionally less developed than the county as a whole. Much of the habitat value of these upland areas stems from their relatively large core areas that are distant from human-caused disturbance. Since the areas immediately proximate to them are overdeveloped in comparison to the rest of the county, there exists the possibility that these habitat patches are more disturbed than previously assumed.

The rate of development data shows that the areas immediately surrounding all of the target areas developed at rates faster than the county as a whole between 1986 and 1995. The rates of development of grassland and upland forest target fell below the rate of the county as a whole between 1995 and 2002. If these trends continue, the developed proportion of the county as whole may come to match that of the areas proximate to the upland target areas. The rates of development of the wetland target areas remained higher than the county as whole during this time period, indicating an increased potential for indirect human impacts on the wetland target areas such those posed by increased runoff from impervious surfaces, compounded with the increased contamination of that runoff from fertilizers and other pollutants associated with development (Brabec et al. 2002).

Table 6.8 Development within 100m of Hunterdon County Habitat Target Areas

	Percent Developed before 1986	**Percent Developed in 1995**	**Percent Developed in 2002**	**Increase in Development, 1986 to 1995**	**Increase in Development, 1995 to 2002**
Emergent Wetland	8.1%	10.7%	12.2%	32.1%	14.0%
Upland Forest	24.7%	30.2%	33.3%	22.1%	10.3%
Grassland Wetland	24.2%	30.3%	32.7%	25.4%	7.8%
Forest	8.7%	11.2%	12.9%	29.6%	14.9%
County as a Whole	***16.4%***	***21.3%***	***24.2%***	***30.1%***	***13.8%***

6.3.4 Development Near Preserved Open Space Over Time

The final analysis concerning the interaction between landscape change and open space preservation examined changes in the percentage of developed land near preserved open space though time. If land is developing faster near preserved open space than farther from preserved open space, then it may be an indication that preserved open space attracts development to its periphery.

The first step in the analysis was to extract parcels preserved as open space prior to 1986, those preserved from 1986 to 1995, and those preserved from 1996 to 2002 into three separate data layers. This was done so that there would be at least 2 post-preservation measures of landscape change for the earlier time periods. If the preserved lands were not separated by acquisition time, there would be only one post-preservation measure of landscape change, and it would impossible to deduce a trend from this single measure. Furthermore, there will inevitably be a lag between preservation and any development it attracts. Separating the older preserved lands provides an opportunity the potential response development to occur. Performing the analysis on the more recent preserved land can show whether there was greater than average development around these lands prior to preservation.

These preserved open space layers were then buffered in 10 concentric 100m rings. The percentage of development occurring within those rings was then determined by overlay analysis, as was the percentage of development occurring beyond 1000m from any preserved open space. The results for Hunterdon and Burlington Counties are shown in Tables 6.9 and 6.10, respectively.

Table 6.9 Development within Buffers around Preserved Open Space in Hunterdon County

a. Land Preserved prior to 1986

Buffer Distance (meters)	**Percent Developed**		
	1986	**1995**	**2002**
100	21.6%	23.6%	24.7%
200	23.5%	25.3%	27.1%
300	21.5%	23.7%	26.0%
400	21.8%	24.2%	26.7%
500	21.1%	23.7%	26.5%
600	20.8%	24.7%	27.7%
700	20.7%	23.0%	26.3%
800	21.9%	26.0%	29.3%
900	21.0%	24.4%	28.6%
1000	21.7%	25.3%	29.3%
>1000	16.2%	19.0%	21.7%
County as a Whole	16.4%	21.3%	24.2%

b. Land Preserved from 1986 to 1995

Buffer Distance (meters)	**Percent Developed**		
	1986	**1995**	**2002**
100	18.6%	20.5%	21.8%
200	20.3%	22.3%	24.4%
300	19.3%	22.4%	24.2%
400	20.5%	22.6%	24.5%
500	20.3%	22.7%	24.6%
600	20.8%	23.8%	25.7%
700	20.3%	23.4%	25.9%
800	20.5%	23.3%	26.0%
900	19.7%	23.0%	26.6%
1000	19.1%	21.3%	25.1%
>1000	16.2%	19.0%	21.7%
County as a Whole	16.4%	21.3%	24.2%

c. Land Preserved from 1996 to 2002

Buffer Distance (meters)	Percent Developed		
	1986	1995	2002
100	17.2%	19.9%	21.9%
200	19.3%	21.8%	23.2%
300	20.0%	22.2%	23.8%
400	20.3%	22.9%	24.6%
500	20.1%	22.3%	24.5%
600	19.3%	21.0%	23.5%
700	20.6%	22.2%	25.1%
800	21.3%	22.9%	25.6%
900	20.5%	22.3%	25.0%
1000	19.0%	21.2%	24.1%
>1000	16.2%	19.0%	21.7%
County as a Whole	16.4%	21.3%	24.2%

For Hunterdon, the data show that land near preserved open space is more developed than land more than 1 km from open space for all three time periods, no matter when the land was preserved. Interestingly, areas that have been preserved longer have more development at their periphery than areas that are more recently preserved, and the effect is greater for land that has been preserved the longest. This is highly suggestive of development being attracted to the periphery of preserved open space.

Table 6.10 Development within Buffers around Preserved Open Space in Burlington County

a. Land Preserved prior to 1986

Buffer Distance (meters)	**Percent Developed**		
	1986	**1995**	**2002**
100	5.1%	5.7%	6.0%
200	5.8%	6.3%	6.7%
300	5.9%	6.6%	7.1%
400	6.2%	7.2%	7.8%
500	6.6%	7.8%	8.3%
600	7.5%	8.8%	9.7%
700	7.6%	9.3%	10.7%
800	7.8%	9.4%	10.8%
900	8.3%	10.0%	11.7%
1000	9.3%	11.1%	13.0%
>1000	21.6%	25.6%	28.2%
County as a whole	14.4%	17.5%	19.4%

b. Land Preserved from 1986 to 1995

Buffer Distance (meters)	**Percent Developed**		
	1986	**1995**	**2002**
100	2.2%	3.0%	3.2%
200	2.5%	3.4%	3.6%
300	3.0%	4.0%	4.1%
400	3.0%	3.9%	4.1%
500	3.7%	4.6%	4.7%
600	3.9%	4.7%	4.8%
700	4.6%	5.3%	5.4%
800	5.0%	5.6%	6.0%
900	5.8%	6.6%	7.2%
1000	6.0%	7.2%	7.8%
>1000	21.6%	25.6%	28.2%
County as a whole	14.4%	17.5%	19.4%

c. Land Preserved from 1996 to 2002

Buffer Distance (meters)	Percent Developed		
	1986	1995	2002
100	11.1%	13.0%	13.6%
200	12.4%	14.2%	15.5%
300	12.2%	14.3%	15.8%
400	12.1%	14.3%	15.9%
500	12.4%	14.9%	16.9%
600	11.6%	14.3%	16.6%
700	12.6%	15.0%	16.7%
800	12.0%	14.1%	15.7%
900	13.1%	14.9%	16.7%
1000	13.6%	15.3%	17.4%
>1000	21.6%	25.6%	28.2%
County as a whole	14.4%	17.5%	19.4%

The data for Burlington apparently show a very different relationship between open space preservation and development than in Hunterdon. In all cases, land near preserved open space is less likely to be developed than land at least 1 km from preserved open space. The difference is the most for lands preserved from 1986 to 1995 and least for lands most recently preserved. This pattern most likely arises from the spatial configuration of preserved open space in Burlington and how it has changed over time. Much of the older preserved land is found in large tracts in the southeastern part of the county, far from the development pressures experienced in the western portion of the county. Since 1979, development around these areas has been restricted by the establishment of the Pinelands National Reserve. The more recently preserved lands are more likely to be located in the western portion of the county, closer to developed and developing areas.

6.4 Conclusions

The landscape changes on preserved open space and on open space preservation target areas examined in this chapter provide insight into the impact of ongoing landscape change on farmland preservation in Hunterdon and Burlington. The analyses dealing with changes in and near target areas are policy specific indicators as discussed in Chapter 3. By showing that the areas within and near certain target areas are developing more rapidly than others, the results suggest that planners and implementers may wish to consider altering the implementation of Hunterdon's open space preservation program by prioritizing areas within these more rapidly developing target areas. The discussion of these results and their synthesis with rest of this study continues in Chapter 8. Chapter 7 focuses on interactions between landscape change and farmland preservation.

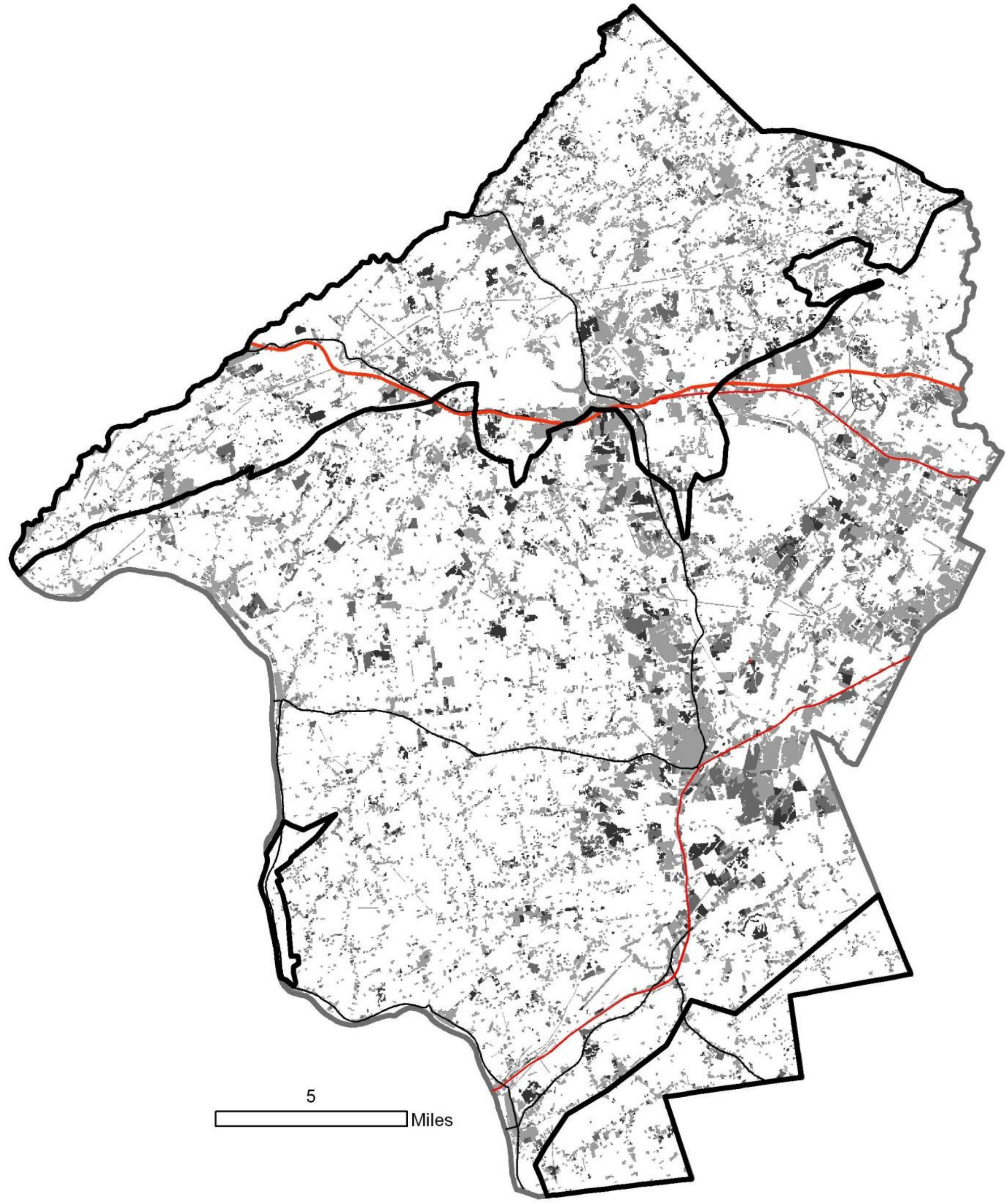


Figure 6.5.a Development in Conservation Zones – light gray areas were developed before 1985, medium gray areas between 1986 and 1995, and dark gray areas between 1995 and 2002. The thick black line is the target area boundary. The thick red line is Interstate 78, the thin red lines are US Routes, and the thin black lines are state roads.

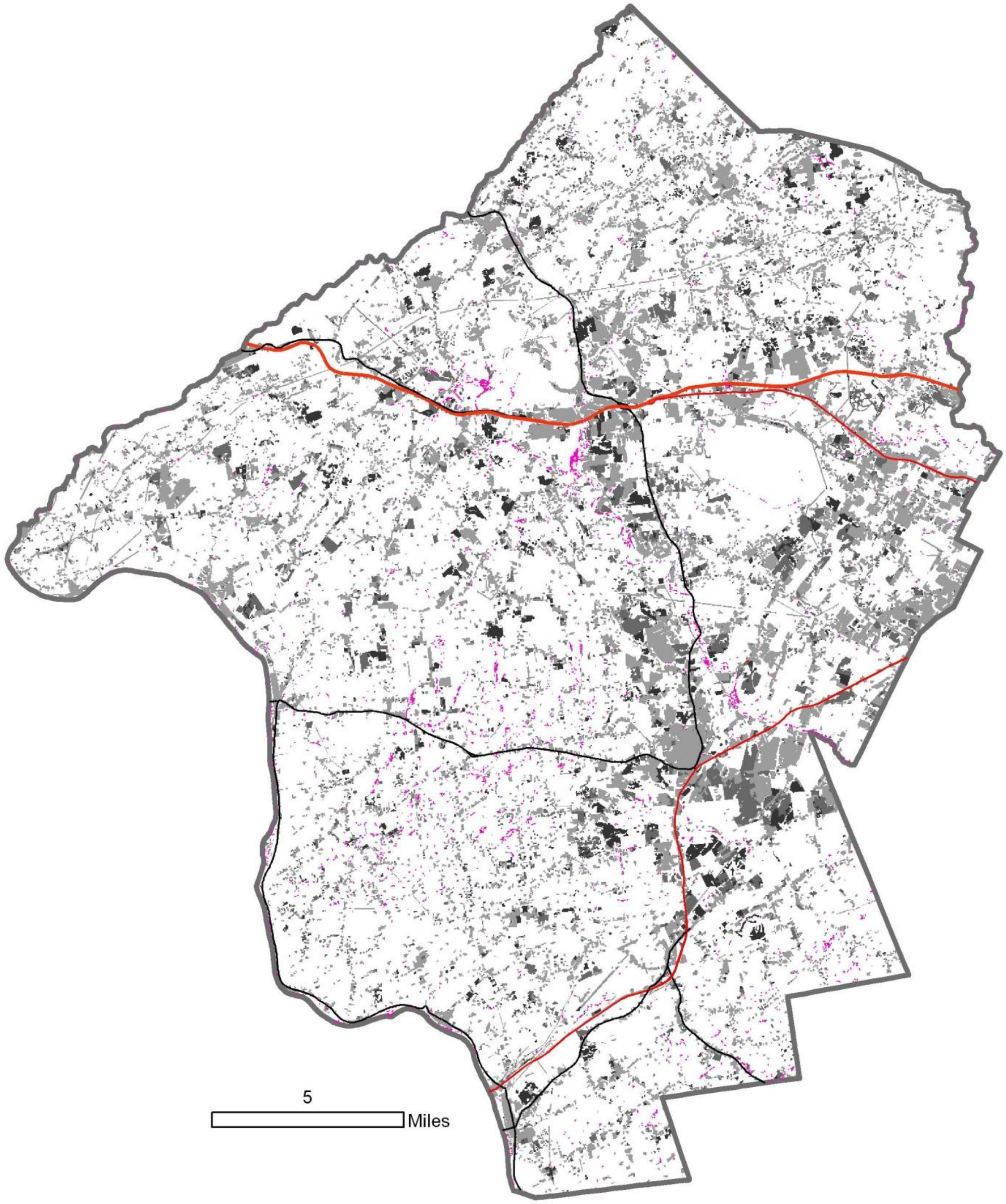


Figure 6.5.b Development near Emergent Wetland Habitat – light gray areas were developed before 1985, medium gray areas between 1986 and 1995, and dark gray areas between 1995 and 2002. The magenta areas are the critical emergent habitat. The thick red line is Interstate 78, the thin red lines are US Routes, and the thin black lines are state roads.

Figure 6.5.c Development near Forest Habitat – light gray areas were developed before 1985, medium gray areas between 1986 and 1995, and dark gray areas between 1995 and 2002. The green areas are critical forest habitat. The thick red line is Interstate 78, the thin red lines are US Routes, and the thin black lines are state roads.

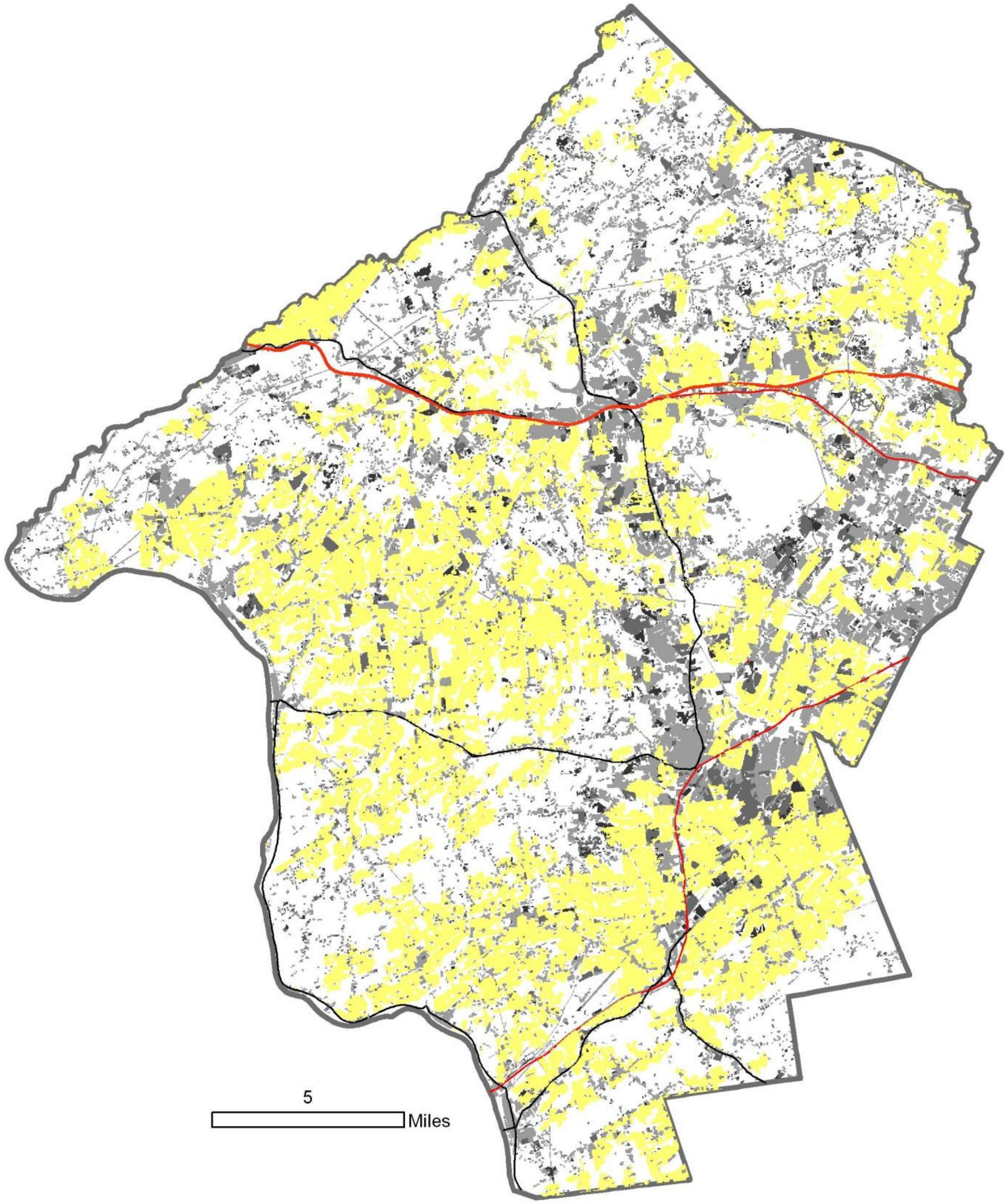


Figure 6.5.d Development near Grassland Habitat – light gray areas were developed before 1985, medium gray areas between 1986 and 1995, and dark gray areas between 1995 and 2002. The yellow areas are critical grassland habitat. The thick red line is Interstate 78, the thin red lines are US Routes, and the thin black lines are state roads.

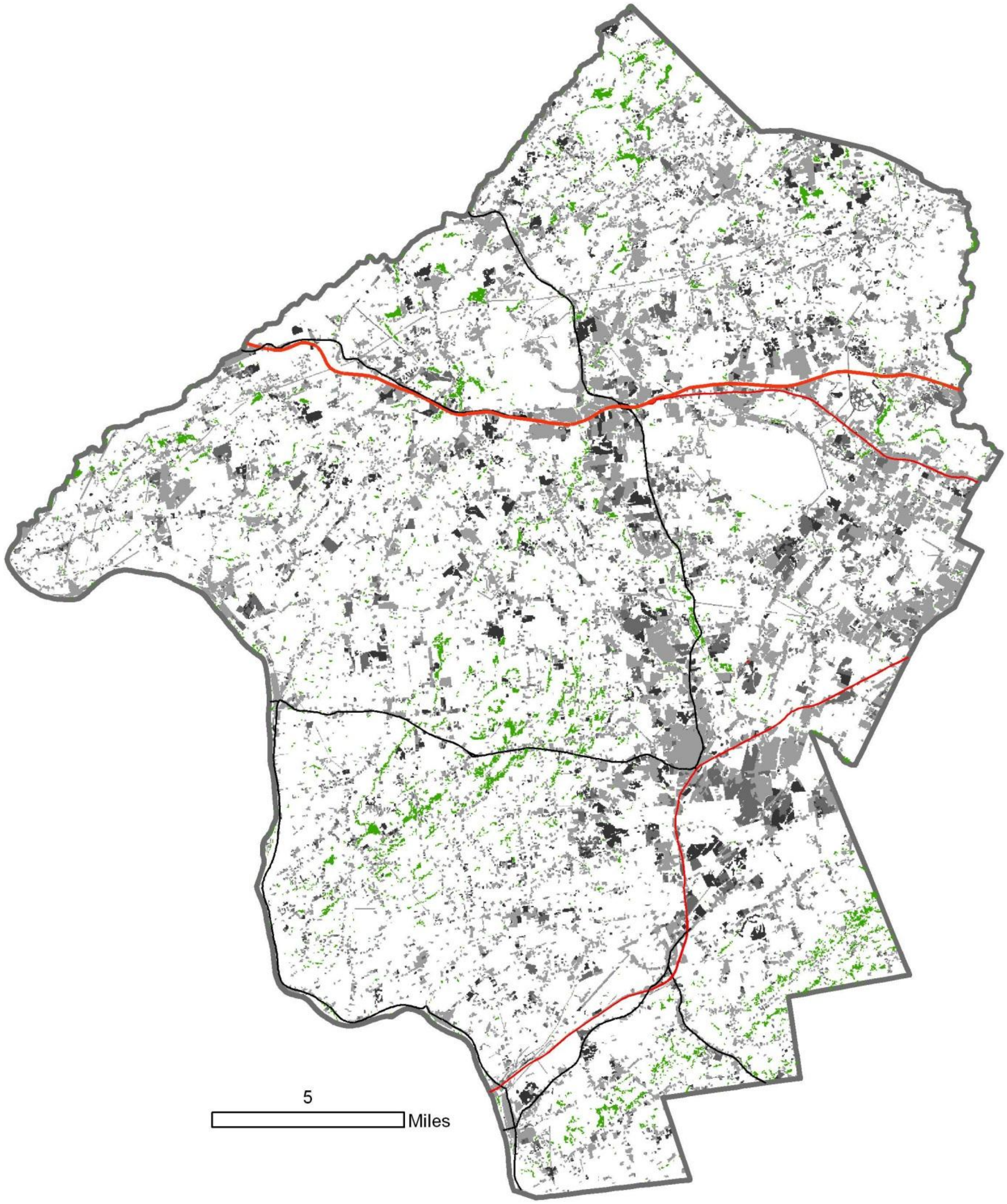


Figure 6.5.e Development near Wetland Forest Habitat – light gray areas were developed before 1985, medium gray areas between 1986 and 1995, and dark gray areas between 1995 and 2002. The green areas are critical wetland forest habitat. The thick red line is Interstate 78, the thin red lines are US Routes, and the thin black lines are state roads.

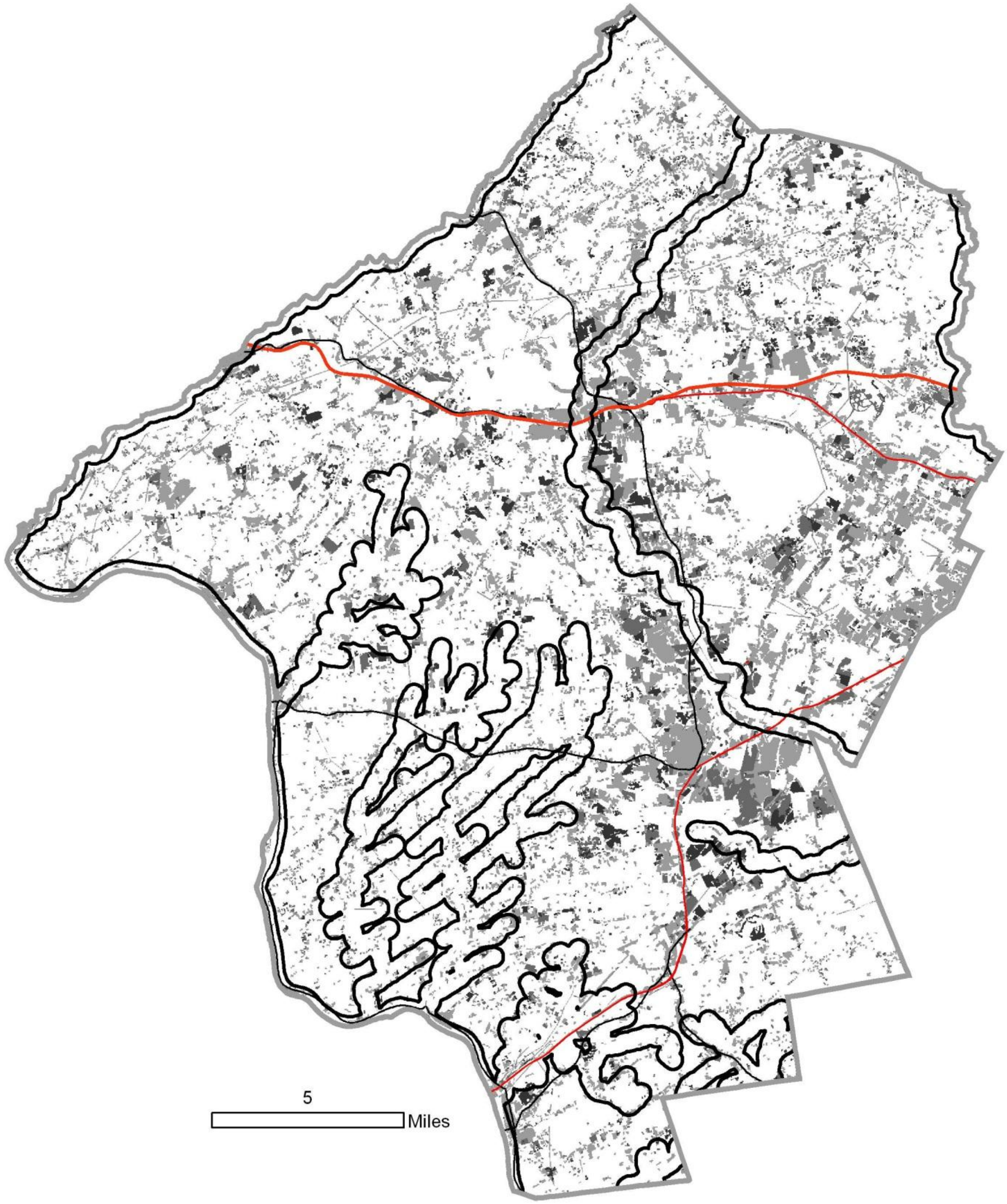


Figure 6.5.f Development within the River Corridor Target Area – light gray areas were developed before 1985, medium gray areas between 1986 and 1995, and dark gray areas between 1995 and 2002. The thick black lines are the target area boundaries. The thick red line is Interstate 78, the thin red lines are US Routes, and the thin black lines are state roads.

Figure 6.5.g Development within the Greenway Links Target Areas – light gray areas were developed before 1985, medium gray areas between 1986 and 1995, and dark gray areas between 1995 and 2002. The thick black lines are the target area boundaries. The thick red line is Interstate 78, the thin red lines are US Routes, and the thin black lines are state roads.

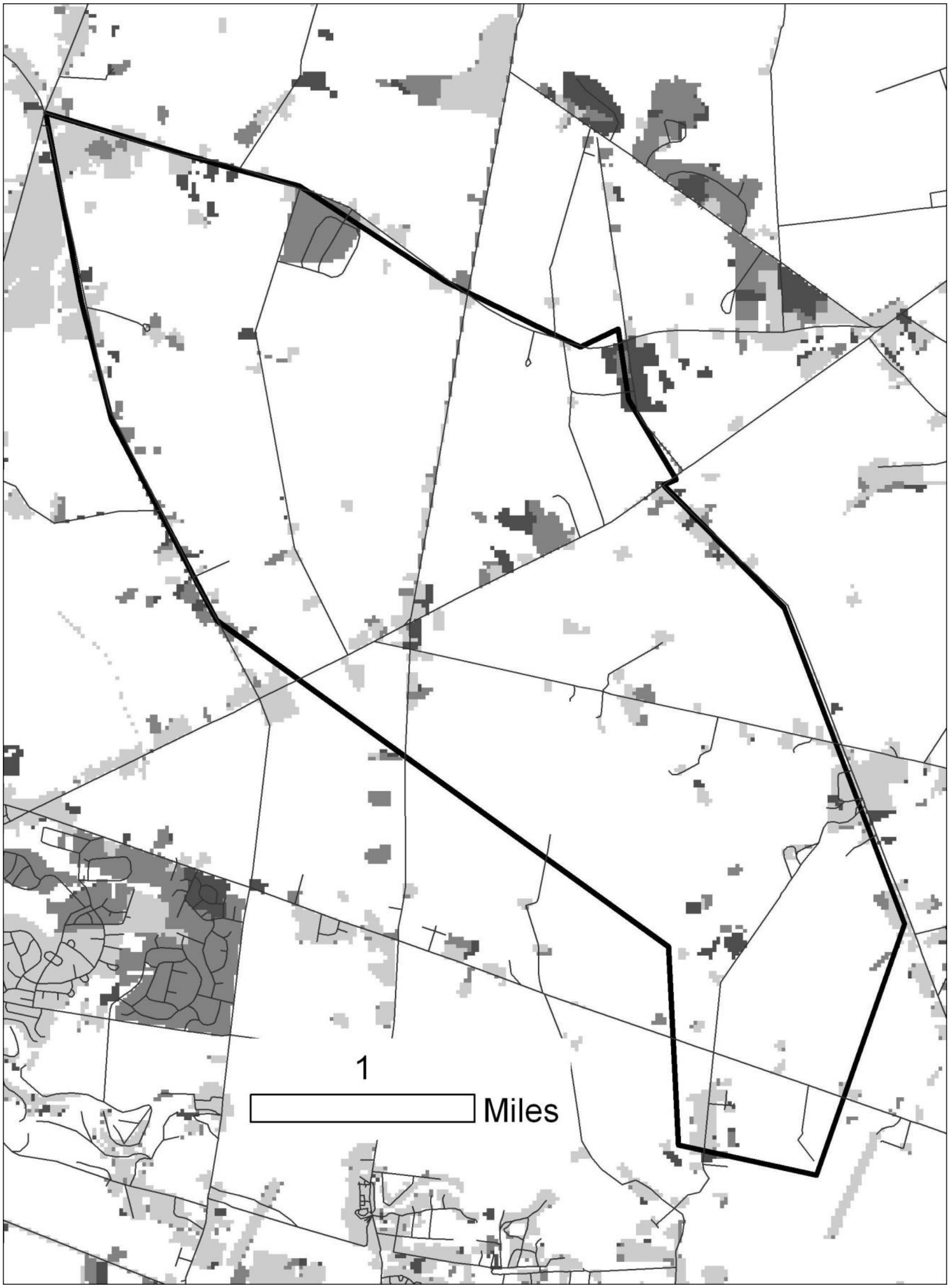


Figure 6.6.a Development in Barker's Brook – light gray areas were developed before 1985, medium gray areas between 1986 and 1995, and dark gray areas between 1995 and 2002. The thin gray lines are roads and the thick black line is the project area boundary.

Figure 6.6.b Development in Mason's Creek – light gray areas were developed before 1985, medium gray areas between 1986 and 1995, and dark gray areas between 1995 and 2002. The thin gray lines are roads and the thick black line is the project area boundary.

Figure 6.6.c Development in Rancocas Creek Greenway – light gray areas were developed before 1985, medium gray areas between 1986 and 1995, and dark gray areas between 1995 and 2002. The thin gray lines are roads and the thick black line is the project area boundary.

Figure 6.6.d Development in Delaware River Greenway – light gray areas were developed before 1985, medium gray areas between 1986 and 1995, and dark gray areas between 1995 and 2002. The thin gray lines are roads and the thick black line is the project area boundary.

Chapter 7 – Interactions between Landscape Change and Farmland Preservation

7.1 Introduction

This chapter presents the results of the analyses of preserved farmland and how farmland preservation programs and purchases interact with the landscape change. First, an analysis of preserved farmlands in Hunterdon and Burlington counties is presented, describing their land cover, how it varies by ownership and how it has changed over time. Then the impact of landscape change in areas targeted by preservation programs is examined in order to understand how recent change may be impacting land preservation programs. The analyses dealing with change in areas targeted by farmland preservation programs represent policy specific indicators as described in Chapter 3. The farmland preservation programs in Hunterdon and Burlington were established in mid-1960s. The changes measured in these analyses therefore represent post-implementation changes.

7.2 Land Use/Land Cover Characteristics of Preserved Farmland

This section describes the results of an that sought to determine the 1986, 1995 and 2002 land use/land cover of preserved farmland using the LULC products described in previous chapters. Because of difficulties in determining the acquisition dates of preserved farmland, the preserved farmland data is not separated by acquisition time period. Given the realities of funding and the histories of the farmland preservation programs, it is likely that the majority of the farmland preservation that occurred in these counties occurred after the passage of the Garden State Preservation Trust Act in 1998, meaning much of the farmland would have preserved between period framed by the 1995 and 2002 LULC products.. The results of this analysis for Hunterdon County are presented in Table 7.1.

Table 7.1 Land use/land cover of preserved farmland in Hunterdon County, (number in parentheses are proportion of each LULC class to total amount of preserved farmland).

	1986	**1995**	**2002**
Developed	357.8	352.0	377.9
	2.2%	*2.1%*	*2.3%*
Agriculture	11885.8	11719.2	11544.9
	72.2%	*71.2%*	*70.1%*
Upland Forest	2647.9	2810.6	2955.1
	16.1%	*17.1%*	*18.0%*
Barren	0.7	3.5	14.1
	0.0%	*0.0%*	*0.1%*
Forested Wetland	653.4	638.2	660.7
	4.0%	*3.9%*	*4.0%*
Emergent Wetland	844.4	847.6	815.6
	5.1%	*5.1%*	*5.0%*
Water	70.5	89.4	92.2
	0.4%	*0.5%*	*0.6%*
Total	16460.5	16460.5	16460.5

When compared to the county as whole (see Table 5.12), the proportions of LULC classes on preserved farmland in Hunterdon show expected but significant differences. Agricultural areas and emergent wetlands are overrepresented on preserved farmland, while forests are underrepresented. There is also little change occurring on the preserved farmlands, with a slight increase in development and upland forest and a slight decrease in agricultural lands. The lack of significant increase in developed areas suggests there was no large scale conversion of preserved farmland to greenhouses and other developed permitted uses, which has been a concern amongst land preservation activists.

It is also clear from comparing Table 6.1 to Table 7.1 that there is a distinct difference in LULC between land preserved for open space and land preserved as farmland. Not unexpectedly, the land preserved as farmland is predominantly agricultural (70%), while upland and wetland forests combine to account for 59.2% of preserved open space. The high percentage of agricultural land on preserved farms is a result of Hunterdon County's requirement that farms must be at least 50% tillable to be eligible for its farmland preservation program.

While the predominance of agricultural areas in preserved farmland is expected and necessary given the aims of the program, the data show that that a significant amount of preserved farmland is not, in fact, given over to agricultural production. Over one-fifth (22%) of preserved farmland is either upland or wetland forest, and another 5% is emergent wetlands. This represents 20% of all preserved forests and 65% of all preserved wetlands. These significant percentages suggest that preserved farmland may an important target for management efforts aimed at preserving species that require these habitats.

The data for Burlington County is presented in Table 7.2. Unsurprisingly, preserved farmland does still favor agricultural areas in Burlington as well as Hunterdon. Emergent wetland is also well represented on preserved farmland in Burlington, which contains one-third of all preserved emergent wetlands in Burlington. As in Hunterdon, there is small decrease in agricultural lands and small increase in upland forests. There is also a larger increase in developed areas than apparent in Hunterdon. Given the aggregate nature of the preserved farmland data, it cannot be said if this represents pre or post preservation changes on the farms. It does suggest some monitoring of preserved farmlands should occur after preservation, however.

Table 7.2 Land use/land cover of preserved farmland in Burlington County, acres and percent total

	1986	**1995**	**2002**
Developed	252.3	304.4	343.6
	1.4%	*1.6%*	*1.8%*
Agriculture	10972.4	10947.6	10853.0
	58.8%	*58.6%*	*58.1%*
Upland Forest	1405.0	1406.5	1447.6
	7.5%	*7.5%*	*7.8%*
Barren	80.7	77.0	17.5
	0.4%	*0.4%*	*0.1%*
Forested Wetland	2339.4	2351.7	2514.2
	12.5%	*12.6%*	*13.5%*
Emergent Wetland	3507.2	3439.9	3351.2
	18.8%	*18.4%*	*18.0%*
Water	111.4	141.3	141.3
	0.6%	*0.8%*	*0.8%*
Total	18668.5	18668.5	18668.5

7.3 Interactions between Landscape Change and Farmland Preservation

Because farmland preservation programs explicitly define areas that will be targeted for acquisition, it is possible to determine the rate and nature of landscape change in these target areas. This section presents the results of several analyses that examine the landscape change occurring in these target areas in a variety of ways. These analyses allow for a detailed examination between one aspect of land preservation program implementation, the establishment of target areas, and landscape change. The results can show whether some target areas are more threatened with development than others, and can be used to assess whether target areas goals should be reprioritized.

These analyses also represent policy specific indicators of change, since they focus on change directly related to the implementation of the policy.

7.3.1 Quantifying Development in Farmland Preservation Target Areas

Target areas for the farmland preservation programs were developed for both counties. In Hunterdon, these were the agricultural development areas as defined by the County Agricultural Development Board, parcels eligible for farmland preservation, and areas of soils of statewide importance and prime soils (as defined by the USDA). Hunterdon parcels that are eligible for farmland preservation are those in agricultural development areas, 40 acres or larger and at least 50% cultivatable (as determined by the 2002 land use/land cover. Burlington has similar criteria for eligibility, but the agricultural development areas were not available, so any parcels meeting the size and tillability criteria were considered eligible. In addition to the prime soils and soils of statewide importance, the Burlington County Agricultural Development Board also gives weight to soils of local importance (also defined by the USDA). These farmland preservation target areas were then assessed for development between 1986 and 2002.

The results for the farmland preservation target areas in Hunterdon County are presented in Table 7.3. Two of the farmland preservation criteria examined, the agricultural development areas and the eligible parcels, were considerably less developed over all time periods than the county as a whole. Soils of statewide importance were as developed as the county as a whole, while prime soils were more developed than the county as a whole.

Table 7.3 Development in Farmland Preservation Target Areas in Hunterdon County

	Percent Developed before 1986	Percent Developed in 1995	Percent Developed in 2002	Increase in Development, 1986 to 1995	Increase in Development, 1995 to 2002
Agricultural Development Areas	10.8%	14.4%	17.1%	33.9%	18.9%
All Eligible Parcels	2.2%	2.6%	4.0%	18.8%	51.2%
Statewide Important Soils	15.7%	21.1%	24.3%	34.2%	15.1%
Prime Soils	21.3%	27.7%	31.8%	30.0%	14.8%

An examination of the proportional rates of development from 1986 to 1995 and 1995 to 2002 show a more complex pattern. The parcels eligible for farmland preservation developed faster than the county as a whole between 1995 and 2002, at a very much higher rate than the county. This may be particularly problematic since that previous research has shown (Myers 2004) that the total area of parcels eligible for farmland preservation is already slightly less than the 50,000 acres that Hunterdon wishes to preserve as farmland by 2020.

The results of the analysis of development in target areas for farmland preservation in Burlington County are presented in Table 7.4. Areas of prime soil and soils of statewide importance were more developed than the county as a whole during all three time periods, while areas of locally important soils and parcels eligible for preservation were less developed than the county as whole.

Table 7.4 Development in Farmland Preservation Target Areas in Burlington County

	Percent Developed before 1986	Percent Developed in 1995	Percent Developed in 2002	Increase in Development, 1986 to 1995	Increase in Development, 1995 to 2002
All Eligible Parcels	2.7%	3.4%	4.1%	29.3%	19.6%
Locally Important Soils	7.8%	10.6%	12.3%	35.1%	16.7%
Statewide Important Soils	18.7%	23.8%	24.2%	27.4%	1.3%
Prime Soils	19.7%	26.5%	30.8%	34.2%	16.4%

The results concerning the proportional changes in development in Burlington's target area show that all of the farmland preservation target areas developed faster than the county as whole between 1986 and 1995, and all but the areas containing soils of statewide importance did so between 1995 and 2002.

7.3.2 Loss of Agricultural Land in Farmland Preservation Target Areas

As noted previously, losses of agricultural land may occur to land uses other than development. This loss can have effects almost as significant as development on the capacity of agriculture to remain a viable industry. Table 7.5 shows the proportion of agricultural land lost in the farmland preservation target areas of Hunterdon and Burlington Counties compared to that lost in the county as a whole. In Hunterdon, the only county for which Agricultural Development Areas (ADAs) were available, shows that ADAs lost agricultural land faster than the county as whole. This is tempered by the fact that parcels actually eligible for farmland preservation are losing agricultural land more slowly than the county as a whole. The farms eligible for preservation in

Burlington County also lost a lower percentage of agricultural land than the counties as whole. These results show that agricultural lands on farms eligible for preservation are more stable than those agricultural lands in areas not chosen as target areas.

Table 7.5 Loss of Agricultural Land in Farmland Preservation Target Areas

a. Hunterdon County

	Percent of Agricultural lands lost between 1986 and 1995	**Percent of Agricultural lands lost between 1995 and 2002**
Agricultural Development Areas	12.1%	9.5%
Eligible Farms	3.5%	5.6%
County as a Whole	***12.0%***	***7.9%***

b. Burlington County

	Percent of Agricultural lands lost between 1986 and 1995	**Percent of Agricultural lands lost between 1995 and 2002**
Eligible Farms	1.6%	1.5%
County as a Whole	***11.0%***	***8.9%***

7.4 Conclusions

The landscape changes on preserved farms and on farmland preservation target areas examined in this chapter provide insight into the impact of ongoing landscape change on farmland preservation in Hunterdon and Burlington. The lack of significant development on preserved farms in both counties suggests that the conversion of preserved farmland into greenhouse operations is not widespread despite some concerns about its possibility. The data also show that there may be land of significant ecological value on preserved farmlands. This suggests that farmland preservation planners and implementers would do well to consider addressing the management of these lands during the preservation planning and implementation process. The rapid development of ADAs in Hunterdon and of eligible farms in both counties highlights the need to engage in post-implementation analyses and subsequent policy amendment. The discussion of these results and their synthesis with rest of this study continues in Chapter 8.

Chapter 8 – Discussion and Synthesis

8.1 Introduction

This chapter discusses in depth the results presented in the previous two chapters. This discussion focuses on how the landscape changes described by these results impact and interact with the county-run land preservation programs in the study areas. Several types of impacts or interactions are given special consideration. These include how an assessment of landscape change prior to the design and implementation of land preservation programs might alter the target areas and goals of the land preservation programs under consideration. Another important interaction addressed is whether landscape change might be making it difficult for the county land preservation programs studied to meet their goals. The chapter also synthesizes these results with previous research regarding landscape change and land preservation. The chapter concludes with a set of recommendations for land preservationists on how to deal with landscape change at the time of preservation policy design and implementation.

8.2 Landscape Change in Hunterdon and Burlington Counties

The results presented in the preceding chapter demonstrate that both Hunterdon and Burlington County have been experiencing significant and complex changes in their land use/land cover over the 1986 to 2002 study period. The rate, direction and consequences of these changes differ by county and by time period, however. This section presents a synopsis of these changes, compares and contrasts the two counties, and explores the implications of these changes on the county run land preservation programs in each county.

8.2.1 Visual Assessment of Landscape Change

The gross trends observable through visual analysis of cartographic products depicting land use/land cover change are an obvious place to start a discussion of such change. The changes evident from comparing the different LULC of different times in Figures 5.1 and 5.2 should be the first step in analyzing landscape change and assessing its interactions with land preservation policies. It requires only a basic knowledge of GIS, and the analysis of such cartographic products can benefit from the local knowledge possessed by those involved with land preservation activities in the area under consideration.

Figures 5.1a-c show that development spread throughout Hunterdon County by 1986. Between 1986 and 1995 and between 1995 and 2002, there was a significant infilling of previously undeveloped areas near developed areas. This is particularly notable in the area around US Routes 202 and 22 in the eastern portion of the county as well as around the Interstate 78 and State Route 31 interchange, but can be detected around most centers of development that existed prior to 1986. There also appears to be an advancement of development down the Interstate 78 corridor.

From this visual analysis it is apparent that goals related to establishing contiguous tracts of farmland, parkland and wildlife habitat are under considerable threat by the type of LULCC occurring in Hunterdon County. With development occurring along most roads in the county, it appears that acquiring contiguous agricultural lands or park property that is uninterrupted by development will be difficult. Some of this visually evident development may represent development related to agricultural activities, which poses little problem for farmland preservation programs. Given the development trends in the county, however, the majority of the development is residential or commercial in nature. The widespread nature of development in the county also means that few places are far from developed areas, and that human related disturbances to agricultural activities and wildlife habitat are going to be widely dispersed throughout remaining agricultural lands and habitat patches.

It is also clear that the largest contiguous tracts of development in Hunterdon are appearing relatively close to existing development and converting the remaining undeveloped land in these areas to development. This has several implications for land preservation programs. Although large tracts suitable for development and near existing development appear to be the most vulnerable to development, they tend not to be targeted for preservation because the proximity of large amounts of development. In general, both the farmland preservation and the open space preservation program in Hunterdon actively discriminate against properties adjacent to large amounts of development. This generality does not hold in one specific instance, however. One of the goals of the open space plan is to provide a small amount of active recreational areas for county residents. If the county wants these areas to be adjacent to where people live, the types of large tracts most vulnerable to development may be precisely the type the county wishes to preserve to meet its active recreational area needs.

In contrast to the countywide development seen in Hunterdon, a visual inspection of LULCC in Burlington County shows quite a different pattern (Figures 5.2a-c). The portions of the county along the Delaware River and the southwester county border evidence a considerable amount of concentrated development that predates 1986. The only large clusters of pre-1986 development in Hunterdon County, on the other hand, are centered around a few well-established towns such as Flemington, Clinton and Lambertville. After 1986 there is considerable infilling along the southwestern border in Burlington, and development spreads inland from the existing development along the Delaware River. There is also some leapfrog development occurring in the northern agricultural portion of the county after 1986. The southeastern third of the county, which is subject to the Pinelands Comprehensive Management Plan, shows limited development that is restricted to the growth centers outlined by the plan (New Jersey Pinelands Commission 2012).

The spread of development into the northern agricultural region of Burlington County poses the same difficulties in Burlington as it does in Hunterdon. It makes it difficult for the county farmland preservation program to preserve large contiguous tracts of farmland that are uninterrupted by development. Visual interpretation also suggests that farmland closer to the Delaware River and closer to the southern border of county are at greater risk than farmland located towards the eastern edge of the main agricultural area. If the county farmland preservation program is interested in preserving farms in these higher risk areas, it may wish to prioritize eligible farms in these locations or actively solicit farmer participation in these areas.

8.2.2 Gross Change and Rates of Change

The percentage changes and annual rates of change for the LULC categories in Table 5.3 provide further insight into the nature of the alterations taking place in Hunterdon and Burlington. Over the entire study period, the greatest percentage increases in both counties occur in developed areas, and the greatest losses occur in agriculture. These categories also have the greatest acres increased and lost in both counties. As previously noted, Hunterdon County evidenced a slight gain in upland forest over the entire study period, while Burlington showed a slight decrease. There were also substantial reductions in the amount of emergent wetlands in both counties, which will be discussed below. Barren areas also showed large changes, increasing in Hunterdon while decreasing in Burlington. Analyzing the data over the entire study period again suggests that agricultural land is more threatened than forested land.

When the rates of change are examined over the individual time periods that comprise the study period, a more complicated picture of landscape change emerges. In both Hunterdon and Burlington, the annual rate of development dropped between the 1986-1995 and 1995-2002 time periods. This may in part be the result of the increase in land preservation activity during this time period. Some of the land preserved during this time period would have been sold to developers if the land preservation programs were not available. Therefore, there is direct competition for land between developers and preservationists, at least for properties owned by those who are willing to either sell their property to developers or to sell their property or its development rights to a preservation agency or organization.

In Hunterdon this slight decrease in the rate of development is accompanied by a slight decrease in the rate of loss of agricultural lands between the two time periods. Burlington, on the other hand saw a slight increase in the rate of loss of agricultural lands. This is the result of the fact that Burlington has more developed land than agricultural land, so that a gain of 9000 acres of development is a smaller percentage change than a loss of 9000 acres of agricultural land. Of course, not all of the development comes from agricultural land, and not all of the loss of agricultural land is to development. This will be discussed further in the next section.

The afforestation in upland forests in Hunterdon evident in the combined data occurred only in the 1986-1995 period. From 1995-2002, there was no net change in Hunterdon's area of upland forest. In contrast, the slight deforestation in upland forests in Burlington remains constant during both time periods. A full assessment of the impact of these changes requires the use of transition data and will be discussed in the next section.

Barren areas evidence a low rate of change in Hunterdon and a moderate rate of change in Burlington over the entire study period, but the data from the individual time periods show that barren areas are extraordinarily dynamic. Both counties experienced a large decline in barren areas between 1986 and 1995 and a large increase between 1995 and 2002. The volatility is not surprising, given that these barren areas are primarily areas being cleared for development. The rapidity of the process of clearing and development relative to the time elapsed between LULC data layers makes it difficult to draw conclusions about the trends in barren lands and what they mean for subsequent development and land preservation. It does, however, indicate that areas which are barren should not be expected to remain so in the future.

8.2.3 Land Use/Land Cover Transitions and Trajectories

A fuller understanding of the impact of LULCC on land preservation activities in the study areas can be gained by examining the information found in the trajectory tables (Tables 5.10 and 5.11) and the gain/loss tables (Tables 5.12, 5.13, 5.15, 5.16). The trajectory and gain/loss information provides information on not just the net change that is occurring in the landscape but also the type of changes that are occurring. The trajectory information shows what the common sequences of change (or stability) are in the landscape, and the gain/loss information provides information about whether these transformations are occurring at random. These change pathways or trajectories have significant implications for land preservation, since they determine whether changes will increase or decrease the preservation value of a particular parcel of land for a particular preservation program. These are the trajectories and transitions that will be focused on.

The trajectories and transitions with the most direct impacts on preservation programs are those that convert agricultural and natural lands to developed uses, rendering them unfit for preservation for either farmland or open space. As Tables 5.10 and 5.11 make clear, these trajectories are the most dominant pathways of change in both Hunterdon and Burlington during the study period. Over the entire period, almost 11700 acres of agricultural land were converted to development in Hunterdon and 11500 acres of agricultural land were converted to development in Burlington.   In both counties, the next most important pathway to development was through the conversion of upland forest. In Hunterdon approximately 6500 acres of upland forest were converted to development, while approximately 8300 acres of upland forest were developed in Burlington. These findings provide justification for the focus of land preservation efforts on farmland and upland forests.

The dominance of these conversion pathways suggest concerns beyond the mere amount of farmland and forest being converted to development. Farmland preservation programs in both counties and the open space preservation plan in Hunterdon County seek to build concentrations of adjacent or proximal preserved lands. The focused conversion of these LULC types threatens to undermine the potential for these programs to build these concentrations. Development in forested areas decrease the connectivity of forest patches and increases the adverse impact of edge effects, making them less functional ecologically (Albert 2005) and diminishing there preservation value as well. Agricultural areas are also deleteriously impacted by encroaching development. Development near and adjacent to farms increase the potential for negative interactions between residents and farmers related to residents displeasure at common agricultural activities such as pesticide spraying. Furthermore, replacing agricultural land with developed uses reduces the concentration of farmers in a given area. This then reduces the market for agricultural services such as seed selling and tractor repair that farmers need convenient access to. If the market shrinks to the point where it can no longer support these services, remaining farmers will find it much more difficult to acquire the goods and services they need to keep their operations running.

One of the most interesting findings present in the trajectory data is the importance of the agricultural land to forest change trajectory, especially in Hunterdon.

In that county, more than 8700 acres of agriculture changed to upland forest over the course of the study period, 75% of the amount of agricultural lands converted to development and 45% of the net loss of agricultural lands. In Burlington, this particular change trajectory is considerably less notable, with slightly less than 2000 acres of agricultural land being converted into forest, which is 16% of the amount of agricultural lands converted to development and 14% of the net loss of agricultural lands.

While having more land in forest may be beneficial for landscape management goals related to wildlife habitat and ecological functioning, this conversion represents a significant issue for farmland preservation programs. If a farm property loses enough farmland forest that it is no longer considered to have 50% of its area tillable, then it is no longer eligible for preservation in either Hunterdon or Burlington. This particular transition of farmland to forest may then be almost as effective at removing properties from the universe of properties eligible for preservation as the conversion of farmland to development. One factor mitigating its impact is this conversion pathway does not have the deleterious effects on agricultural activities on adjacent farms that development can bring, as discussed above.

The agriculture to upland forest change trajectory also relates to one of the long-held but undocumented beliefs about New Jersey landscapes. Many observers of landscape change in New Jersey have casually postulated a change trajectory from farmland to scrub/shrub or forest to development. The process behind this trajectory of change is the delay between purchase of farmland by speculators or developers and the subsequent development of the property. This delay could come about for any number of conceivable reasons. It might take time for speculators to find developers willing to buy the property, developers may have trouble securing necessary funding before building, or the permitting process may take longer than expected. In any event, it is often thought that some portion of farmland reverts to forest after it is sold to developing interests but before it is developed. If this were so, there should be a notable agriculture – upland forest – developed trajectory.

In Hunterdon, the 705.5 acres that changed from agriculture to upland forest to developed over the course of the study represents 6% of the agricultural land converted to developed uses. At first glance, this does not seem like a significant percentage and appears to argue against the hypothesis that there is a considerable amount of agricultural land that converts to scrub-shrub or forest before being developed. This may not be surprising, since developers and speculators have a significant financial incentive to keep lands in agricultural production until development activities are ready to commence. Active farmland qualifies for significant property tax reductions in New Jersey, and the power of this incentive is only increased by the fact that property tax rates in New Jersey are among the highest in the nation.

There are several factors that argue against drawing firm conclusions about this hypothesis from this particular analysis, however. It takes several years for an abandoned agricultural field to become sufficiently colonized by successional plant species to be classified as scrub-shrub or old field in photointerpreted LULC products. Thus, any agricultural lands that were abandoned only a few years before the acquisition of aerial photography or satellite imagery used to develop a LULC product will likely be classified as agriculture. Conversely, agricultural lands abandoned just after one period of data acquisition may go through a period of succession or afforestation and subsequent clearing or development before the next period of data acquisition, and therefore fall into the agriculture-developed-developed trajectory. Likewise, agricultural areas abandoned a few years prior to the first data acquisition period are likely to be classified as scrub-shrub or old field, in which case they would become part of the upland forest-developed-developed or upland forest-upland forest-developed trajectory. Finally, given that only three time periods of data were available for this study, it was only possible to capture one sequence of abandonment, revegetation and development. It seems likely, therefore, that this analysis underdetects this trajectory of abandonment, revegetation and development. Future research seeking to clarify this issue should use a data source that is affordable, since frequent, perhaps yearly, LULC products are required to adequately address the concerns noted above.

8.2.4 Land Use/Land Cover Gains and Losses

Tables 5.12 and 5.13 analyze the LULCC between 1986 and 2002 in Hunterdon in a way that shows whether gains or losses in particular categories occur at rates higher or lower than would be expected if the amount of change in a given category was distributed proportionally to the other categories. This provides an indication of which transitions are favored by the processes producing LULCC and which ones are not. This particular analysis also provides information regarding persistence within a category, which can be an important factor in determining the ecological quality and the stability of a particular area.

Not surprisingly, the amount of development gained from agricultural areas and barren areas is higher than expected. The contribution of these categories to development has been noted in previous analysis. What may be surprising is that development gains from upland forest at a rate lower than expected. This lends support to the contention that agricultural areas are developed in preference to forested areas. It also reinforces the finding that agricultural areas in Hunterdon are more threatened by development than forested areas.

Upland forest and barren also gained more than expected from agricultural areas. The former is suggestive of agricultural land abandonment and subsequent revegetation. The later represents the significance of transitional land uses in the barren LULC. As agricultural areas are prepared for development, they are usually cleared of vegetation down the soil. This will be classified as barren in the classification system used. Upland forest also gained considerably more than expected from barren areas. Although the proportions and areas in question are small, this suggests that the 16 years that elapsed between 1986 and 2002 is a long enough period of time to capture the revegetation and maturation of vegetation on barren areas that were not subsequently developed. The higher than expected gain of agricultural lands from development again suggests that some areas considered developed in the first classification were converted to or were recognizable as agriculture in the higher resolution 2002 product. Again, horse pastures can account for a significant amount of this capture of developed lands by agriculture, either through conversion of areas surrounding a home to pasture or the ability to correctly classify such pastures as agriculture given the higher resolution of the 2002 product.

In terms of losses (Table 5.13), development lost less than expected to agriculture but more than expected to the upland forest and barren categories. The larger than expected loss to upland forest is most likely a consequence of maturing vegetation in areas with older dispersed development. The larger than expected loss to barren may indicate the presence of redevelopment activities, where older development is cleared to make way for newer developed uses.

Agricultural lands lost more to the developed and the barren categories than expected while losing less than expected to upland forest. These results reinforce the importance of agricultural areas to the development process. Upland forest areas also lost more than expected to developed and barren uses. When the magnitude of change is taken into consideration, a clearer picture of the development process in Hunterdon comes into view. Agricultural lands are clearly favored for conversion to development, while forested lands are secondary in importance throughout the county as a whole. This most likely varies on a municipal basis, since the proportion of farmland to forest varies across municipalities and suggests an interesting avenue for future studies.

The gain and loss information as summarized in Table 5.14 provides information on how much total gain, loss and swap occurred for each LULC category in Hunterdon County between 1986 and 2002, expressed as percentage of the study area. In that table, Total Change is determined by summing the gain and loss. The absolute value of the net change is determined by subtracting the percentage of the study area occupied by a category in 1986 from the percentage occupied by that category in 2002. The amount of swap is determined by subtracting the absolute value of the net change in a category from the total amount of change that category, representing the amount of the change occurring in a category not represented in net change measures.

The results from Hunterdon County clearly show the utility of this type of analysis for ecological and environmental planning efforts. The data in Table 5.13 clearly show that upland forests are experiencing a significant amount of change that does not appear in the net change statistics. Because of their ecological, hydrological and recreational value, upland forests form one of the most targeted LULC categories for open space preservation. The value of a forest is correlated to its age, however. If planners only focus only on net change of the forest they would potentially compromise their plans in two ways. First, since the net change in forest is small, they may erroneously conclude that upland forests are stable and unthreatened relative to classes that show more net change. Secondly, by not realizing that older forest is being swapped for younger of presumably lower quality, they may miss an opportunity to adequately protect the older more valuable forests.

Table 5.14 also suggests that the net change figures underestimate the increase in developed areas. In the case of developed areas, their loss is best explained as an artifact of vegetation maturation masking developed areas. It is unlikely that a significant area of developed use was converted to other uses, except perhaps for the amount of areas previously classified as developed being classified as agriculture because it was converted to or detectable as horse pasture. By comparing the data in Table 5.13 to that in Table 5.14, it appears that only 1/3 of the loss of development could be explained by conversion to or appropriate classification as agriculture. This leaves an additional 1% of the landscape that is likely remained developed but is not included in the developed category in 2002.

As Table 5.15 shows, developed areas in Burlington gained more than expected from agricultural areas and barren areas, much as they did in Hunterdon. Another similarity between the counties is that upland forest is underrepresented in its contribution to developed areas. In Hunterdon this was suggestive of the fact that agricultural areas may be less costly and more profitable to develop than forested areas. While this would also be the case in Burlington County, the situation there is compounded by the fact that a significant percentage of the forests are found in preserved lands and cannot be developed.

Agricultural areas in Burlington saw larger than expected gain from developed uses and barren uses. Again, the apparent gain from developed areas may be the result of the conversion of areas surrounding homes into horse pastures. The gain from barren, although very small, may indicate that the initial LULC data set captured several farms engaged in activities that resulted in barren areas which later were returned to agricultural use. Upland forest in Burlington showed greater than expected gains from developed, agricultural and barren areas, again matching the pattern seen in Hunterdon County.

The pattern of losses in Burlington County, as displayed in Table 5.16, is largely similar to that in Hunterdon County. The losses from developed to barren, agriculture and upland forest are larger than expected. Agriculture saw larger than expected losses to development and barren uses. Upland forest and barren uses saw a larger than expected loss to developed uses. The results suggest that the processes controlling gross LULCC operate similarly in both counties.

8.2.5 Landscape Metric Assessment

The metrics suggested by Letao and Ahern (2002) were applied to the LULC data for Hunterdon and Burlington and those results were reported in Tables 5.20 and 5.21. The purpose of using these metrics was twofold. First, it was thought that the metrics would provide useful information on landscape change beyond what can be generated by transition tables and gain/loss analysis. Second, they were applied to see how they might or might not inform the implementation of land preservation policies. In other words, do they provide information useful for assessing the progress of land preservation programs or for suggesting ways in which land preservation programs might better accommodate landscape change?

It is clear that they provide significant information on change beyond what it is generated by transition tables and gain/loss analysis. For instance, the landscape metrics show that development in Hunterdon seems to be infilling areas near but not adjacent previous development, while in Burlington development seems to be occurring adjacent to areas previously developed in the county. Likewise, agricultural areas in Hunterdon appear to be undergoing fragmentation and separation, rather than the wholesale conversion of large contiguous areas as in Burlington. The fact that upland forest in Hunterdon is increasing in area while fragmenting at the same time highlights the value of using landscape metrics as well as simple measures of landscape change.

But in what ways can these results be used inform land preservation policies operating in these counties? Examining the pattern of changes implied by the landscape metrics can lead to adjustment in prioritization for preservation. For instance, in Hunterdon, the tendency for development to infill areas near previous developed areas suggests that preservation worthy land located in prime infill areas should be prioritized for preservation. The fragmentation of upland forest in Hunterdon suggests that preservation efforts should focus on preserving the most valuable contiguous tracts before they become fragmented.

In the case of farmland, the fragmentation in Hunterdon undermines the capacity of the farmland preservation program to create large areas of contiguous preserved farmland. Farmland in Burlington does not appear to be as threatened by fragmentation, but areas experiencing rapid development may be losing large areas of contiguous farmland. Acknowledgement of the differences between the counties, and between different areas within the counties, allows the farmland preservation programs to tailor their activities to meet the actual conditions in areas where they are active.

Although not the primary focus of this study, it is also important to consider the articulation of land preservation programs with regulations and other activities that impact landscape change. The information gleaned about landscape change from repeated measurements of landscape metrics could be used to suggest changes in zoning, for instance. Altering zoning regulations to allow clustered development that preserves large areas of forest independent of county-based preservation is one possible response to the fragmentation of upland forests in Hunterdon. In New Jersey, where zoning is handled at the municipal level, it may be more difficult than in other states for counties to influence zoning. One alternative may be for counties to provide to financial incentives to promote clustered developments, which may be more cost effective for them than preserving land outright.

8.3 Characteristics of Preserved Lands

The first analysis of preserved lands examined the 2002 land use/land cover of preserved lands. Table 6.1 presents these results for preserved open space in and Table 7.1 presents these results for preserved farmland in Hunterdon County, showing the LULC of preserved open space by owner and of preserved farmland. It is clear that preserved open space overrepresents upland forest versus the county as a whole. Upland forests occupy approximately 50% of preserved open space while accounting for only 36% of the county as a whole. Wetland forests are also overrepresented. State and county owned preserved open space also underrepresents agricultural areas. These results suggest that open space preservation in Hunterdon County is being implemented in a way congruent with the stated goals of the programs with respect to preserving habitat for critical species and areas suitable for passive recreation. Interestingly, municipal and nonprofit owned preserved lands have a greater percentage of their area in agriculture than state and county owned preserved lands. This may be reflective of different management policies favoring the maintenance of agricultural areas on preserved land for environmental management or revenue from rents paid by farmers.

Likewise, preserved farmland in Hunterdon County significantly overrepresents agricultural land while underrepresenting both upland and wetland forests. Again, this is congruent with the goals of the farmland preservation program. It is also not a surprising result given the eligibility criteria and scoring system that the Hunterdon farmland preservation program uses to screen and rank applicant farms. What is surprising is that 65% of the emergent wetlands preserved in Hunterdon occur on preserved farms. Numerous studies have shown that agricultural activities can have direct and indirect negative impacts on wetland and water quality. If Hunterdon wishes to manage its preserved emergent wetlands to maintain the valuable ecosystem services they provide, it may be necessary for farmland preservationists to more actively encourage or induce wetland friendly agricultural practices on preserved farms. While it may not be possible, given political and economic constraints, to require this management to qualify for preservation, the preservation process does provide an opportunity for the county to meet with farmers and encourage them to consider such management.

The situation in Burlington is considerably different, especially with respect to upland forests (Tables 6.2 and 7.2). All but state owned preserved lands underrepresents upland forest land as compared to the county as a whole. For the county, this represents their conscious decision to pursue opportunities for active recreation. Preserved farmland in Burlington still favors agricultural land, as is expected. As in Hunterdon, a large percentage (40%) of preserved emergent wetlands is found on preserved wetlands. Although this is less than the 60% in Hunterdon County, the importance of preserved farmland for emergent wetland is still considerable given that preserved farmland accounts for 11% of the total preserved land in Burlington. There is also a geographic component to the importance of the emergent on wetland farms in Burlington County. The emergent wetland on preserved farmland is even more important than the percentages suggest because most of the preserved emergent wetlands in the agricultural belt in northwestern Burlington are found on preserved farms. As in Hunterdon, extra attention should be paid to these wetlands during the preservation process to encourage appropriate management.

Table 6.3 details the LULC on preserved open space in Hunterdon County in 1986, 1995 and 2002. The data are divided by the acquisition period of the preserved land, assigned as described in Chapter 6. The three periods used for this analysis are open space preserved before 1986 (Table 6.3a), open space preserved between 1986 and 1995 (Table 6.3b), and open space preserved between 1995 and 2002 (Table 6.3c).

Development increased for all lands for all three acquisition periods. The temporal pattern of this development shows that it may be related to the preservation date. For open space preserved before 1995, development increased between 1986 and 1995 but was stable between 1995 and 2002. Open space preserved between 1995 and 2002 show only a small increase in development between 1986 and 1995 but a larger increase between 1995 and 2002. The large post-preservation increase apparent in the later acquisitions periods is most likely a signal of post-preservation development of recreational facilities. If these changes in development were the result of differences in the data collection and production for each LULC, there should be consistent changes through time for all 3 acquisition periods, yet this is not observed. Development in the two earlier acquisition periods appears to stabilize between 1995 and 2002, when the latest acquisition period shows it greatest development. Future updates to the LULC and open space acquisition data will allow for further testing of this trend.

Agricultural lands show interesting and divergent trends across acquisition periods. In the earliest acquired preserved open space, there was a decrease then increase in agricultural lands to a level higher than the original amount. Open space acquired later shows a steady decrease in agricultural area across all three time periods. In the case of the later periods, this might be reflective of cessation of agricultural activities prior to preservation, followed by conscious management decisions to allow agricultural lands to decrease. The pattern of decrease than increase seen in older preserved lands may indicate a shift in management priorities that lead to an eventual increase in agricultural lands, either to provide habitat to nesting grassland birds or to increase revenues from renting land to farmers.

The LULCC data for preserved open space in Burlington County is presented in Table 6.4 a-c. Open space preserved in the first two acquisition periods show a trend toward increasing development, with some stabilization seen in the earliest acquisition period. Open space preserved in the last acquisition period shows a slight decrease in developed area. This, coupled with the lack of development between 1986 and 1995 on lands preserved between 1986 and 1995, may be an indication that more time elapses between preservation and facility construction in Burlington than in Hunterdon. Future LULC layers will show if the open space preserved in Burlington between 1995 and 2002 gains recreation facilities or if those lands are, in fact, going to remain undeveloped.

A much smaller percentage of agricultural lands are preserved as open space in Burlington County than in Hunterdon County through all three time periods. This indicates that there is a strong segregation between the open space and the farmland preservation programs there. It suggests an active discrimination against agricultural lands in the open space preservation process. This may be a result of the fact that Burlington County is looking to preserved land in specific project areas for specific recreational purposes. Nonprofit groups in Burlington, on the other hand, tend to concentrate on more on lands that have unique or valuable ecological characteristics.

These foci tend to eliminate agricultural lands from consideration as preserved open space.

8.4 Characterizing Landscape Change in Target Preservation Areas

Examining nature of landscape change in areas targeted for preservation provides insight into how landscape change is impacting the capacity of land preservation to meet their goals. Analyzing each preservation target area independently allows for exploration of the similarities and differences between preservation target areas. Differential development within different target areas may suggest the need to prioritize the target areas to adequately reflect the level of threat.

8.4.1 Visual Assessment of Gross Landscape Change In or Near Land Preservation Target Areas

The first analysis of landscape change in or near the land preservation target areas was a visual assessment based on cartographic products. These maps (figures 6.5 a-g for Hunterdon and 6.6 a-d for Burlington) show development from the three LULC data sets (1986, 1995, 2002), along with major roads and the boundaries of the target areas.

8.4.1.1 Development in and around Hunterdon County Conservation Zones

Figure 6.5a shows development in and around Hunterdon's conservation zones target area. The northern Highlands conservation zone appears to be suffering the most development, with both widespread, diffuse development throughout and smaller areas of more concentrated development. The diffuse development appears to follow linear features such as roads, which may pose a problem for establishing connections between preserved areas, since this type development is effective at separating patches of habitat. Development in the southern Sourland Mountain conservation zone is less dramatic then in the north, with no noticeable large patches of development, but it still appears to be fragmenting the zone. The Delaware Bluffs conservation zone the west is the least affected by development, most likely because its extent coincides with steep terrain that discourages building.

8.4.1.2 Development around Hunterdon County Emergent Wetland Habitat

As shown in Figure 6.5b, the emergent wetlands along the South Branch of the Raritan River, paralleling NJ Route 31 north-south through the center of the county, have experiencing significant amounts of development. This development threatens unprotected and protected wetlands alike because development proximate to wetlands to can diminish the water quality and functioning of the wetland.

8.4.1.3 Development around Hunterdon County Forested Habitat

As shown in Figure 6.5c, the forested habitat in the southern part of the county is experience scattered development. This sort of development can lead to increased fragmentation, which has well documented negative effects on the species the forest habitat goal is supposed to help protect. Forests in the northern part of the county appear to suffering more from separation caused by larger tracts of development than fragmentation caused by smaller developments.

8.4.1.4 Development around Hunterdon County Grassland Habitat

As shown in Figure 6.5d, grassland habitat in the county is suffering from fragmentation. This is problematic in the context of grassland because the species that use this habitat require a large core area. Even relatively low levels of fragmentation can substantially reduce core area.

8.4.1.5 Development around Hunterdon County Forested Wetland Habitat

As shown in Figure 6.5e, forested wetland in Hunterdon is threatened by proximate development. As with emergent wetlands, forested wetlands can suffer from development occurring nearby, even if the wetlands themselves are protected through regulations or preservation.

8.4.1.6 Development in Hunterdon County River Corridor Target Areas

As shown in Figure 6.5f, the river corridor target areas in Hunterdon at risk of becoming interrupted by development. Development in the river corridors can lead to diminishment in their effectiveness at flood water retention and pollutant filtering, the very functions that they county is trying to preserve.

8.4.1.7 Development in Hunterdon County Greenway Links Target Areas

As shown in Figure 6.5g, the greenway links target areas in Hunterdon are threatened by interruption caused by development. Significant development across the width of a greenway link diminishes the potential to develop uninterrupted greenways.

Greenway links across the county are under development pressure, but those in the north and the east appear to be under the most.

8.4.1.8 Development in Burlington County Barker's Brook Project Area

As shown in Figure 6.6a, the Barker's Brook Project Area in Burlington is experiencing development primarily in its center. If this continues, it may split the project area in half, limiting the potential for significant connections between the two halves.

8.4.1.9 Development in Burlington County Mason's Creek Project Area

As shown in Figure 6.6b, the Mason's Creek Project Area in Burlington is experiencing dispersed development around its periphery and concentrated development in its north central area. The concentration of large recent developments in the north has essentially split that part of the project area in half, limiting the potential to establish ecological and recreational links. The other development, if it continues as it has been, will likely do the same to other portions of the project area.

8.4.1.10 Development in Burlington County Rancocas Greenway Area

As shown in Figure 6.6c, the Rancocas Greenway Area in Burlington has been experiencing significant recent development in its eastern part, and has a very developed central area. Since Rancocas Creek is the focus of this greenway, any development along the creek threatens the integrity of the greenway itself.

8.4.1.11 Development in Burlington County Delaware Greenway Area

As shown in Figure 6.6d, the Delaware Greenway Area in Burlington has been heavily developed since 1986. Any development continuing to occur there will greatly diminish the capacity of the county to add to preserved lands there.

8.4.2 Quantifying Development in Land Preservation Target Areas

An analysis of the development in open space preservation target areas in Hunterdon County was presented in Table 6.6a. The results showed that a greater percentage of the grasslands and viewshed target areas were developed than the county as whole in 1986, 1995 and 2002. In 1986 the greenway links and conservation zones were almost as developed as the county as a whole, but between 1986 and 1995 these areas developed more slowly than the county as a whole. Between 1995 and 2002 the greenway links target area continued to develop more slowly than the county as whole, while the conservation zones target area developed slightly faster than the county as whole.

There are several implications of these findings for the open space preservation program in Hunterdon. Since the grasslands target area is primarily agricultural in nature, arresting the continued development of this target area may require the open space preservation program to work with the farmland preservation program to ensure the preservation and management of these habitats. The conservation zones target area may also require extra attention from the open space preservation program since it was developing faster than the county as a whole during the final time period.

Table 7.3 lists development percentages and rates for two farmland eligibility criteria areas and two agriculturally important soil types. Although agricultural development areas and eligible parcels are less developed than the county as a whole, except for the eligible parcels between 1986 and 1995 they are developing at a rate higher than the county as a whole. In order to stem this erosion of preservable farmland, the farmland preservation program may need to interact more closely with municipal planning and zoning boards in order to decrease the likelihood of the development of these areas. As noted in the previous chapter, the total acreage of eligible parcels in Hunterdon is very close to their 50,000 acre preserved farmland goal. It is possible for the county to expand or add agricultural development areas, but the continuing development of the county makes this problematic. ADAs are supposed to be areas where farming can persist as a viable industry because of soil fertility and density of farms. Continuing development reduces the potential density of farms within existing and potential ADAs. Areas with soils of prime or statewide importance are also developing as fast or faster than the county as a whole. These represents a potential for local planning agencies and the county to work together creating zoning which encourages farming and discourages development in areas with these soil types, keeping appropriate land available for preservation.

The results for the target areas for open space preservation in Burlington County are found in Table 6.7. There are both differences between the two project areas and the two greenways and between the individual project areas. The two project areas are developing more rapidly than the county as a whole, in contrast to the two greenways. This suggests that these project areas are more acutely threatened by future development and represent good choices for project areas. The greenways are more developed than the county as whole in all three time periods. Both project areas are less developed than county as whole in 1986. The Barker's Brook Project Area remains this way through 2002, but the Mason's Creek Project Area has been developing so rapidly that in 1995 and 2002 it was actually more developed than the county as a whole. This rapid development suggests that the Mason's Creek Project Area should be prioritized, and key properties identified and preserved before they are developed. Key properties and pathway opportunities should be identified in the greenways areas as well, since they offer fewer preservation options because of their high percentage of development. Any proposed development in the greenways should be evaluated for potential contributions to pathways for the greenway.

Table 7.4 presents results showing development in farmland preservation eligible parcels and agricultural important soils in Burlington County. Eligible parcels and soils of local importance are less developed than the county as a whole, while prime soils and soils of statewide importance are more developed than the county as a whole. All have been developing faster than the county as a whole with the exception of statewide important soils between 1995 and 2002. The rapid development of eligible farmland parcels indicates that Burlington's farmland preservation program is focusing its efforts on threatened farmland. The proportion of prime soil areas that have already been developed suggest that these areas are preferred for development, and the rapid development of these areas suggest that the farmland preservation program should consider engaging with municipalities to protect these soils through zoning and other local land use regulations.

8.4.3 Loss of Agricultural Land in Farmland Preservation Target Areas

Table 7.5 shows the loss of agricultural lands targeted for preservation in Hunterdon and Burlington counties. In contrast to previous analyses, this analysis is not limited to conversion of farmland to developed uses and shows the loss of agricultural lands to all other uses. Agricultural lands in agricultural development areas in Hunterdon (Table 7.5a) are being lost at rates greater than those agricultural lands countywide. Eligible farms, which must be located in agricultural areas but also meet criteria for tillable percentages and minimum size, are being lost at rates less than the county a whole. This suggests that the criteria used by the Hunterdon Farmland preservation program restrict the eligibility for their programs to farms that are more likely to remain as farms. The higher rate of loss of agricultural lands within the agricultural development areas may undermine the potential for these areas to have the amount of agricultural activity to support the businesses, such as tractor sales and service and seed companies, which the farmers rely.

Another potentially problematic point raised by this analysis is the increased rate of loss of agricultural lands on eligible farms between the two time periods. This increase is primarily the result of the increased development of eligible farms (Table 7.4). The loss of eligible farmland, the amount of which in 2002 was roughly equal to the 50,000 acres of farmland that Hunterdon would like to preserve by 2020, means that Hunterdon will need to relax its eligibility criteria and/or create new or extend old agricultural development areas in order to have a sufficient amount of farmland eligible for preservation. Doing so does not assure that 50,000 acres of eligible farmland will be preserved by 2020, and given the apparent increase in development rate of eligible farmland, this goal may not be possible to meet no matter how relaxed the criteria become. In this context, the higher rate of agricultural land lost in agricultural development areas than the county as whole can be interpreted as reducing the amount of farmland potentially eligible for preservation if eligibility criteria are relaxed.

The results for Burlington County are presented in Table 7.5b. The agricultural development areas were not available for Burlington, so the eligible farms are those that meet the size and tillable percentage criterion alone. Burlington seems to be in a better position than Hunterdon with respect to agricultural land loss in target areas, with the loss of agricultural lands on eligible farms being much lower than the county wide rate of loss. There was, however, an increase in the yearly rate of loss between the two periods studied, suggesting that similar processes might be occurring in Burlington as in Hunterdon. Overall, though, the rate of change is much slower than the county as a whole, which suggests that Burlington is not in danger of having agricultural land loss interfere with its capacity to preserve farmland in aggregate. In both Hunterdon and Burlington there will, no doubt, be losses of particular farms that were worthy of preservation for agricultural, historic and environmental reasons. If residents of these counties wish to see particular properties preserved, it will be necessary for them to work with government agencies, non-profits and land owners to ensure preservation of these properties.

8.4.4 Development Near Habitat Target Areas

The final analysis undertaken to investigate the interactions between land preservation and landscape change looked at the potential for negative impacts caused by development within 100 m of habitat target areas in Hunterdon County (Table 6.8), as compared to data for the county as whole. Given the regulations that limit development within certain distances of wetlands, it is not surprising that they are surrounded by lands with a relatively low proportion of development. It is somewhat surprising that the lands surrounding upland forest and grassland habitat areas are considerably more developed than the county as whole. As mentioned previously, this may indicate that these habitat areas are more impacted then previously assumed, and potentially more threatened than their rate of development would suggest, to the extent that surrounding development leads to a loss of quality regardless of its impact on quantity of habitat.

The comparably high rates of development in the areas surrounding wetlands pose an interesting dilemma for land preservation programs. It is clear that development in areas adjacent to wetlands can impact the quality and functioning of those wetlands (Harper et al. 2008). The State of New Jersey has imposed restrictions on development near wetlands in order to prevent development in these sensitive peri-wetland areas (NJDEP 2009). The state imposes a no-development buffer of 0 to 150 feet around a regulatory wetland (which can only be determined by site inspection). The width of the buffer depends on whether the wetland contains critical habitat for species of concern or legally threatened or endangered species. The high rate of development in the area within 100m (326 feet) of wetlands suggests that these wetlands may not be as protected from impacts as assumed. This result suggests that developers may be striving to maximize development to the boundary of the buffers. If the 0 to 150 foot buffers are as inadequate as some studies suggest (e.g. Baldwin et al. 2006), then these wetlands with regulatory protection are not as protected from impact as the regulatory status would suggest. Land preservation programs should take this into consideration when prioritizing areas for preservation, and not exclude wetlands and their buffers from consideration simply because they may be protected by regulation.

8.4.5 Development Near Preserved Open Space

Hunterdon and Burlington show interesting differences in the amount of development occurring near preserved open space (Tables 6.8 and 6.9). The data for Hunterdon is highly suggestive of development being attracted to the periphery of preserved open space. The desirability of properties located near preserved open space is anecdotally obvious from perusing the advertisement found in the real estate sections of local newspapers, where adjacent to preserved areas is often listed as a selling point. This anecdotal evidence has been supported by numerous studies, including Correll et al. (1978) and Geoghegan (2002). If preserved open space is indeed attracting development to its periphery, the capacity of preservation programs to meet their goals may be compromised. Many programs, including Hunterdon, specifically seek to create large continuous tract of preserved open space. Development along the periphery of current preserved open space constrains future preservation choices near that preserved land. Nearby development may also reduce the ecological value of preserved land increasing disturbance, pollution and fragmentation (Alberti 2005).

Unlike Hunterdon, in Burlington land near preserved areas is less likely to be developed than land farther away. This is likely a result of the restrictions placed on development by the regulations associated with the establishment of the Pinelands National Reserve, which covers a significant portion of the eastern part of Burlington. More recently preserved lands in the western part of the county, outside the purview of the Pinelands National Reserve, may suffer more encroachment by development in the future.

8.5 Comparing Generic versus Policy Specific Metrics of Landscape Change

The generic metrics of landscape change suggested by Leitao and Ahern (2002) captured many details about the nature of land use/land cover change in Hunterdon and Burlington counties that can be used to inform the creation and implementation of land preservation policies in those counties. They provide a broad overview of trends in landscape change and are good for inventorying the condition of the landscape. Depending on the metrics, they can also be used for comparison between areas as well. Because of these qualities, the generic metrics can be useful for setting goals for land preservation policies.

Policy specific metrics, on the other hand, provide information regarding specific goals. Because of this, they are useful for prioritizing and, if used as part of a mid-program assessment, reprioritizing goals based on the threat to goals and target areas posed by ongoing landscape change. Of course, depending on the specific goals of the policy, one or more of the generic metrics may match one or more of the goals enough to be considered policy specific.

8.6 Reassessing Land Preservation Policies in Light of New Data

In order to illustrate the utility of considering the impact of landscape change on land preservation, this section will consider the potential changes to land preservation policies suggested by the analyses of landscape change described earlier. The differing uses of the generic metrics and the policy specific metrics will be considered.

In Hunterdon County, the generic measures of landscape change suggest a landscape in which development is filling in between previously developed areas and agricultural and upland forest areas are experiencing fragmentation. These results suggests that land preservation policies in Hunterdon should concentrate on preserving existing large patches of upland forest and agricultural areas and increasing connectivity between existing and preserved areas, particularly for forest. The current open space plan in Hunterdon (Hunterdon County Board of Planning 2000) prioritizes important habitat, which includes large tracts of forest, and areas which are adjacent to or connect preserved areas. It does not, however, specifically address connectivity between habitat patches, nor does it explicitly prioritize large tracts of forest. The farmland preservation program does seek to concentrate preserved farmland, which addresses the fragmentation issue.

Both preservation programs fail to consider the particular impact of the infilling of development in developed areas. Although both programs are biased against preserving properties surrounded by development, the propensity of development to infill suggests that properties within potential infill areas should be reviewed to see if they are particularly worthy of preservation based the programs respective goals and priorities. Although it is true that the farmland preservation programs in both Hunterdon and Burlington must assess only properties whose owners apply for the program, it is possible for the programs to conduct outreach to farmers in order to encourage their application. It is also possible for the farmland preservation program to coordinate with the open space program to preserve properties of mutual interest to both programs.

8.7 Synthesis with Existing Studies

A number of studies consider land preservation in various ways. Bengston et al (2004), for instance, provides a typology of land preservation methodologies. Other research presents case studies comparing land preservation programs in different places. Alterman's (1997) study of farmland preservation compares the programs used to preserved farmland in six nations. More recently, Maruani and Amit-Cohen's (2007) review of open space preservation planning models explores how different models of open space preservation foster and constrain their use as planning tools. Most research that focuses on land preservation does so from a conceptual point of view, describing and comparing methodologies without significant reference to the impact of these plans on the landscape. Even in the broader planning literature, there is little assessment of the efficacy of planning, as Brody and Highfield (2005) point out, as discussed in Chapter 2.

A handful of existing studies address the interactions between land preservation and landscape change. Comparing and synthesizing their results with the results of this study highlights both the strengths and weaknesses of the differing approaches used. Brabec and Smith (2002) is one of the few studies focused on the impact of land preservation policies on the landscape. They examine how three different agricultural land preservation methods prevent or enhance fragmentation of farmland. In terms of the analytical model presented in Chapter 2, they focus on how the implementation of these agricultural land preservation programs might affect landscape change. Their use of measures of parcel size and contiguity as an indicator for fragmentation are an example of a policy specific indicator, since the programs in question seek to halt the fragmentation of agricultural lands. In contrast to the current study, their work focuses exclusively on a single goal of the farmland preservation programs they are studying. The study is limited to a unidirectional consideration of land preservation and landscape change.

Taking a different approach, Irwin and Bockstael (2004) look at factors affecting conversion of parcels to developed uses, including several related to open space preservation policies. To explore this issue they use a model they constructed that measures the contributions of variables to the rate of conversion (Irwin and Bockstael 2002), which steps through the data on a year-by-year basis. They find that proximity to small and medium sized open space parcels created by certain kinds of clustered development increases the likelihood of near-by parcels becoming developed. They then use the results of this model to simulate the effects of several types of clustering on future development. This work also addresses the impact of the implementation of land preservation policies on landscape change, and explicitly explores options for modifying the implementation of those policies. As such, it takes a sophisticated view of the relationship between landscape change and land preservation policies by suggesting that post-implementation change should be used to assess and, when necessary, alter policy implementation.

The research presented here differs from the work discussed above because it focuses on open space and farmland preservation policies as a whole. It explores the interaction between landscape change and land preservation in a more thorough and holistic manner than these other studies. By doing so, it expands and complements the more narrowly focused previous work, and provides a blueprint for how planning agencies and other interested parties might better accommodate the interactions between landscape change and land preservation when devising and assessing preservation policies.

8.8 Extending the Study With 2007 LULC Data

Near the completion of this work a new set of LULC data become available for the study areas, digitized from aerial photos taken in 2007. The data set was developed by the State of New Jersey and was designed to be commensurable with the existing data sets that were used in this study. Although it is beyond the scope of this current study to fully integrate the data set into the work presented here, an examination of what the new data shows about the rates of change between LULC categories and the trajectories of change was undertaken.

Tables 8.1 and 8.2 are a reprise of Tables 5.2 and 5.3, respectively, amended to include the new LULC data. The data clearly show that development is still occurring at a relatively rapid pace in both counties, even as open space and farmland preservation programs were fully implemented. Hunterdon saw no change in the average annual rate of development between 1995-2002 and 2002-2007, while Burlington actually saw an increase in the rate of development between those time periods. This indicates that while land preservation programs may be effective at preventing development of particular parcels and reducing the amount of development possible at build-out, they did not appear to have substantially decrease the development rates in the study areas. Both Hunterdon and Burlington saw a decrease in rate of agricultural lands being lost, suggesting that farmland preservation programs may be slowing the rate of loss of those lands. Both counties also saw an increase in the rate of upland forest loss, which may be a consequence of the decrease in agricultural loss.

Table 8.1 Land use/land cover, in acres, in Hunterdon (a) and Burlington (b), for 1986, 1995, 2002 and 2007

a.

LU/LC	**1986**	**1995**	**2002**	**2007**
Developed	45808	55881	62961	68714
Agricultural	101523	89376	82294	79724
Upland Forest	99679	102368	102383	99365
Barren	1409	1121	1525	986
Forested Wetland	18251	17774	18278	17944
Emergent Wetland	7336	7078	6142	5998
Water	6115	6523	6537	7052

b.

LU/LC	**1986**	**1995**	**2002**	**2007**
Developed	76468	89896	98702	107166
Agricultural	72044	64126	58430	55284
Upland Forest	194507	191128	188795	185203
Barren	5456	4187	4623	3843
Forested Wetland	117858	116383	120758	127027
Emergent Wetland	44523	44208	38848	31567
Water	13353	14280	14053	14597

Table 8.2. Percentage change in Hunterdon (a) and Burlington (b) land cover for four time periods (annual change in parenthesis).
a.

LU/LC	**1986 - 1995**		**1995 – 2002**		**2002 - 2007**		**1986 – 2007**	
Developed	22.0	(2.4)	12.7	(1.8)	9.1	(1.8)	50.0	(2.4)
Agricultural	-12.0	(-1.3)	-7.9	(-1.1)	-3.1	(-0.6)	-21.5	(-1.0)
Upland Forest	2.7	(.3)	0.0	(0.0)	-2.9	(-0.6)	-0.3	(0.0)
Barren	-20.5	(-2.3)	36.1	(5.2)	-35.3	(-7.1)	-30.0	(-1.4)
Forested Wetland	-2.6	(-0.3)	2.8	(0.4)	-1.8	(-0.4)	-1.7	(-0.1)
Emergent Wetland	-3.5	(-0.4)	-13.2	(-1.9)	-2.3	(-0.5)	-18.2	(-0.9)
Water	6.7	(0.7)	0.2	(0.0)	7.9	(1.6)	15.3	(0.7)

b.

LU/LC	**1986 - 1995**		**1995 – 2002**		**2002 - 2007**		**1986 – 2007**	
Developed	17.6	(2.0)	9.8	(1.4)	11.1	(2.2)	40.1	(1.9)
Agricultural	-11.0	(-1.2)	-8.9	(-1.3)	-4.4	(-0.9)	-23.3	(-1.1)
Upland Forest	-1.7	(-0.2)	-1.2	(-0.2)	-1.8	(-0.4)	-4.8	(-0.2)
Barren	-23.2	(-2.6)	10.4	(1.5)	-14.3	(-2.9)	-29.6	(-1.4)
Forested Wetland	-1.3	(-0.1)	3.8	(0.5)	5.3	(1.1)	7.8	(0.4)
Emergent Wetland	-0.7	(-0.1)	-12.1	(-1.7)	-16.4	(-3.3)	-29.1	(-1.4)
Water	6.9	(0.8)	-1.6	(-0.2)	4.1	(0.8)	9.3	(0.4)

The process of analyzing LULC data for gains and loss as described in Chapter 5 (as represented in Tables 5.12-13 and 5.15-16) was also undertaken utilizing the 2007 LULC data. Tables 8.3-6 show the results for the analysis over the 1986-2007 time period.

					2007					
		Developed	Agriculture	Upland Forest	Barren	Wetland Forest	Emergent Wetland	Water	1986 Total	Loss
	Developed	14.32%	0.68%	1.17%	0.04%	0.07%	0.02%	0.05%	16.35%	2.03%
		14.32%	0.54%	1.31%	0.04%	0.20%	0.08%	0.08%	16.57%	2.25%
		0.00%	0.13%	-0.14%	0.00%	-0.12%	-0.06%	-0.03%	-0.22%	-0.22%
		0.000	0.245	-0.110	0.053	-0.634	-0.731	-0.336	-0.013	-0.097
	Agriculture	5.99%	26.39%	3.36%	0.13%	0.17%	0.19%	0.05%	36.27%	9.88%
		4.45%	26.39%	2.91%	0.09%	0.43%	0.19%	0.17%	34.64%	8.24%
		1.54%	0.00%	0.45%	0.03%	-0.27%	0.00%	-0.12%	1.64%	1.64%
		0.35	0.00	0.15	0.34	-0.61	-0.01	-0.69	0.05	0.20
	Upland Forest	3.42%	1.11%	30.35%	0.08%	0.42%	0.04%	0.16%	35.59%	5.23%
		4.36%	1.18%	30.35%	0.09%	0.43%	0.18%	0.16%	36.76%	6.41%
		-0.94%	-0.07%	0.00%	-0.01%	-0.01%	-0.14%	0.00%	-1.18%	-1.18%
		-0.216	-0.063	0.000	-0.106	-0.017	-0.780	-0.024	-0.032	-0.184
1986	**Barren**	0.32%	0.02%	0.07%	0.09%	0.00%	0.00%	0.00%	0.50%	0.41%
		0.06%	0.02%	0.04%	0.09%	0.01%	0.00%	0.00%	0.22%	0.13%
		0.26%	0.00%	0.03%	0.00%	-0.01%	0.00%	0.00%	0.28%	0.28%
		4.161	0.117	0.628	0.000	-0.835	-0.897	0.994	1.244	2.150
	Wetland Forest	0.27%	0.13%	0.45%	0.00%	5.30%	0.24%	0.12%	6.51%	1.21%
		0.80%	0.22%	0.52%	0.02%	5.30%	0.03%	0.03%	6.91%	1.62%
		-0.53%	-0.08%	-0.08%	-0.01%	0.00%	0.21%	0.09%	-0.40%	-0.40%
		-0.658	-0.387	-0.145	-0.811	0.000	6.135	2.954	-0.058	-0.250
	Emergent Wetland	0.23%	0.17%	0.07%	0.00%	0.43%	1.64%	0.07%	2.62%	0.98%
		0.32%	0.09%	0.21%	0.01%	0.03%	1.64%	0.01%	2.31%	0.67%
		-0.09%	0.09%	-0.14%	-0.01%	0.40%	0.00%	0.05%	0.31%	0.31%
		-0.274	0.998	-0.645	-0.804	12.638	0.000	4.395	0.133	0.460
	Water	0.02%	0.01%	0.05%	0.00%	0.03%	0.01%	2.03%	2.16%	0.13%
		0.26%	0.07%	0.17%	0.01%	0.03%	0.01%	2.03%	2.58%	0.55%
		-0.25%	-0.06%	-0.12%	-0.01%	0.01%	0.00%	0.00%	-0.42%	-0.42%
		-0.928	-0.888	-0.686	-0.905	0.271	0.235	0.000	-0.164	-0.767
	2007 Total	24.57%	28.51%	35.53%	0.35%	6.42%	2.14%	2.48%	100.00%	19.87%
		24.57%	28.51%	35.53%	0.35%	6.42%	2.14%	2.48%	100.00%	9.70%
		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Gain	10.25%	2.12%	5.17%	0.26%	1.12%	0.50%	0.45%	19.87%	
		10.25%	2.12%	5.17%	0.26%	1.12%	0.50%	0.45%	9.70%	
		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	

Table 8.3 Hunterdon LULCC, 1986 – 2007, analyzed for gains.

		2007								
		Developed	**Agriculture**	**Upland Forest**	**Barren**	**Wetland Forest**	**Emergent Wetland**	**Water**	**1986 Total**	**Loss**
	Developed	14.32%	0.68%	1.17%	0.04%	0.07%	0.02%	0.05%	16.35%	2.03%
		14.32%	0.77%	0.96%	0.01%	0.17%	0.06%	0.07%	16.35%	2.03%
		0.00%	-0.09%	0.21%	0.04%	-0.10%	-0.04%	-0.02%	0.00%	0.00%
		0.000	-0.121	0.220	3.692	-0.585	-0.609	-0.248	0.000	0.000
	Agriculture	5.99%	26.39%	3.36%	0.13%	0.17%	0.19%	0.05%	36.27%	9.88%
		3.40%	26.39%	4.91%	0.05%	0.89%	0.30%	0.34%	36.27%	9.88%
		2.59%	0.00%	-1.55%	0.08%	-0.72%	-0.11%	-0.29%	0.00%	0.00%
		0.76	0.00	-0.32	1.58	-0.81	-0.38	-0.85	0.00	0.00
	Upland Forest	3.42%	1.11%	30.35%	0.08%	0.42%	0.04%	0.16%	35.59%	5.23%
		1.99%	2.31%	30.35%	0.03%	0.52%	0.17%	0.20%	35.59%	5.23%
		1.43%	-1.21%	0.00%	0.05%	-0.10%	-0.13%	-0.04%	0.00%	0.00%
		0.716	-0.521	0.000	1.883	-0.195	-0.768	-0.200	0.000	0.000
1986	**Barren**	0.32%	0.02%	0.07%	0.09%	0.00%	0.00%	0.00%	0.50%	0.41%
		0.10%	0.12%	0.15%	0.09%	0.03%	0.01%	0.01%	0.50%	0.41%
		0.22%	-0.10%	-0.08%	0.00%	-0.03%	-0.01%	-0.01%	0.00%	0.00%
		2.159	-0.840	-0.549	0.000	-0.962	-0.970	-0.543	0.000	0.000
	Wetland Forest	0.27%	0.13%	0.45%	0.00%	5.30%	0.24%	0.12%	6.51%	1.21%
		0.32%	0.37%	0.46%	0.00%	5.30%	0.03%	0.03%	6.51%	1.21%
		-0.05%	-0.24%	-0.01%	0.00%	0.00%	0.21%	0.09%	0.00%	0.00%
		-0.144	-0.642	-0.030	-0.302	0.000	7.591	2.707	0.000	0.000
	Emergent	0.23%	0.17%	0.07%	0.00%	0.43%	1.64%	0.07%	2.62%	0.98%
		0.25%	0.28%	0.35%	0.00%	0.06%	1.64%	0.02%	2.62%	0.98%
		-0.01%	-0.11%	-0.28%	0.00%	0.36%	0.00%	0.04%	0.00%	0.00%
		-0.050	-0.389	-0.789	-0.622	5.687	0.000	1.645	0.000	0.000
	Water	0.02%	0.01%	0.05%	0.00%	0.03%	0.01%	2.03%	2.16%	0.13%
		0.03%	0.04%	0.05%	0.00%	0.01%	0.00%	2.03%	2.16%	0.13%
		-0.01%	-0.03%	0.01%	0.00%	0.02%	0.01%	0.00%	0.00%	0.00%
		-0.411	-0.786	0.160	0.144	2.885	3.847	0.000	0.000	0.000
	2007 Total	24.57%	28.51%	35.53%	0.35%	6.42%	2.14%	2.48%	100.00%	19.87%
		20.40%	30.28%	37.23%	0.19%	6.97%	2.21%	2.71%	100.00%	19.87%
		4.17%	-1.77%	-1.70%	0.16%	-0.56%	-0.07%	-0.23%	0.00%	0.00%
		0.20	-0.06	-0.05	0.86	-0.08	-0.03	-0.08	0.00	0.00
	Gain	10.25%	2.12%	5.17%	0.26%	1.12%	0.50%	0.45%	19.87%	
		6.09%	3.89%	6.88%	0.10%	1.68%	0.57%	0.68%	19.87%	
		4.12%	-1.82%	-1.77%	0.16%	-0.57%	-0.07%	-0.45%		
		0.673	-0.463	-0.254	1.687	-0.337	-0.124	-0.657		

Table 8.4 Hunterdon LULCC, 1986 – 2007, analyzed for losses.

					2007					
		Developed	**Agriculture**	**Upland Forest**	**Barren**	**Wetland Forest**	**Emergent Wetland**	**Water**	**1986 Total**	**Loss**
	Developed	13.35%	0.21%	0.66%	0.05%	0.20%	0.04%	0.07%	14.59%	1.24%
		13.35%	0.17%	0.57%	0.06%	0.83%	0.23%	0.10%	15.31%	1.96%
		0.00%	0.04%	0.09%	-0.01%	-0.63%	-0.18%	-0.03%	-0.72%	-0.72%
		0.000	0.236	0.155	-0.145	-0.760	-0.805	-0.273	-0.047	-0.366
	Agriculture	3.00%	9.53%	0.52%	0.15%	0.17%	0.35%	0.04%	13.75%	4.23%
		1.14%	9.53%	0.54%	0.06%	0.78%	0.21%	0.09%	12.35%	2.83%
		1.86%	0.00%	-0.02%	0.09%	-0.61%	0.14%	-0.06%	1.40%	1.40%
		1.62	0.00	-0.04	1.55	-0.78	0.63	-0.60	0.11	0.50
	Upland Forest	2.43%	0.40%	32.86%	0.18%	1.04%	0.10%	0.12%	37.12%	4.27%
		3.09%	0.44%	32.86%	0.16%	2.10%	0.58%	0.25%	39.48%	6.62%
		-0.66%	-0.04%	0.00%	0.02%	-1.07%	-0.48%	-0.12%	-2.35%	-2.35%
		-0.214	-0.089	0.000	0.102	-0.507	-0.830	-0.501	-0.060	-0.355
1986	**Barren**	0.54%	0.03%	0.13%	0.30%	0.01%	0.01%	0.02%	1.04%	0.74%
		0.09%	0.01%	0.04%	0.30%	0.06%	0.02%	0.01%	0.52%	0.22%
		0.45%	0.02%	0.09%	0.00%	-0.05%	-0.01%	0.02%	0.52%	0.52%
		5.185	1.703	2.259	0.000	-0.889	-0.686	2.542	0.985	2.328
	Wetland Forest	0.61%	0.13%	0.98%	0.02%	19.81%	0.74%	0.20%	22.49%	2.69%
		1.87%	0.27%	0.88%	0.10%	19.81%	0.35%	0.15%	23.42%	3.62%
		-1.26%	-0.13%	0.10%	-0.08%	0.00%	0.39%	0.05%	-0.93%	-0.93%
		-0.674	-0.498	0.112	-0.774	0.000	1.115	0.322	-0.040	-0.258
	Emergent Wetland	0.48%	0.24%	0.12%	0.02%	2.84%	4.60%	0.20%	8.50%	3.89%
		0.71%	0.10%	0.33%	0.04%	0.48%	4.60%	0.06%	6.32%	1.72%
		-0.22%	0.14%	-0.21%	-0.02%	2.36%	0.00%	0.14%	2.18%	2.18%
		-0.317	1.356	-0.641	-0.473	4.897	0.000	2.469	0.345	1.269
	Water	0.05%	0.00%	0.05%	0.00%	0.14%	0.19%	2.07%	2.50%	0.43%
		0.21%	0.03%	0.10%	0.01%	0.14%	0.04%	2.07%	2.59%	0.53%
		-0.16%	-0.03%	-0.04%	-0.01%	0.00%	0.15%	0.00%	-0.09%	-0.09%
		-0.775	-0.899	-0.439	-0.602	-0.022	3.782	0.000	-0.036	-0.178
	2007 Total	20.46%	10.55%	35.32%	0.73%	24.19%	6.02%	2.72%	100.00%	17.49%
		20.46%	10.55%	35.32%	0.73%	24.19%	6.02%	2.72%	100.00%	17.49%
		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
	Gain	7.10%	1.03%	2.47%	0.43%	4.39%	1.42%	0.65%	17.49%	
		7.10%	1.03%	2.47%	0.43%	4.39%	1.42%	0.65%	17.49%	
		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%		
		0.000	0.000	0.000	0.000	0.000	0.000	0.000		

Table 8.5 Burlington LULCC, 1986 – 2007, analyzed for gains.

		2007								
		Developed	**Agriculture**	**Upland Forest**	**Barren**	**Wetland Forest**	**Emergent Wetland**	**Water**	**1986 Total**	**Loss**
	Developed	13.35%	0.21%	0.66%	0.05%	0.20%	0.04%	0.07%	14.59%	1.24%
		13.35%	0.16%	0.55%	0.01%	0.38%	0.09%	0.04%	14.59%	1.24%
		0.00%	0.05%	0.11%	0.04%	-0.18%	-0.05%	0.03%	0.00%	0.00%
		0.000	0.303	0.197	3.738	-0.476	-0.531	0.668	0.000	0.000
	Agriculture	3.00%	9.53%	0.52%	0.15%	0.17%	0.35%	0.04%	13.75%	4.23%
		0.97%	9.53%	1.67%	0.03%	1.14%	0.28%	0.13%	13.75%	4.23%
		2.03%	0.00%	-1.15%	0.12%	-0.97%	0.06%	-0.09%	0.00%	0.00%
		2.10	0.00	-0.69	3.40	-0.85	0.23	-0.71	0.00	0.00
	Upland Forest	2.43%	0.40%	32.86%	0.18%	1.04%	0.10%	0.12%	37.12%	4.27%
		1.35%	0.70%	32.86%	0.05%	1.60%	0.40%	0.18%	37.12%	4.27%
		1.08%	-0.29%	0.00%	0.13%	-0.56%	-0.30%	-0.06%	0.00%	0.00%
		0.800	-0.421	0.000	2.682	-0.351	-0.753	-0.310	0.000	0.000
1986	**Barren**	0.54%	0.03%	0.13%	0.30%	0.01%	0.01%	0.02%	1.04%	0.74%
		0.15%	0.08%	0.26%	0.30%	0.18%	0.04%	0.02%	1.04%	0.74%
		0.38%	-0.05%	-0.13%	0.00%	-0.17%	-0.04%	0.00%	0.00%	0.00%
		2.520	-0.573	-0.494	0.000	-0.964	-0.887	0.218	0.000	0.000
	Wetland Forest	0.61%	0.13%	0.98%	0.02%	19.81%	0.74%	0.20%	22.49%	2.69%
		0.72%	0.37%	1.25%	0.03%	19.81%	0.21%	0.10%	22.49%	2.69%
		-0.11%	-0.24%	-0.27%	0.00%	0.00%	0.53%	0.10%	0.00%	0.00%
		-0.158	-0.641	-0.216	-0.148	0.000	2.463	1.063	0.000	0.000
	Emergent	0.48%	0.24%	0.12%	0.02%	2.84%	4.60%	0.20%	8.50%	3.89%
		0.85%	0.44%	1.46%	0.03%	1.00%	4.60%	0.11%	8.50%	3.89%
		-0.36%	-0.20%	-1.34%	-0.01%	1.83%	0.00%	0.08%	0.00%	0.00%
		-0.430	-0.455	-0.918	-0.359	1.830	0.000	0.749	0.000	0.000
	Water	0.05%	0.00%	0.05%	0.00%	0.14%	0.19%	2.07%	2.50%	0.43%
		0.09%	0.05%	0.16%	0.00%	0.11%	0.03%	2.07%	2.50%	0.43%
		-0.04%	-0.04%	-0.10%	0.00%	0.03%	0.16%	0.00%	0.00%	0.00%
		-0.486	-0.936	-0.650	0.326	0.285	5.920	0.000	0.000	0.000
	2007 Total	20.46%	10.55%	35.32%	0.73%	24.19%	6.02%	2.72%	100.00%	17.49%
		17.48%	11.32%	38.21%	0.46%	24.21%	5.66%	2.64%	100.00%	17.49%
		2.97%	-0.77%	-2.89%	0.28%	-0.02%	0.36%	0.07%	0.00%	
		0.17	-0.07	-0.08	0.61	0.00	0.06	0.03	0.00	
	Gain	7.10%	1.03%	2.47%	0.43%	4.39%	1.42%	0.65%	17.49%	
		4.13%	1.80%	5.36%	0.15%	4.41%	1.06%	0.58%	17.49%	
		2.97%	-0.77%	-2.89%	0.28%	-0.02%	0.36%	0.07%		
		0.719	-0.429	-0.540	1.795	-0.004	0.339	0.124		

Table 8.6 Burlington LULCC, 1986 – 2007, analyzed for losses.

Extending the analysis period by 5 years produces a few minor changes in the results, but mostly shows a continuation of the previously observed transitions. Comparing the two sets of tables, it is apparent in both data sets that the development favors agricultural areas in Hunterdon and Burlington more than expected if the gain and losses from each LULC category were distributed proportionally among the other categories. In Hunterdon, there does appear to an equalizing of expected to observed gains of agriculture from development and a change in the gains of upland forest from development from more than expected to less than expected.

Like Tables 5.14 and 5.17, Tables 8.7 and 8.8 show a summary of the gains, losses and swap for each LULC type in Hunterdon County, this time using the 1986-2007 analysis. Swap shows that amount of gain offset by loss in each category. It is equal to two times the minimum of the gain and loss, and indicates LULCC not represented in the net change statistics. In comparison to the 1986-2002 analysis, the percentages are larger, since more of the landscape has changed given the 5 additional years the analysis incorporated. However, the general trends are the same, with upland and wetland forests showing the largest amount of swap with almost no net change in Hunterdon and a small net loss in Burlington. This reinforces the fact that those forest habitats are more threatened than simple net change figures indicate. This means that preservation programs should continue to target forest habitats while being sure that they are protecting the type of forest they wish to protect. Since the quality of forest habitat is affected by its age, preservation programs and other groups involved in landscape management should verify that forests patches considered in planning and preservation activities are of the appropriate age, rather than just relying on the categorization of the patch in the latest LULC product.

Table 8.7 Summary of gains, losses, swap and net change in Hunterdon County LULC, 1986-2007, expressed as percentage of landscape.

	Gain	**Loss**	**Total Change**	**Swap**	**Absolute Value of Net Change**
Developed	10.250	2.030	12.280	4.060	8.22
Agriculture	2.120	9.880	12.000	4.240	7.76
Upland Forest	5.170	5.230	10.400	10.340	0.06
Barren	0.260	0.410	0.670	0.520	0.15
Wetland Forest	1.120	1.210	2.330	2.240	0.09
Emergent Wetland	0.500	0.980	1.480	1.000	0.48
Water	0.450	0.130	0.580	0.260	0.32
Total	19.870	19.870	19.870	11.330	8.540

Table 8.8 Summary of gains, losses, swap and net change in Burlington County LULC, 1986-2007, expressed as percentage of landscape.

	Gain	**Loss**	**Total Change**	**Swap**	**Absolute Value of Net Change**
Developed	7.100	1.240	8.340	2.480	5.860
Agriculture	1.030	4.230	5.260	2.060	3.200
Upland Forest	2.470	4.270	6.740	4.940	1.800
Barren	0.430	0.740	1.170	0.860	0.310
Wetland Forest	4.390	2.690	7.080	5.380	1.700
Emergent Wetland	1.420	3.890	5.310	2.840	2.470
Water	0.650	0.430	1.080	0.860	0.220
Total	17.490	17.490	17.490	9.710	7.780

The landscape trajectory analysis was also undertaken utilizing the 2007 LULC data. Tables 8.9 and 8.10 reprise Tables 5.11 and 5.12, respectively, showing the major LULCC trajectories for 1986-1995-2002-2007 for Hunterdon and Burlington counties.

As in the early analysis, the overall stability of the landscape of each county is apparent, with the stable trajectories of the six major LULC categories (excluding barren) at or near the top of the list in terms of acreage. Also in both counties the majority of the acreage represented in the trajectories that show change culminates in development. Similar to the previous analysis, another large area is represented by change vectors showing agriculture transitioning to upland forest.

Concern about agricultural transitioning to upland forest prior to development does seem somewhat warranted using these new data. In Hunterdon, 1529 acres transitioned from agriculture to upland forest to developed between 1986 and 2007, 23% of the 6526 acres that transitioned between agriculture and upland forest by 2002 and remained upland forest in 2007. Another 2168 acres converted from agriculture to forest between 2002 and 2007, but obviously the fate of this land remains to be seen. In Burlington, 380 acres transitioned from agriculture to upland forest to developed between 1986 and 2007, 32% of the 1188 acres that transitioned between agriculture and upland forest by 2002 and remained upland forest in 2007. Another 1247 acres converted from agriculture to forest between 2002 and 2007 and again, its future trajectories remain to be seen. Although Burlington has a higher percentage of land passing through this agriculture to upland forest to developed transition than Hunterdon, the amount of land experiencing this trajectory in Hunterdon is much higher, and a greater percentage of overall development. This suggests that the development process in the two counties is somehow different, with quicker transitions from agriculture to development in Burlington.

Table 8.9 - Major LULCC trajectories in Hunterdon County, 1986-1995-2002-2007.

Acres	**1986**	**1995**	**2002**	**2007**
83474.2	UF	UF	UF	UF
71481.8	AG	AG	AG	AG
38823.7	D	D	D	D
14482.9	WF	WF	WF	WF
6851.5	AG	D	D	D
5568.5	W	W	W	W
4355.5	EW	EW	EW	EW
3951.1	AG	UF	UF	UF
3928.4	AG	AG	D	D
3740.4	UF	D	D	D
3375.4	UF	UF	UF	D
3098.1	AG	AG	AG	D
2575.4	AG	AG	UF	UF
2167.8	AG	AG	AG	UF
1947.3	UF	UF	D	D
1569.7	D	UF	UF	UF
1395.7	D	D	D	UF
1379.9	UF	UF	UF	AG
1155.5	WF	WF	WF	UF
1052.7	UF	UF	UF	WF
922.9	UF	AG	AG	AG
829.3	D	AG	AG	AG

Table 8.10 - Major LULCC trajectories in Burlington County, 1986-1995-2002-2007.

Acres	1986	1995	2002	2007
170804.6	UF	UF	UF	UF
102237.2	WF	WF	WF	WF
68595.4	D	D	D	D
49124.2	AG	AG	AG	AG
22703.2	EW	EW	EW	EW
10376.9	W	W	W	W
8953.1	EW	EW	EW	WF
7095.5	AG	D	D	D
5118.8	UF	UF	UF	WF
4877.1	WF	WF	WF	UF
4740.3	UF	UF	UF	D
4245.8	UF	D	D	D
4058.5	EW	EW	WF	WF
3769.4	AG	AG	D	D
3633.8	AG	AG	AG	D
2991.0	UF	UF	D	D
2060.5	WF	WF	WF	EW
1994.5	D	D	D	UF
1640.1	WF	WF	WF	D
1609.8	EW	WF	WF	WF
1532.4	B	B	B	B
1375.8	UF	UF	UF	AG

These results with the 2007 LULC data show that the new data do have implications for the questions with which this study is concerned. Future effort should be directed at integrating the results more fully with the analysis that were performed during the course of this study. In a broader sense, the preliminary results, and indeed, this study as a whole, show the value of having multiple, commensurate LULC data sets spanning a multi-decade period.

8.9 Extending the Methods to Explore Causality

The purpose of this study has been to empirically characterize landscape change in two New Jersey counties where land preservation programs have been implemented, and to assess the implications of that landscape change on the preservation programs capacity to attain their goals. As part of that assessment, potential drivers of the landscape change have been discussed (including the land preservation program themselves) when the assessment results suggests them, however, the nature of the analyses undertaken here cannot provide a determination of what drivers are operational in the landscapes studied.. Different types of analyses would be needed to understand what the causes are of the landscape changes empirically described here.

Consider the analysis of proximity of development to preserved open space presented in section 6.3.4. The results show that in Hunterdon County areas that have been preserved longer have more development at their periphery than areas that are more recently preserved, and the effect is greater for land that has been preserved the longest. This data suggests that development is attracted to the periphery of preserved lands, but there are alternative potential explanations. It could be that open space is more likely to be preserved in areas where development is likely to occur for reasons independent of the presence of open space. For instance, it could be that parcels likely to be developed and parcels likely to be preserved coincide spatially because of one or more environmental factors, such as slope, soil type or proximity to surface water. Alternately, planners might target areas for preservation in anticipation of proximate future development to ensure that the recreational needs of future residents are met with nearby preserved lands. It could even be that open space preservation is attracted to development.

In order to understand whether parcels proximate to open space are more likely to be developed or one of the alternative explanations holds, techniques such as propensity score matching (PSM) may have promise. PSM, developed by Rosenbaum and Rubin

(1983) allows the matching of treatment and control parcels to ensure that they have similar characteristics aside from the treatment itself (in this case, proximity to open space). The characteristics would be variables such lot size, sewer availability, percent of various LULC types, and others that might have an impact on whether a parcel is likely to be developed. A logistic regression can be used to determine which of these characteristics are important for development. Once the significant variables are identified, treatment parcels (those proximate to preserved open space) and control parcels (those distant from preserved open space) can be selected using thresholds of the variables to ensure a similar propensity towards development. Once the control and treatment groups are selected, they can be compared to see if there is a treatment effect. Lynch and Liu (2007) use this technique to determine that parcels inside Rural Legacy (preservation target) areas in Maryland are more like to be preserved than parcels outside the target area, and are likely to be larger in size.

Other techniques that may be used to determine drivers of landscape change are similarly based around regression techniques. Basic logistic regression has been used to study the factors influencing conversion of farmland to development (Levia 1998). Batisani and Yarnal (2008) used stepwise logistic regression to determine explanatory variables of conversion of non-urban areas to urban land use. Probit analysis has also been used in a similar fashion (Carrion-Flores and Irwin 2004). The use of regression models for determining the causes of landscape change has been questioned for a variety of reasons, including that modeling projections based on their results are often no better than the null model of no landscape change at predicting change (Pontius et al. 2004), and can fail to adequately account for multiple, interacting explanatory variables or provide robust inferences of causality in the case of multi-collinearity between explanatory variables. Hierarchical partitioning has been shown to provide a way to determine which explanatory variables explain most of the variance in the model independent of the other variables (Millington et al. 2007). It is clear much work remains to be done in developing viable techniques for determining drivers of landscape change.

8.10 Conclusions

The research presented shows that ongoing landscape change is having an impact on the ability of land preservation programs in Hunterdon and Burlington counties to meet their goals in several ways. Forest fragmentation in both counties renders the remaining forest less suitable for many species whose habitat is targeted as a preservation goal. The disruption of forest and grassland contiguity by development also makes it more difficult for open space preservation programs to establish large areas of preserved land, a goal for both recreational and wildlife habitat needs. Continuing conversion of agricultural lands to developed uses (and especially agricultural lands with prime soils and those eligible for preservation) threatens agricultural preservation programs by reducing the contiguity of potentially preserved farmland and reducing the amount of current eligible farmland below the preservation programs goals (in Hunterdon). Another issue seen in Hunterdon is that the areas immediately surrounding preserved open space are being developed at a rate faster than the county as a whole. As the caveats regarding causation in previous section make clear, the analysis cannot determine if preserved open space in Hunterdon is attracting preservation to its margins, but the idea that does is supported by both anecdotal evidence and previous studies (e.g. Correll et al. (1978) and Geoghegan (2002)).

Chapter 9 - Conclusions

9.1 Introduction

The research presented in the preceding chapters showed how a full and nuanced consideration of landscape change has the potential to inform the development and implementation of land preservation policies. This, in turn, can lead to more efficient and effective land preservation programs. This concluding chapter will review the evidence presented and suggest avenues for additional research.

9.2 Landscape Change and Land Preservation Policies

The central hypothesis of this dissertation is that land preservation programs are, in part, a response to real or perceived landscape change and, yet, this very change can compromise the efficacy of the land preservation implemented in response to it. Land preservation programs such as the county administered ones considered in this study operate in the medium to long term, often over multiple decades. Landscape change does not stop during the implementation phase of these programs, and significant landscape change can occur in less than two decades. This ongoing landscape change can compromise the ability of land preservation programs to meet their goals. These interactions were conceptualized in the model introduced in Chapter 2 (Figure 9.1).

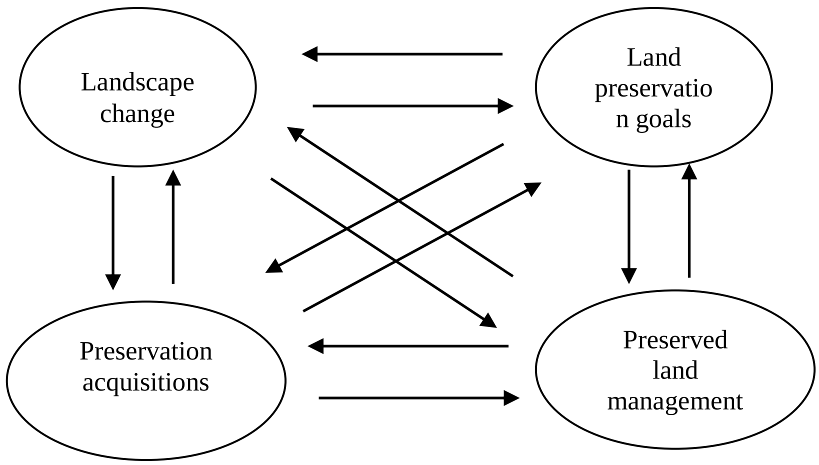


Figure 9.1. The model detailing interactions between landscape change, land preservation policy formulation, policy implementation(i.e. acquisition) and management.

Landscape change must therefore be investigated and quantified both during the policy formulation and the policy implementation and management phases of land preservation policies. Understanding the nature of landscape change during the period that precedes the policy's formulation can help ensure that the policy adequately addresses the actual landscape change that is occurring in the target landscape. Specific preservation goals and criteria that can help counter specific undesirable aspects of local landscape change can then be included in the policy. For example, a particular municipality may be experiencing significant loss of unprotected uplands adjacent to important wetlands. Such losses may reduce of the quality that wetland in the future. The municipality may then choose to give extra weight to these upland areas when ranking or prioritizing areas for preservation.

As shown in this study, a general inventory approach to quantifying landscape change such as that suggested by Letaio and Ahern (2002) can have some utility in the policy formulation and implementation phase. General inventories of change that rely on a number of carefully selected but not policy specific indicators of change can provide a useful baseline measure of landscape change. They have the advantage of being relatively easy to implement since they are based on measures of change that are well-described in the literature and currently implemented in existing software packages such as Fragstats. This is a distinct benefit to municipalities and counties that may not have access to staff with expertise sufficient enough to perform customized change analysis. They can also provide useful comparisons of how landscape changes are similar and how they differ between areas, which in turn can lead to an investigation into how areas with similar change have developed and implemented land preservation programs. This utility is increased to the extent that a common set of change indicators is widely adopted.

The general inventory approach has been shown here to have its limitations as well, however. The specific set of indicators proposed by Letaio and Ahern (2002) are not sophisticated enough to catch many of the nuances of landscape change. For example, their indicators do not include a thorough evaluation of change between land use/land cover classes, such as one that explores actual versus expected gains and losses between land use/land cover classes (as in Pontius et al. 2004). As shown in Chapter 5, simple measures of transitions between land use/land cover classes can miss ecologically or environmentally important changes, such as the replacement of mature forest with young forest. Despite these caveats, the use of a generalized suite of landscape change indicators to assess landscape change is recommended as part of the policy formulation phase for preservation policy.

Evaluations of landscape made after policy formulation should include additional indicators aimed at assessing whether land preservation policies are having the desired effect on the landscape and whether continuing landscape change may impact the ability to meet preservation policy goals. Doing this requires going beyond a generalized suite of indicators and necessitates the development of policy specific indicators of landscape change. The need for and development process of policy specific indicators is explained fully in Chapter 3. A number of policy specific indicators were developed in Chapters 6 and 7, including assessing LULC change in landscape preservation target areas and assessing development rates proximate to preserved open space. These analyses show that measuring landscape patterns or conditions that represent specific goals of land preservation policies is an integral step in being able to effectively assess both the performance of land preservation programs post-implementation and the prospects for adverse impacts on policy goal achievement from ongoing landscape change.

In turn, these assessments allow for post-implementation corrections of policy goals and implementation if the information from assessments suggests the need for it. This can increase the efficacy and efficiency of the land preservation in a number of ways. Through the use of policy specific analyses of change, ongoing landscape change may be shown to threaten certain preservation goals more than others. Preservation agencies could therefore decide to focus preservation efforts on areas that contain these more threatened goals. A post-implementation study can also indicate how well preservation efforts create desired landscape outcomes, as shown by the policy specific indicators. If the expected positive outcomes are not seen in areas with sufficient preservation, the implementation of the preservation programs may need to be adjusted in order to better achieve the desired outcomes.

The main disadvantage of policy specific indicators is, in essence, the mirror image of the advantage of using a general inventory approach. The latter are relatively easy to implement because the indicators used are typically built into readily accessible landscape analysis software. Using policy specific indicators, on the other hand, requires ind-depth knowledge of the policies being analyzed and how to create custom landscape metrics using GIS software. Although some policy specific indicators may be quite simple to implement, other policy relevant metrics may require significant time, expertise and resources (see Tulloch et al. (2003) for an example from a farmland preservation planning context). These requirements mean that organizations with poorly developed GIS expertise such as municipalities and non-profits and some counties may find it difficult to develop policy specific indicators in house. Such organizations may also be limited in the funding they have to seek outside help. The utility of policy specific indicators suggests that that their use should be made a priority in any applicable planning exercise, however.

9.3 Limitations and Future Research

The limitations of the research presented here is of two kinds. First, there are limitations with the methodologies used to explore interactions between landscape change and land preservation. The methodologies used here are primarily descriptive and not predictive. The work attempts to explore how ongoing landscape change may impact the functioning of land preservation programs after their implementation. It does this by describing and quantifying landscape change, in the form of land use/land cover change, both before and after the implementation of significant land preservation programs. It does not attempt to determine the causes behind the observed landscape change and also does not attempt to rigorously isolate landscape change that may be caused or influenced by land preservation programs. There are implications in the data presented that land preservation may be influencing landscape change on unpreserved lands, but the methodologies used here do not attempt to tease out these potential impacts from other factors affecting landscape change.

Because the potential of land preservation itself to impact landscape change on unpreserved lands, future research should be directed towards to explaining how the implementation of land preservation programs can affect landscape change. Statistical modeling methods such as econometric modeling may be useful for understanding how land preservation can impact change on unpreserved lands, while isolating the effects of other variables that affect landscape changes such as proximity to highways and infrastructure availability. Spatially explicit agent-based modeling approaches, in which landowner, developer, and land buyer decision making modeling is coupled with parcel information, may also illuminate the relationship between land preservation and landscape change on unpreserved lands.

The other primary limitation to the work presented here involves its extensibility and data availability. In order to engage in research exploring the interactions between landscape change and land preservation, it is necessary to have land use/land cover or other relevant data from at least three time periods – before policy implementation, concurrent with policy implementation and after policy implementation. There also needs to be enough elapsed time between each data set to record an adequate amount of change.

New Jersey has recently released LULC data for 2007 and will soon be releasing data for 2011. The 2007 data was used to extend several of the analyses conducted here as reported at the end of Chapter 8. When the 2011 data is released, it and the 2007 data should be fully integrated into the analyses used in this study. As a first step, the simple measures of LULCC, transition, trajectories, and gain/loss/swap analysis should be completed. This will show whether and how the LULCC trends from 1986 to 2007 have changed. Once the general nature of LULCC over the new time period has been established, the implications for the land preservation policies can be determined. The analysis of change in target areas and preserved lands should be undertaken to assess whether recommendations for policy alterations from the earlier analysis need to be adjusted in light of the new LULC data.

New Jersey is a relatively data rich state with a progressive policy of regularly updating land use/land cover data sets. Not all areas will have such readily available data of adequate temporal and spatial resolution. Thus, following the above recommendations for studying post policy implementation landscape change may prove to be difficult in many counties and municipalities interested in performing assessments of their land preservation policy. Future research should investigate the potential for the development of adequate data sets from existing data sets, recent aerial photography and satellite imagery and ancillary data such as building permit data that can be used to determine which parcels in an area have undergone development. Such research should focus on the determining the feasibility for organizations to produce adequate landscape change data with minimum availability and commitment of resources, since the organizations involved in such policy assessments are likely to be resource limited.

New Jersey has recently released LULC data for 2007 and will soon be releasing data for 2011. The 2007 data was used to extend several of the analyses conducted here as reported at the end of Chapter 8. When the 2011 data is released, it and the 2007 data should be fully integrated into the analyses used in this study. As a first step, the simple measures of LULCC, transition, trajectories, and gain/loss/swap analysis should be completed. This will show whether and how the LULCC trends from 1986 to 2007 have changed. Once the general nature of LULCC over the new time period has been established, the implications for the land preservation policies can be determined. The analysis of change in target areas and preserved lands should be undertaken to assess whether recommendations for policy alterations from the earlier analysis need to be adjusted in light of the new LULC data.

9.4 Extending the Analytical Model

Given the demonstrated utility of the analytical model (presented in Figure 9.1) in aiding the understanding of landscape change-land preservation interactions, it is reasonable to consider if the model can be extended to other situations. The model is fundamentally concerned with landscapes and human responses to them. More specifically, the responses examined here are interventions (see Steiner (2004) for more discussion concerning landscape interventions) intended to have explicit effects on the landscapes they target. As noted above, there are data availability considerations that influence the application of the model. If the needed data is available, can the model used here be generalized to accommodate a large variety of these landscape interventions?

Taking each element of the model separately, the prospects for generalization become evident. Whereas the discussion above concerned landscape change, this portion of the model can be generalized to represent a landscape or landscape element of interest. A landscape element could be a particular land use or land cover type, or an environmental characteristic which has a spatial extent (e.g. the habitat of an endangered species or a groundwater recharge area). A landscape element could also be a process which occurs on a landscape, such as the general land use/land cover change considered here. More specific processes could as be represented, such as the fragmentation of agricultural land and the conversion of forest to residential land. Geomorphic processes that generate human interventions, such as beach erosion, could also be represented by this portion of the model.

The portion of model in Fig. 9.1 that represents land preservation policy can be generalized to cover any land management goal or intent. In some cases, these goals will be explicitly quantitative, such as preserving a target acreage of agricultural land or replenishing a beach to a given width or dune height. In other instances the goal or intent may not be absolutely numerical. For example, a plan to slow forest fragmentation in a developing rural region may not specify a specific target rate of fragmentation, seeking simply to reduce the rate from current levels.

The third and fourth portions of the model, which in Fig. 9.1 represented preservation program acquisitions and management, can be extended to cover any implementation of the goals or intents of the intervention represented in the second portion of model. For the generalized model these elements are combined into one. This element represents the actual management or intervention activity undertaken to meet the stated goals. The types of activities represented here obviously depend on both the intervention goals and the target landscape or landscape element. Combining all of these generalized elements together results in the model depicted in Figure 9.2.

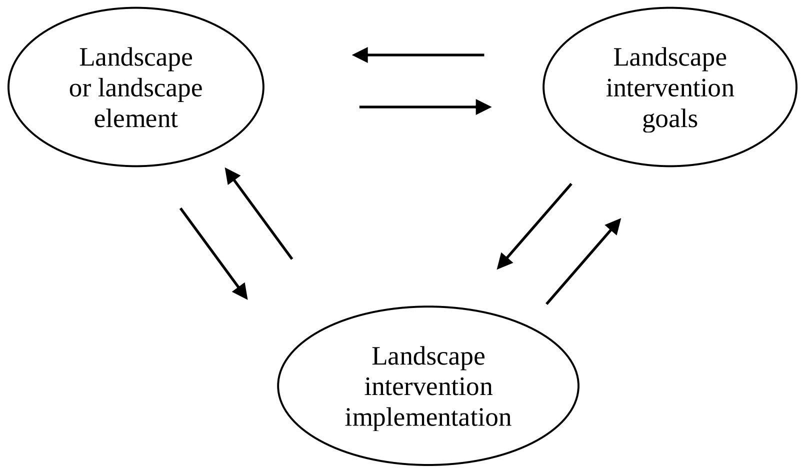


Figure 9.2. A generalized model for studying interactions between landscapes and landscape interventions

9.5 Concluding Remarks

The research presented here demonstrates the utility of exploring the interactions between landscape change and land preservation programs. Major findings include:

- In both counties, agricultural land is developed more than expected at random, and upland forest developed less than expected
- A small but significant proportion of land in each county transitions from agriculture to upland forest before being developed
- 45% of agricultural land loss in Hunterdon and 16% in Burlington is the result of agricultural converting to upland forest, which impacts the amount land eligible for farmland preservation

- Simple measures of landscape change underestimate the amount flux in upland forest, meaning that mature upland forests are more threatened than those simple measures suggest
- Measures of landscape fragmentation show that upland and wetland forests are suffering from fragmentation, which decreases their ecological integrity
- Preserving and establishing the contiguity of farmland, parkland and wildlife habitat- all major goals of land preservation – are being made more difficult by the patterns of development in both counties
- In both counties, a significant percentage of preserved emergent wetland are found on preserved farmland
- Certain areas targeted for preservation are developing faster than other targeted areas in both counties – grasslands and conservation areas in Hunterdon, greenway target areas in Burlington, and farmland eligible for preservation in both counties

The study shows that quantifying and understanding landscape change, especially through the use of policy-specific indicators, can help those that administer land preservation programs adapt their programs goals and implementation to account for landscape change. This adaptation can increase the efficacy and efficiency of those land preservation program. This is always important in publicly funded programs, of course, but it is even more imperative in land preservation programs because of the potential for land values to rise significantly during the implementation phase of programs.

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